

EUROPEAN BIOCHAR CERTIFICATE

Standard 10.5E



Standard for European Biochar Certification (EBC)

These guidelines are effective since 1st January 2012 and constitute the basis for biochar certification in Europe and throughout the world. The EBC standard is developed by the Ithaka Institute and is own by Carbon Standards International.

Please cite as:

EBC (2012-2025) 'European Biochar Certificate – Guidelines for a Sustainable Production of Biochar.' Carbon Standards International (CSI), Frick, Switzerland. (<http://carbon-standards.com/ebc>).
Version 10.5E from 15th September 2025.

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Table of Content

Summary of the EBC to prepare the inspection	5
1. Objective of the guidelines and certification.	8
2. Definition of biochar.	9
3. The EBC certification classes	10
4. Biomass feedstock.	12
5. Definition of biochar batches and their registration	14
6. Biochar sampling	15
6.1. Representative sample.	15
6.2. Sending of the representative biochar sample to the endorsed laboratory	15
6.3. Retention Sampling.	15
7. Biochar properties	16
7.1. The biochar's organic carbon (C_{org}) content must be declared.	16
7.2. The molar H/ C_{org} ratio must be less than 0.7 and less than 0.4 for EBC-Feed	16
7.3. The molar O/ C_{org} ratio should be below 0.4	16
7.4. The biochar nutrient contents must be declared at least for nitrogen, phosphorus, potassium, magnesium, calcium, and iron.	16
7.5. The following limit values for heavy metals must not be exceeded.	17
7.6. pH, salt content, bulk density, and water content must be declared.	17
7.7. The determination of the water holding capacity (WHC).	18
7.8. Electrical conductivity of the solid biochar	18
7.9. Specific surface area and pore size distribution are non-obligatory additional parameters	18
7.10. Limit values for PCB and PCDD/F must be observed.	18
7.11. Limit values for PAH contents must not be exceeded.	19
8. Pyrolysis	22
8.1. Biomass pyrolysis must be operated in an energy efficient manner.	22
8.2. Homogeneity of biochar quality	22
8.3. The pyrolysis gases produced during pyrolysis must be recovered or burned. They are not allowed to escape into the atmosphere.	22
8.4. Syngas combustion must comply with national emission limit values.	22
8.5. Biochar production must be energy efficient.	22
8.6. Certification of individual pyrolysis units.	23

9.	Work safety and health	24
10.	Biochar for use as a feed additive.	24
10.1.	Approval as animal feed producer.	24
10.2.	Biomass – only pure plant biomass feedstocks are permitted	24
10.3.	Separation of impurities	25
10.4.	Pyrolysis temperature ($HTT > 500\text{ }^{\circ}\text{C}$) and intensity ($H/C_{org} < 0.4$)	25
10.5.	Heavy metals	25
10.6.	PAHs	26
10.7.	Dioxine, furane, dioxin-like PCB (WHO-PCB) und non-dioxin-like PCB (DIN- PCB).	26
10.8.	Fluor $< 150\text{ mg kg}^{-1}$ (88% TS)	26
10.9.	Dry matter, crude ash, ash insoluble in hydrochloric acid.	26
10.10.	Crude protein, crude fibre, crude fat	26
11.	Certification of companies that process biochar and manufacture biochar-based products.	27
11.1.	Exclusive use of EBC certified biochar	27
11.2.	Incoming goods inspection	27
11.3.	Storage	27
11.4.	Processing journal	27
12.	Labeling and Advertising with EBC Certification.	28
12.1.	Trademark protection and compulsory information.	28
12.2.	Mandatory information on biochar	29
12.3.	Mixing of biochars.	29
13.	Control, quality management and certification	30
13.1.	Principles of certification	30
13.2.	EBC-certified companies.	30
13.3.	Registration for certification	31
13.4.	Technical pre-audit of pyrolysis units	32
13.5.	EBC instruction manual.	32
14.	References.	33
APPENDIX		
1.	Analytical Methods for EBC-biochar Basic Package.	36
2.	Analytical Parameters for EBC-Feed	41
3.	Additional Parameters	43
4.	Representative sampling.	45
5.	Country Annex: Sweden	47
6.	Country Annex: Austria	48
7.	Country Annex: Switzerland	49
8.	Country Annex: Denmark	51

Summary of the EBC to prepare the inspection

Companies that do not produce but process and trade certified biochar should consult Chapter 11 directly.

1. Inscription

- 1.1 Biochar producers can contact Carbon Standard through the website at www.carbon-standards.com, where they will find all relevant information and process updates. Following a personal phone contact, the producer may register and gain access to the Biochar-Tool as well as to the online Academy.
- 1.2 Once the biochar production unit is registered in the Biochar-Tool and the necessary technical documentation for the technical pre-audit is uploaded, an online meeting will be arranged to conduct the audit.
- 1.3 During the technical pre-audit, a company-specific quality assurance plan will be prepared and noted in the technical EBC inspection manual. Additionally, instructions are provided regarding the EBC methodology and the protocols to be followed for the annual on-site inspection.
- 1.4 Once the technical pre-audit is passed, the company information is transmitted to the appointed inspection and certification body.

2. Production batch

- 2.1 A production batch starts with its registration in the Biochar Tool. The production batch receives a unique ID number and QR code.
- 2.2 A production batch lasts a maximum of 365 days including all possible interruptions in production.
- 2.3 The pyrolysis temperature in °C shall not change by more than 20% during production. At a declared pyrolysis temperature of, for example, 600 °C, short-term fluctuations between 480 °C and 720 °C are thus permitted.
- 2.4 The composition of the biomass must not change by more than 20%. If, for example, a mixture of 50% grain husks and 50% landscape conservation wood is pyrolyzed, the proportions may vary in the range 40% to 60% ($\pm(50\% \times 20\%) = \pm 10\%$).
- 2.5 If a biochar producer registers for the first time a biochar production batch, a representative sampling has to be carried out by an endorsed sampler within the first two months after registration.
- 2.6 After a production batch has expired, a subsequent, new production batch must be registered in the Biochar Tool. If the new batch uses the same parameters as the previous one, a sample must be taken two months before the current batch's expiration to ensure timely analysis and registration of the new batch.
- 2.7 A pyrolysis plant can produce several batches during the reference time of one year if feedstock and/or production conditions are changed. The interruption of one batch must be documented in the Biochar Tool.
- 2.8 The documentation of production times in the Biochar Tool is mandatory. Produced quantities must be submitted at least quarterly.

3. Sampling and sending the sample for analysis

- 3.1 The representative sample of a production batch must be taken by a CSI-endorsed sampler in accordance with the sampling plan contractually specified during the technical pre-audit.
- 3.2 The sample must be registered in the Biochar Tool and sent with the EBC sample ID generated by the Biochar Tool to an EBC-endorsed laboratory.
- 3.3 In accordance with the sampling plan specified in the contract, the production company shall ensure the sampling and sealed storage of the retained samples.

4. Permissible biomass for the production of biochar

- 4.1 All biomasses included in the EBC positive list may be used individually or in combination as feedstock for the production of EBC biochar. For each certification class certain restrictions apply, which are set out in the EBC positive list. For example, not all biomasses that may be used for EBC-Urban may be used for EBC-Feed. Within a batch, the type of biomass may not be changed, and the mixing ratios may not change by more than 20% (cf. 2.5).
- 4.2 Mineral additives according to the EBC positive list may be added by up to 10% of the mass. No mineral additives are permitted for EBC-Feed.

5. Specifications for pyrolysis technology

- 5.1 The use of excess heat or the use of liquid and gaseous pyrolysis products must be ensured.
- 5.2 Pyrolysis gases must not be released without passing a dedicated combustion chamber.
- 5.3 Nationally defined emission limit values must be complied with.
- 5.4 Pyrolysis parameters such as temperature and residence time must be continuously monitored to ensure that biochar quality does not vary significantly within a single production batch.

6. Properties of biochar

- 6.1 The biochar for all certification classes must be analysed at least according to the EBC Basic Analysis Package. For EBC-FeedPlus the analyses of the EBC-FeedPlus package are additionally required.

6.2 The following limit values and declaration requirements must be observed:

Tab.1 Overview of the most important analytical parameters for EBC biochar

EBC -Certification Class		EBC-FeedPlus	EBC-AgroOrganic	EBC-Agro	EBC-Urban	EBC-Materials	EBC-Basic
Elemental analysis	Declaration of C _{tot} , C _{org} , H, N, O, S, ash						
	H / C _{org}	< 0.4	< 0.7				
Physical parameters	Water content, dry matter (as received and @ < 3mm particle size), bulk density (DM), WHC, pH, salt content, electrical conductivity of the solid biochar						
Major elements	Declaration of N, P, K, Mg, Ca, Fe						
Heavy metals	Pb	5 g t ⁻¹ (88%DM)	45 g t ⁻¹ DM	120 g t ⁻¹ DM	120 g t ⁻¹ DM	120 g t ⁻¹ DM	declaration, no limit values for certification
	Cd	0.5 g t ⁻¹ (88% DM)	0.7 g t ⁻¹ DM	1,5 g t ⁻¹ DM	1,5 g t ⁻¹ DM	1,5 g t ⁻¹ DM	
	Cu	70 g t ⁻¹ DM	70 g t ⁻¹ DM*	100 g t ⁻¹ DM*	100 g t ⁻¹ DM*	100 g t ⁻¹ DM	
	Ni	25 g t ⁻¹ DM	25 g t ⁻¹ DM	50 g t ⁻¹ DM	50 g t ⁻¹ DM	50 g t ⁻¹ DM	
	Hg	0.1 g t ⁻¹ (88% DM)	0.4 g t ⁻¹ DM	1 g t ⁻¹ DM	1 g t ⁻¹ DM	1 g t ⁻¹ DM	
	Zn	200 g t ⁻¹ DM	200 g t ⁻¹ DM*	400 g t ⁻¹ DM*	400 g t ⁻¹ DM*	400 g t ⁻¹ DM	
	Cr	70 g t ⁻¹ DM	70 g t ⁻¹ DM	90 g t ⁻¹ DM	90 g t ⁻¹ DM	90 g t ⁻¹ DM	
	As	2 g t ⁻¹ (88% DM)	13 g t ⁻¹ DM	13 g t ⁻¹ DM	13 g t ⁻¹ DM	13 g t ⁻¹ DM	
Organic contaminants	16 EPA PAH	6±2.4 g t ⁻¹ DM	6±2.4 g t ⁻¹ DM	6.0+2.4 g t ⁻¹ DM	CSI-declaration	CSI-declaration	CSI-declaration
	8 EFSA PAH	1.0 g t ⁻¹ DM					4 g t ⁻¹ DM
	benzo[e]pyrene benzo[j]fluoranthene	< 1.0 g t ⁻¹ DM for each of both substances					
	PCB, PCDD/F	See chapter 10	Only required if 8 EFSA PAH > 1.0 mg kg ⁻¹ . For PCB: 0.2 mg kg ⁻¹ DM, for PCDD/F: 20 ng kg ⁻¹ (I-TEQ OMS), respectively				

(*) when traded as micronutrient fertilizer, the respective limit value can be overruled.

6.3 Specifications, additional limit values, or more stringent limit values that apply only to certain countries are regulated in the respective country annex.

6.4 The biochar of the classes EBC-FeedPlus, EBC-Agro, EBC-AgroOrganic and EBC-Urban must be adjusted to a water content that prevents dust formation and thus also spontaneous combustion (30% is recommended). Biochar of the classes EBC-Materials and EBC-Basic can only be sold with a lower water content if the appropriate safety precautions, especially with regard to explosion and health protection, have been taken and the biochar is sold exclusively to business customers (B2B) with appropriate safety precautions.

7. Health and safety

7.1 A safety data sheet must be available.

7.2 The workers must sign that they have been informed about possible dangers at the workplace, read the data safety sheet, and that they have the necessary personal protective equipment.

1. Objective of the guidelines and certification

For thousands of years, charcoal has been one of civilisation's basic materials. By far the most common use of charcoal was for cooking, for heating and for smouldering when producing metal tools. However, for centuries charcoal and biochar have also been used for conditioning soils, or as litter (bedding) materials, as medicine and also as a feed additive. Over the course of the last century most of this traditional knowledge has been lost yet is being rediscovered since 2010.

Thanks to wide-ranging multidisciplinary research and field trials, the understanding of the biological and physico-chemical processes involved in the production and use of biochar has made great progress. A significant increase in the use of biochar has been recorded since 2020. Further acceleration is expected from 2025 onwards, particularly in industrial applications.

Agricultural applications range from soil conditioners, composting additives, and carriers for fertilisers to manure treatment and stable bedding, silage additives and feed additives. Industrial applications are particularly relevant to the construction, plastics, composite, and textile industries.

Traditional kiln production of charcoal and biochar without the combustion of pyrolytic gases is unsatisfactory with regards to its carbon efficiency and its overall environmental footprint.

Accordingly, those kilns are unsuitable for the production of larger amounts of biochar to be used in agriculture or industry. Modern pyrolysis plants as well as certain types of farmer-scale kilns such as flame curtain pyrolysis systems are now ready to produce biochar from a large variety of different feedstocks in an energy-efficient way and without harming the environment. As both biochar properties and the environmental footprint of its production are largely dependent on the pyrolysis conditions and the type of feedstocks to be used, a secure control and assessment system for its production and analysis had to be introduced.

In issuing these guidelines, Carbon Standards International presents an assessment mechanism based on

the latest research, practices, and legislation. By requiring the use of this assessment system, the European Biochar Certificate (EBC) will enable and guarantee sustainable biochar production, processing, and sale. It is introduced to provide customers with a reliable quality standard, while giving producers the opportunity to prove that their products meet well-defined and recognized quality standards. It further aims to provide a firm state-of-the-art knowledge transfer as a sound basis for future legislation (e.g., EU fertilizer regulations or carbon dioxide removal regulations).

Biochar technology continues to develop very rapidly. Numerous research projects around the world are investigating the properties of biochar and their interaction with other substances, materials, and the environment. Every year sees new manufacturers of pyrolysis equipment entering the market and the areas in which biochar and biochar products are used is growing rapidly. The European Biochar Certificate is closely aligned with this research and technical momentum and will accordingly be revised regularly to consider the latest findings and developments. Limit values and test methods will be adapted to reflect the latest findings and amended or updated as necessary. In addition to this standard, the webpage <https://www.carbon-standards.com/ebc> lists the latest clarifications, frequently asked questions, and guidance documents, as well as relevant information and process updates.

The goal of these guidelines is to encourage and ensure the control of biochar production and quality based on well-researched, legally backed-up, economically viable and practically applicable processes. Users of biochar and biochar-based products will benefit from transparent and verifiable monitoring and quality assurance. It is our moral obligation as well as the duty of every biochar user to make sure that a good idea is not corrupted. The certificate was designed to serve this goal.

Currently, the European Biochar Certificate is a voluntary industry standard in Europe. Several countries aligned their biochar-related regulations with the EBC.

2. Definition of biochar

Biochar is a porous, carbonaceous material that is produced by pyrolysis of biomass and is applied in such a way that the contained carbon remains stored as a long-term C sink or replaces fossil carbon in industrial manufacturing. It is not made to be burnt for energy generation.

Biochar is produced by biomass pyrolysis, a process whereby organic substances are broken down at temperatures above 350 °C in a low-oxygen process. Although torrefaction, hydrothermal carbonisation and coke production are carbonisation processes, the end products cannot, however, be called biochar under the above definition. Biochars are therefore specific pyrolysis chars characterised by their additional environmentally sustainable production, quality and usage features. Gasification is understood as being part of the pyrolysis technology spectrum and can, if optimized for biochar production, be equally certified under the EBC.

Biochar is defined by its quality characteristics, by the raw materials used, its sustainable production, and end use.

Biochar is a hyper versatile material with an increasing number of applications in agriculture, environmental engineering, and basic industry. Each application, like the use as a soil amendment, stormwater filter, or additive for building materials, textiles, and plastics, demands specific biochar qualities. Thus, each application requires proper certification parameters that must be specified, controlled, and guaranteed.

The EBC-Basic certification class sets the minimum standards for a material to be recognized as biochar.

3. The EBC certification classes

To keep pace with the growing number of biochar uses, the EBC has introduced a number of certification classes. According to the requirements and safety regulations of the different applications, different parameters are controlled, and limit values apply. With the publication of EBC v10.0, the certification class EBC-Basic was introduced as the basic and fundamental certification class. It defines what can be considered a biochar or not according to the EBC. All present and future certification classes meet at least the requirements of EBC-Basic and are entitled for C-sink certification.

The definition of a certification class (e.g., EBC-Urban or EBC-Materials) is a statement of admissibility of biochar for a given purpose regarding applicable laws, regulations, and relevant industry standards. The assignment to a certification class is not a statement about the excellence of biochar (i.e., good, better, or best biochars for a specific purpose/use) – but it does distinguish between biochars that are admissible or inadmissible for a defined form of application (e.g., in agriculture or construction). Each application and thus certification class has its specific requirements.

When selling to end-user (B2C), every biochar and biochar-based product must be labelled according to the EBC certification class under which it is traded. If, e.g., a biochar is sold as a building material it must be labelled as EBC-Material or EBC-Basic. An EBC-Agro labelled biochar cannot be traded as building material. A biochar labeled as EBC-FeedPlus cannot be sold as a soil amendment. A packaging unit for end users must not be labelled with more than one certification class.

When sold to other businesses (B2B) that process or trade biochar, the biochar may be labeled with multiple certification classes. For example, biochar can be certified with EBC-FeedPlus, EBC-Agro, EBC-Materials and EBC-Basic and sold to other companies (B2B) carrying these different certification classes. An EBC-certified biochar processor can then label its products according to the applicable certification classes for end users. It is thus possible to market different products, each with a different certification class, to end users from a biochar supply that was delivered with multi-

ple certification classes. If a biochar qualifies for different certification classes, different packaging units from one and the same production batch can be sold under different EBC-labels.

While EBC-FeedPlus certified biochar meets all requirements of all other certification classes, a general “downward compatibility” is not given within the EBC. This is also not intended since the demands on biochar properties vary greatly depending on the field of application and can also be contradictory in some cases. This will become even more pronounced with the increasing professionalization of biochar product design and the progress of research and development.

EBC-FeedPlus¹ meets all EU and EFTA regulations relevant for animal feeding and agricultural soil applications [2,3]. It can be used for all livestock operations and also be applied to soil. In addition to the EBC-FeedPlus certification, a biochar producer must be approved as a feed producer in accordance with the respective national requirements.

Biochars certified with **EBC-Agro and EBC-AgroOrganic** meet all requirements of the new EU fertilizer product regulation [3]. It can be traded under the CE mark (i.e., Conformité Européenne) in all EU countries. Several EU countries, such as Austria, Sweden, and Hungary, have approved the use of biochar according to the requirements of EBC-Agro. Based on these national approvals, such biochars can be exported and used in all other EU countries. Several EU and EFTA countries apply their own restrictions for the agricultural use of biochar. Switzerland, for example, requires pyrolysis temperatures of at least 500 °C for at least 10 minutes and only allows a maximum application amount of 1 t biochar per ha and year (see Swiss Annex). Germany currently requires a minimum carbon content of 80% for biochar that must be produced from untreated wood. Sweden has defined limits beyond the EU regulation and EBC-Agro, which are covered by the Sweden Annex of the EBC. The EBC-AgroOrganic certificate meets all requirements of the EU Commission regulation on organic production [4]. The respective specifications and limit values are continuously adapted to align with the ongoing development of relevant European legislation and scientific advances.

1 Version 10.4 of this standard contained an additional certification class, “EBC-Feed.” Producers are granted a transition period until December 31, 2026, during which a batch can still be certified as EBC-Feed in accordance with the rules of standard version 10.4. As of 2027, no more batches will be certified with “EBC-Feed.”

EBC-Urban provides a strong standard for the use of biochar in tree planting, park maintenance, sidewalk embellishments, ornamental plants, and rainwater drainage and filtration. The main risk of all those uses is ground- and surface water contamination and work safety, which EBC-Urban certification prevents effectively. As the urban use of biochar is not subject to agricultural legislation, some parameters, and their respective limit values were replaced by limit values that are better adapted to the special matrix of biochar. For example, the EBC-Urban limit value for PAHs is limited to the eight carcinogenic PAHs. PAHs are ubiquitous in urban environments (e.g., from tyre abrasion and car exhaust), and urban soil applied biochar which is a strong adsorber of PAHs will act as a net adsorber of those environmental toxins when low biochar PAH-contents are guaranteed (as is the case when EBC-Urban biochar is used).

Biochar certified under **EBC-Urban** must not be used as soil amendment for food or feed production. If biochar shall be used in urban community gardens or home-gardening projects, EBC-Agro or EBC-AgroOrganic quality is recommended. EBC-Urban can further be used for remediation of polluted soils, sediments or groundwater, the production of ornamental plants, and tree nurseries for non-food species. EBC-Agro and EBC-AgroOrganic fulfill all requirements of EBC-Urban and can be used for any urban soil applications.

The certification classes **EBC-Materials** and **EBC-Basic** cover all necessary environmental requirements for non-soil applications.

EBC-Materials is destined for biochar to be used in products that may come into direct skin contact with consumers or food-grade products. Examples would be takeaway coffee cups, plastic computer cases, toothbrushes, carpets, textiles, flowerpots, freshwater pipes, etc. However, this does not include medical and healthcare products or food. The biochar must be included in the consumer products in such a way that no biochar dust is released because of product use.

The **EBC-Basic** certificate guarantees sustainably produced biochar, which can be used in basic industry such as to produce building materials, road construction asphalt, electronics, sewage drains, and composite materials like skis, boats, cars, rockets without risk to the environment and users. However, precautions in handling, storing, and labeling the materials are re-

quired, as described in the dedicated sections of the EBC (see chapter 11).

Both EBC-Materials and EBC-Basic must not be used in agriculture or other soil applications such as planting urban trees, remediating polluted areas, or mine reclamation. EBC-Basic must not be sold directly to private customers (B2C) but is traded exclusively to other businesses (B2B) where adequate handling (i.e., avoidance of dust generation, respiratory protection, avoidance of skin contact) can be ensured.

EBC-Basic defines what can be considered “biochar” and used as a sustainable raw material. Other solid residues obtained from pyrolysis or gasification of biomass that exceed EBC-Basic limit values must be considered as (potentially) toxic waste and be disposed of as waste material according to local, national, or international laws. Pyrolytic products from feedstock that are not listed on the EBC feedstock positive list (e.g., industrial wastes or fossil carbon like lignite) should not be considered biochar and must not be traded under the EBC label.

For all certification classes, the same sustainability criteria regarding the production of biochar (i.e., emissions, feedstock storage, the definition of batches, control of pyrolysis conditions), sampling, and on-site inspection do apply.

If European biochar producers are interested in having new certification classes included into the EBC, a formal application should be sent to the Carbon Standards International (standards@carbon-standards.com). The EBC Scientific Committee will review the application in detail and either add the certification class or publish the reasons for the refusal or deferment.

4. Biomass feedstock

- 4.1 Only biomass and no fossil carbon may be used to produce biochar. The EBC positive list (Appendix 1) indicates which types of biomasses are permissible for each certification class.
- 4.2 Deliberately mixed feedstock containing fossil carbon such as plastics or products made using fossil carbon and biomass may be authorized for EBC-Basic if proper organic and fossil carbon tracking is provided. Using such mixed fossil–organic carbon feedstock needs the written approval of Carbon Standards International.
- 4.3 The clean separation of non-organic substances such as metals, construction waste, electronic scrap, etc., must be ensured.
- 4.4 To produce biochar for soil and agriculture (EBC-FeedPlus, EBC-Agro, EBC-AgroOrganic, EBC-Urban), the biomass used must not contain any paint residues, solvents or other potentially toxic impurities.
- 4.5 To produce EBC-FeedPlus, EBC-Agro, EBC-AgroOrganic, and EBC-Urban qualities, unavoidable contamination of the biomass by plastic and rubber waste must not exceed 1% (m/m). To produce biochar for materials (EBC-Material, EBC-Basic) plastic and rubber contents of up to 10% can be accepted, though these are subject to declaration and require the written approval of Carbon Standards International. In the latter case, Carbon Standards International may define additional requirements for the pyrolysis process, request additional analyses to ensure the safety of the product and its application, and deduce plastic-derived carbon from the C-sink potential of the biochar. Based on ongoing research showing the complete elimination of plastic feedstock under defined pyrolysis conditions, higher limit values for feedstock plastic contamination may be introduced in the future.
- 4.6 When using primary agricultural products (e.g., miscanthus or short rotation forestry), it must be guaranteed that the soil organic carbon is preserved, and they are grown in a sustainable manner regarding the use of fertilizer and pesticides.
- 4.7 Biochar may only be produced from forest wood and primary products from forest wood processing if sustainable management of the corresponding forest can be proven by PEFC, FSC, or EU-RED (SURE) or by comparable regional standards or laws. Clear-cutting of forests or forest parts is not permitted.
- 4.8 The pyrolysis of animal by-products, such as livestock manure and manure containing biogas digestates, is authorized as feedstock for all certification classes except EBC-Feed. Biochars from such feedstocks must present an H/C_{org} ratio below 0.4 to ensure that biological hazards and micropollutants are eliminated. Its use for industrial materials should be avoided to preserve the valuable plant nutrients from the manures. To mitigate health risks to workers during the handling of animal by-products, a comprehensive treatment plan must be implemented and authorized by Carbon Standards International, covering the entire process from arrival at the production site to pyrolysis.
- 4.9 Biosolids may be used as feedstock to produce EBC-Basic provided that health risks for workers during the handling of the biosolids are prevented. A treatment plan for the biosolids from the arrival at the production site till the pyrolysis must be provided and authorized by Carbon Standards International. Pyrolysis conditions must exceed 500 °C for 3 min at minimum to eliminate biological hazards and micropollutants.

Unfortunately, the heavy metal contents of most biosolids are usually too high for EBC-Agro and EBC-Urban and, thus, for soil application. Some countries adopted fertilizer or waste management ordinances based on nutrient-to-heavy-metal ratios rather than total heavy-metal content to regulate soil application and allow pyrolysis to treat biosolids, e.g., Denmark. Based on the respective country annex, pyrolyzed biosolids may be certified for soil application in those countries, but not yet in other countries where the EBC applies.

- 4.10 Mineral additives such as rock powder, biochar, and ashes, as detailed in the EBC positive list (Appendix 1), which may be used to control the quality of biochar, are subject to declaration and require written approval from the EBC. Carbon Standards International may request additional quality controls with regard to organic and inorganic contaminants. To produce EBC-FeedPlus, no mineral additives are admitted.
- 4.11 Complete records of the processed biomasses and additives must be kept and archived for at least five years.

If biochar producers are interested in adding new biomass or mineral additive materials on the EBC-feedstock list, a formal application should be sent to Carbon Standards International. The EBC Scientific Committee will review the application in detail and either add the feedstock or publish the reasons for the refusal.

5. Definition of biochar batches and their registration

A biochar production batch is defined as:

- 5.1 The amount of biochar produced from the same feedstock, at the same temperature, with the same quality, during a maximum of 365 days.
 - 5.2 Each production batch has to be registered in the Biochar Tool and receives a unique ID number with a corresponding QR code. The ID number and the QR code ensure the traceability of the biomass feedstock, the conditions of production, and the quality of the biochar.
 - 5.3 A production batch lasts a maximum of 365 production days including all possible interruptions in production.
 - 5.4 A batch is always linked to a unique production unit. A batch cannot be produced by more than one production units.
 - 5.5 The pyrolysis temperature in °C must not change by more than 20 % during production. With a declared pyrolysis temperature of, for example, 600 °C, short-term fluctuations between 480 °C and 720 °C are thus permitted. Documented production interruptions, both planned and unplanned, are permitted provided that the specified temperature range is maintained after resuming production. Depending on the pyrolysis process, biochar from the plant start-up and shut-down process may need to be carefully separated and documented, and must not be marketed as EBC-FeedPlus, EBC- AgroOrganic, or EBC-Agro.
 - 5.6 The blend of different types of biomass listed in the EBC positive list may not change by more than 20 percentage points. For example, if a mixture of 50% cereal husks and 50% landscape conservation wood is pyrolyzed, the proportions may vary in the range 40% to 60% [$\pm(50\% \times 20\%) = \pm 10\%$].
 - 5.7 Biochar whose production conditions did not fall within the tolerance limits of a batch may not be labelled and sold with the registered certification class. The quality control to ensure homogeneous quality of biochar within a batch is the responsibility of the producer.
 - 5.8 If a biochar producer registers for the first time a biochar production batch, a representative sampling has to be carried out by an endorsed sampler within the first two months after registration.
 - 5.9 After a production batch has expired, a subsequent, new production batch must be registered in the Biochar Tool.
 - 5.10 If the new production batch is produced with the same parameters as the preceding batch, the new sample must be taken two months before the current batch's expiration to ensure timely analysis and registration of the new batch.
 - 5.11 Complete production records must be kept, providing detailed descriptions and dates of any production problems or stoppages. Furthermore, the daily taking of the retention sample must be recorded (see chapter 6.3 retention sample).
 - 5.12 The daily production quantities of biochar must be documented. The total biochar production amount must be reported in the Biochar Tool at least every three months, usually at the end of each quarter.
 - 5.13 A pyrolysis plant can produce several batches during the reference time of one year if feedstock and/or production conditions are changed. The interruption of one batch must be registered before starting or restarting another batch with its own ID and it must be declared if the batch shall be ended or is to be continued. A batch may be restarted after producing one or several other batches in between. Still, the batch must end eventually the latest 365 calendar days after the first start (cf. 2.2.).
- As soon as either point 5.4 or point 5.5 is no longer fulfilled, a production batch is considered completed. A new production batch with the changed parameters must be registered in the Biochar Tool. A new representative sample must be taken. The annual inspection visit takes place at least once per calendar year, irrespective of the number of batches produced.

6. Biochar sampling

6.1. Representative sample

Biochar samples sent to the endorsed laboratory for EBC analysis must be taken by an endorsed sampler. The sampling plan must be submitted by the producer in preparation for the technical pre-audit. It must be approved by Carbon Standard International, registered in the Biochar Tool, and followed by the endorsed sampler.

The certification body (e.g., Cert AG) is entitled to take additional samples at any time and send them to an endorsed laboratory or to Carbon Standard International.

6.2. Sending of the representative biochar sample to the endorsed laboratory

The representative samples for analysis must be sealed by the endorsed sampler and registered in the Biochar Tool before shipping the sample. Only samples that have been registered via the Biochar Tool and assigned a unique ID number are considered EBC analysis samples.

The producer sends the sealed sample to an EBC-endorsed laboratory, which has been selected by the producing company.

6.2.1 The endorsed laboratory shall send the results of the analysis to the biochar producing company and a copy to the accredited inspection body, Carbon Standard International and the Ithaka Institute.

6.2.2 Carbon Standard International and the Ithaka Institute have the right to use the results of EBC analyses in anonymised form for statistical and scientific purposes.

6.3. Retention Sampling

In addition to the EBC analysis sample, the manufacturer is obliged to take regularly (in general every day) retention samples. The exact procedure must be submitted by the producer in preparation for the techni-

cal pre-audit. It must be approved by Carbon Standard International, registered in the Biochar Tool. The following procedure can be used as a model:

Daily, a fresh sample of one liter, either from the cross-flow or from the collected daily production has to be taken. The cross-flow sample can be taken both manually and automatically from the daily production [5].

The daily sampling time has to be entered in the production record. The daily samples must be collected for one month at a time in a sample container as a composite 30-liter sample. After one month the composite sample shall be sealed. The next 30 cross-flow samples shall be collected in a new sample container until this container is also sealed and stored.

The monthly retention sample must be kept dry and protected for two years. The retained samples serve to protect the producer, who will thus be able to prove in the event of any complaints from authorities or customers that the relevant biochar was free of pollutants and that it met the quality guaranteed by the EBC certificate. Retention samples may also be used by the certification body to verify results of the representative samples.

Company-specific regulations for the creation and storage of reserve samples can be defined by the certification body and/or Carbon Standards International.

7. Biochar properties

The aim of the EBC certificate is to guarantee compliance with all environmentally relevant limit values and to declare those biochar properties which are relevant for the respective certification class and that can be analyzed at reasonable cost.

There are numerous additional analytical possibilities to characterize and classify biochar even more comprehensively. However, many of these would go beyond reasonable cost limits. We do not seek to analyze, regulate and guarantee all possible parameters, but rather those that are necessary to ensure safety and sustainability.

The limit values mentioned in the following chapter are only valid in conjunction with the permissible test procedures and permissible analytical methods. These are detailed for the individual parameters in Appendices 1-3.

Additional or more stringent limit values that apply only to certain countries are regulated in the respective country annex (see Annex A5ff). Compliance with a Country Annex becomes mandatory for biochar producers in the respective country or when exporting biochar to that country.

7.1. The biochar's organic carbon (C_{org}) content must be declared.

The organic carbon content of biochar varies between less than 20 % and 95 % of dry matter, depending on the biomass feedstock and the pyrolysis conditions. For example, the carbon content of pyrolyzed straw is usually between 40 and 50%, and that of wood and nutshells is between 70 and 90%.

7.2. The molar H/C_{org} ratio must be less than 0.7 and less than 0.4 for EBC-Feed

The molar H/C_{org} ratio is an indicator of the degree of carbonisation and therefore of the biochar stability. The ratio is one of the most important characterising features of biochar and is indispensable for the determination of the C-sink value. Values fluctuate

depending on the biomass and process used. Values exceeding 0.7 are an indication of non-pyrolytic chars or pyrolysis deficiencies [6]. For EBC-FeedPlus, H/C_{org} must be less than 0.4 (c.f. chapter 10).

7.3. The molar O/C_{org} ratio should be below 0.4

In addition to the H/C_{org} ratio, the O/C_{org} ratio is also relevant for characterising biochar and differentiating it from other carbonisation products [6]. Compared to the H/C_{org} ratio, direct measuring of the O content is expensive and not standardized. Therefore, the calculation of the O content from C, H, N, S and ash content is accepted.

The O/C_{org} ratio can sometimes exceed 0.4 due to post-pyrolytic treatment or by co-pyrolysis with oxidative or catalytically acting additives. In this case, Carbon Standards International would carry out a plausibility check and grant an appropriate exemption, provided that product quality and environmental protection are guaranteed.

7.4. The biochar nutrient contents must be declared at least for nitrogen, phosphorus, potassium, magnesium, calcium, and iron.

The nutrient contents of different biochars depends on the feedstock selection and can account for up to a third of the total weight. It should be noted that these nutrients are only partially available to plants due to covalent bonds (especially in the case of nitrogen) and/or the high adsorption capacity of the biochar and may only be reincorporated into the biological cycle over decades. The nutrient availability of the phosphorus found in biochar is for instance only about 15% in the first year, that of nitrogen a mere 1%, while availability of potassium can reach 50% [9].

For the use in agriculture and animal husbandry nutrient information is legally required. For material uses, the nutrient contents are generally less relevant, but depending on the application, they may influence certain material properties, especially with higher contents of calcium, potassium, and magnesium, which is why the declaration of the nutrient contents is also mandatory for both material certification classes.

7.5. The following limit values for heavy metals must not be exceeded

For EBC-Agro, the maximum values for heavy metal contents are based on the EU-Fertilising Products Regulation EU 2019/1009 [10], the German Federal Soil Protection Ordinance [11]; and for EBC-AgroOrganic on the EU regulations 2019/2164 on organic production, and the Swiss Ordinance on Risk Reduction related to Chemical Products (ChemRRV). EBC thresholds for heavy metals never exceed EU and country regulations. However, the EBC may decide on lower limit values by precautionary principles. EBC-Urban and EBC-Materials must meet the same heavy metal limit values as EBC-Agro. As biochar certified under EBC-Basic has to be included into material matrices from where the biochar cannot leach, no limit values for heavy metals apply.

Additional parameters and methods apply to EBC-FeedPlus, which are described in Chapter 10.

Tab. 2: Limit values for heavy metals according to the EBC certification classes.

		EBC-FeedPlus	EBC-AgroOrganic	EBC-Agro / EBC-Urban / EBC-Materials	EBC-Basic
Heavy metals	Pb	5 g t ⁻¹ (88%DM)	45 g t ⁻¹ DM	120 g t ⁻¹ DM	no limit value, only declaration required
	Cd	0.5 g t ⁻¹ (88% DM)	0.7 g t ⁻¹ DM	1,5 g t ⁻¹ DM	
	Cu	70 g t ⁻¹ DM	70 g t ⁻¹ DM	100 g t ⁻¹ DM	
	Ni	25 g t ⁻¹ DM	25 g t ⁻¹ DM	50 g t ⁻¹ DM	
	Hg	0.1 g t ⁻¹ (88% DM)	0.4 g t ⁻¹ DM	1 g t ⁻¹ DM	
	Zn	200 g t ⁻¹ DM	200 g t ⁻¹ DM	400 g t ⁻¹ DM	
	Cr	70 g t ⁻¹ DM	70 g t ⁻¹ DM	90 g t ⁻¹ DM	
	As	2 g t ⁻¹ (88% DM)	13 g t ⁻¹ DM	13 g t ⁻¹ DM	
	Ag	no limit value, only declaration required			

Heavy metals are an essential component of all ecosystems. Even in natural soils that are hardly influenced by human activities, every plant absorbs more than 50 geogenic elements of the periodic table and amidst those there are all essential heavy metals. Heavy metals are only toxic if their concentration is exceedingly high and if they are bio-available, which is why the limit values listed in Table 2 have been defined for each type of application.

With the exception of a few heavy metals that are volatile or semi-volatile at the prevailing pyrolysis temperatures (e.g., mercury), the amount of heavy metals originally contained in the biomass is retained in the

biochar. While the weight of the original biomass is reduced during pyrolysis by more than 50% due to the loss of carbon, hydrogen, and oxygen, heavy metals remain which leads to increased concentration, i.e., the heavy metal content in the biochar is higher than in the original biomass.

As long as the biomass was not grown on contaminated soils or has increased heavy metal contents due to plant treatments (e.g., copper spraying in viticulture) or due to contamination with wastes, the concentration effect from pyrolysis is not critical. Heavy metal contents beyond the limit values thus indicate above all the contamination of the biomass used and thus represent an additional control of the biomass quality.

Soils in certain regions are deficient in Zinc and Copper, requiring the replacement of those elements in the form of micronutrient fertilizers. Biochars with Zinc and Copper concentrations exceeding the EBC-Agro or EBC-AgroOrganic thresholds may, therefore, be labeled and traded as Zinc and/or Copper micronutrient fertilizers. However, trading such biochars exceeding Zinc and/or Copper thresholds is not authorized without clearly labeling them as micronutrient fertilizers, labeling the concentration of the micronutrients, and including recommendations for their application.

In industrial applications, including the use of biochar in asphalt, concrete and composite materials, the risk of heavy metals being leached into the environment or harming users of these industrial materials is generally quite low. For this reason, EBC-Basic only requires the declaration of heavy metal contents but does not define limit values. It is incumbent upon industrial manufacturers that seek to incorporate biochar into their products to comply with the respective limit values pertinent to their industry. In addition, all industrial producers and users are urged to carefully consider end of the life handling of their industrial materials to prevent pollutants from entering the environment.

7.6. pH, salt content, bulk density, and water content must be declared.

The pH value of biochar is an important criterion for the targeted use in substrates as well as for the fixation of nutrients in animal husbandry as well as in industrial products. The salt content, measured via electrical conductivity of the biochar leachate, may in-

dicating a contamination of the feedstock, and should therefore be measured. Bulk density (on dry matter base) and water content are necessary specifications for trading biochar as well as for the production of consistent substrate mixtures and materials requiring consistent carbon contents.

The biochar of the classes EBC-FeedPlus, EBC-Agro, EBC-AgroOrganic, and EBC-Urban must be adjusted to a water content that prevents dust formation and thus also spontaneous combustion (see also chapter 9.3). Appropriate storage must prevent the biochar from drying. EBC recommends a water content of 30% for this purpose. There are no guidelines regarding water content for EBC-Materials and EBC-Basic, which may only be traded B2B. However, if the biochar is sold with a water content of less than 30% or a water content that cannot effectively prevent dust formation, the manufacturer and trader must indicate the associated hazards following relevant standards and local, national, and international requirements. This includes, but may not be limited to, spontaneous ignition, dust explosion, and the health hazards of inhaling (fine) dust. Appropriate safety precautions must be indicated.

7.7. The determination of the water holding capacity (WHC)

Water holding capacity (WHC) provides guidance for mixing biochar with liquids, e.g., liquid fertilizer, digestate, storm water management. It is also a valuable indication of its effectiveness in increasing a soil's water holding capacity and for humidity buffering when e.g., applied to the root zone. WHC may also help to evaluate the moisture absorption and buffering capacity of construction and other biochar-based materials.

7.8. Electrical conductivity of the solid biochar

The electrical conductivity of biochar is a highly important indirect parameter to compare batches and the homogeneity of biochar within a given batch. Moreover, it was shown that certain effects of biochar in soil, in the digestions system, in anaerobic digesters, in composting, and in certain composite and construction materials may be related to the electrical conductivity of the solid biochar. It should not be confounded

with the electrical conductivity of the aqueous leachate of biochar, which is used to estimate the salt content.

7.9. Specific surface area and pore size distribution are non-obligatory additional parameters

The specific surface area according to BET is an important characterization and comparison criterion for the physical structure of biochar. It should be noted, however, that no method provides absolute values for the specific surface area, but only relative values which allows for standardized comparisons. The BET surface area is often over- and misinterpreted: The BET does not allow any statement about the colonization potential for microorganisms. A higher BET surface does not necessarily mean a higher potential for contaminant binding. For a more precise evaluation of the pore properties, at least data on pore size distribution would be required. Due to the costs, the measurement of specific surface area and pore size distribution are recommended as additional parameters but are not mandatory.

7.10. Limit values for PCB and PCDD/F must be observed

In modern pyrolysis plants, only minimal quantities of PCBs, polychlorinated dibenzo-p-dioxins and furans (PCDD/F) are produced [4]. Significant PCB and PCDD/F contaminations can only occur when pyrolysis gases condense on biochar surfaces. If the latter is the case, PAH contamination would be high too [5]. Therefore, it is considered sufficient that PCB and PCDD/F must only be quantified if the sum of the 8 EFSA PAH exceeds $1 \text{ g t}^{-1} \text{ DM}$.

The limit values for PCB are $0.2 \text{ mg kg}^{-1} \text{ (DM)}$, and for PCDD/F they are $20 \text{ ng kg}^{-1} \text{ (I-TEQ OMS)}$, respectively. The limit values are based on the soil protection regulations in force in Germany and Switzerland [6,7].

7.11. Limit values for PAH contents must not be exceeded

EBC-Certification Class	Certification Class	EBC-FeedPlus	EBC-Agro / EBC-AgroOrganic	EBC-Urban	EBC-Materials*	EBC-Basic
Organic contaminants	16 EPA PAH	6.0+2.4 g t ⁻¹ DM	6.0+2.4 g t ⁻¹ DM	CSI-declaration	CSI-declaration	CSI-declaration
	8 EFSA PAH	1.0 g t ⁻¹ DM				4 g t ⁻¹ DM
	benzo[e]pyrene benzo[j]fluoranthene	< 1.0 g t ⁻¹ DM for each of both substances				

The pyrolysis of organic materials causes the formation of polycyclic aromatic hydrocarbons (PAH) [14]. The PAH content of biochar depends primarily on the pyrolysis conditions like temperature and the separation of biochar and pyrolysis gases in the reactor and discharge [15,16]. Appropriate production technologies with both classical kilns and modern pyrolysis reactors can avoid undesired PAH-contamination of biochar, correct process control provided. The type of biomass feedstock used for biochar production has a negligible influence on the PAH content [17].

During biochar production, PAHs are usually released with the pyrolysis gases and are destroyed when these pyrolysis gases are combusted to produce thermal and electric energy. However, depending on the process conditions, a smaller or larger part of the released PAHs can be adsorbed by the simultaneously produced biochar. Moreover, if biochar is cooled down in the presence of PAH-containing pyrolysis gas, significant amounts of PAHs condensate on the biochar surfaces within the complex porous system. Thus, biochar and pyrolysis gas must be separated at temperatures that do not allow condensation and sorption of PAH on the biochar. Controlled vapor quenching may support avoidance of PAH accumulation.

In principle, biochar with a very low PAH content can be produced even by the simplest of means, as demonstrated by the Kon-Tiki flame curtain kiln [18]. However, some industrial pyrolysis and gasification technologies developed over the past decades resulted in biochars with elevated PAH levels [19], which are an indication of unsatisfactory or unsuitable production conditions. The technical feasibility to produce biochar with very low PAH contents is demonstrated by all EBC- certified biochar companies and their technology suppliers since 2012.

Individual PAH differ widely in their toxicity [20]. The type and degree of toxicity (e.g., genotoxicity, carcinogenicity, ecotoxicity) depends on the molecular structure, the concentration, the bioavailability, the exposure route, and the temporal course of the exposure. The bioavailability of a PAH molecule is determined by the matrix to which the toxin is bound when exposed to humans, animals, or ecosystems.

As shown by Hilber et al. [21,22], biochar that is amended to soil acts more as sink than a source of PAHs. As PAHs are ubiquitous in agricultural and urban environments such as soil or the atmosphere, low-PAH-biochars that are used in soil adsorb more PAHs from the soil than they release into the soil. The high adsorption capacity distinguishes biochars from other amendments like compost, digestate, manure, and other fertilizers. The use of identical PAH limit values for low and high PAH-adsorbing materials can thus be questioned.

Biochar is not only a potent adsorber of PAHs [23] but also the bioavailability of biochar-bound PAHs is extremely low [21]. Compared to compost, digestate, fertilizer, atmospheric depositions, or hay which are all important entry points of PAHs into agronomic systems [24,25], PAH- bioavailability from biochar is most likely the lowest. The risks of bioavailable PAHs for plants, soil biota, animals, and humans are rather well known and investigated [20,26–28]; however, to our knowledge, only one initial investigation about the risks of exposure to biochar bound PAHs was published yet [29]. In the absence of a proper risk assessment, the precautionary principle led the regulators to apply for biochar the same limit values for PAH contents as for compost or digestate.

Another reason for applying the same PAH limit values to all soil amendments is the principle of not allowing total PAH concentrations in soil to build up over time and keeping total concentrations below the limit values set in regulations to protect soil from pollution.

Hilber et al. 2019 [30] demonstrated that using low PAH limit values is prudent and reasonable. When biochars with higher contents of PAHs (up to 60 mg Σ 16 EPA-PAH per kg biochar) were introduced in the rumen of a fistulated bovine, more than half of the PAHs from the biochar were released in the digestive system of the cow and may thus have impaired the biological system.

Therefore, applying the precautionary principle and complying with existing regulations for other substrates and materials in agriculture and industry, the EBC limit values for PAHs were set for the various certification classes on the following existing legal regulations and considerations:

In the EU fertilizer product regulation, a limit value of 6 mg kg⁻¹ DM was set for the sum of 16 EPA-PAH [3,31]. Since 2021, this limit value applies to EBC-Agro. The list of 16 individual PAH compounds was compiled by the U.S. Environmental Protection Agency to allow monitoring and regulation of PAHs. These 16 compounds were selected from hundreds of PAHs [32] based on environmental relevance, toxicity, and ability to measure them.

The reason for using the 16 EPA-PAHs as reference and the selection of such low limit values is, as explained above, not based on biochar science or biochar-based risk assessments but is entirely based on limit values that were established for other soil-amendments like compost, digestate, plant substrates, and (contaminated) soil itself. In absence of investigations how PAHs in biochar may pose risks to the environment and health, it was easier and faster to use the lowest known limit values for any type of soil amendment and apply it for biochar, too. The alternative to this pragmatic decision would have been to wait until systematic research would eventually provide the evidence to set new limit values specifically for biochar to protect soils, plants, animals, workers, and consumers. As a result, the application of biochar would not have been authorized for many years to come. For this reason, the EBC applied and defended the low PAH limit values in its standards since 2012.

For animal feed, no EU or member state limit value for PAHs exist so far, and thus no PAH limit value for feed grade biochar neither. However, with the publication of Hilber et al. [30], we know that PAHs might get desorbed in cattle rumen and thus may harm animals that are regularly fed with biochar containing fodder. Moreover, the EBC should not allow that biochar with too high amounts of PAHs entered the soil via the animal feed pathway. As the current EU laws do not prohibit feeding an animal with substances that would not be permissible as a soil amendment, it is extremely important that biochar used as an animal feed additive is subjected to PAH quality control.

It is at least questionable, if selecting the 16 EPA-PAH compounds is the best choice for monitoring PAHs on biochar. Using a limit value for the simple sum of those 16 PAHs attributes equal importance to each of the individual substances in the interpretation of the analysis.

Although all 16 PAHs are among EPA's priority environmental pollutants, this list can be divided into eight PAHs with insufficient or no evidence of carcinogenicity and eight carcinogenic PAHs². The latter compounds 'should be given special attention [33] and, consequently, the EBC defines limit values for Σ 8 EFSA PAHs as follows.

In 936 biochar analyses using the EBC-endorsed methods, we found that the eight non-carcinogenic PAHs accounted for more than 80% of all analysed PAHs. Given the high number of analyses this can be considered a common distribution of PAHs adsorbed by biochar in common pyrolysis and gasification technologies [16]. The current Σ 16 EPA-PAH limit values for biochar are thus based on the assumption that this is the general distribution of the individual PAH compounds. It is, however, technically possible to reduce the content of smaller (non-carcinogenic) PAHs in post-pyrolytic treatments whereas the more complex (carcinogenic) PAHs remain in the biochar because of the higher affinity of biochar for higher molecular weight-PAHs. Hence, the 6 mg Σ 16 EPA PAHs kg⁻¹ of such a biochar could mainly consist of carcinogenic substances like Benzo[a]pyrene (BaP). Such high contents of carcinogenic substances would pose a considerable health risk when applied to feed and soil. To

2 The eight carcinogenic compounds within 16 EPA PAH = 8 EFSA PAH are Benzo[a]pyrene, Benzo[a]anthracene, Chrysene, Benzo[b]fluoranthene, Benzo[k]fluoranthene, Dibenzo[a,h]anthracene, Indeno[1,2,3-cd]pyrene, Benzo[ghi]perylene

avoid such risks due to potential post- pyrolytic treatment of highly PAH-contaminated biochars, the EBC introduced in 2022 a new limit value for the eight cancerogenic compounds that are included in the 16 EPA PAHs (see footnote).

The EBC follows the European Food Safety Authority's (EFSA) suggestion to evaluate food safety by monitoring the total concentrations of these eight cancerogenic PAHs [34]. In the data set of the 936 EBC $\Sigma 16$ EPA PAHs analyses, 99% of all analysed samples that complied with the EBC-Agro limit value of 6 mg $\Sigma 16$ EPA PAHs kg⁻¹ contained less than 1 mg $\Sigma 8$ EFSA PAHs kg⁻¹. As we do have assurance from the EBC-certification control that none of the 936 samples were subjected to post-pyrolysis treatment to reduce selected PAH-species, we can assume with sufficient confidence that the 936 sample represent the common distribution of PAHs adsorbed by biochar in common pyrolysis and gasification technologies. In the case of post-pyrolytic treatment or the use of novel pyrolysis technologies that reduce selectively the lighter (non-cancerogenic) PAHs, the new limit value of 1 mg $\Sigma 8$ EFSA PAHs kg⁻¹ is safer than the (higher) $\Sigma 16$ EPA PAHs limit values that could mask elevated amounts of cancerogenic PAHs.

For the above reasons, 1 mg $\Sigma 8$ EFSA PAHs kg⁻¹ is defined as the only PAH threshold for EBC-Urban, and EBC-Materials. For the purpose of quality control and to provide Carbon Standards International with a solid data base for (i) the introduction of further EBC classes, (ii) possible upcoming legislative changes, as well as (iii) the expansion of EBC to further countries/regions, the $\Sigma 16$ EPA-PAH must be declared to Carbon Standards International for all certification classes.

To maximize safety of EBC-FeedPlus, EBC-Agro, and EBC-AgroOrganic, the 1 mg $\Sigma 8$ EFSA PAHs kg⁻¹ and the 6 mg $\Sigma 16$ EPA PAHs kg⁻¹ provided by the EU fertilizer product regulation apply concurrently. For EBC-Basic a limit value of 4 mg $\Sigma 8$ EFSA PAHs kg⁻¹ is defined. The EU-REACH regulation's list of eight carcinogenic PAHs has two substances that differ from the 8 EFSA and the 16 EPA compounds³. To comply with the EU-REACH regulations, the EBC includes these two addi-

tional PAHs into its analytical program and controls that neither benzo[e]pyrene nor benzo[j]fluoranthene is contained at higher concentrations than 1 mg kg⁻¹ for all certification classes.

The **EBC-Urban** limit value for PAHs is defined by the eight carcinogenic PAHs which provides reliable safeguards for workers, citizens and soil. Because PAHs are ubiquitous in urban environments (e.g., from car exhaust, tyre abrasion, domestic heating, and atmospheric deposition), and because biochar applied to urban soil is a strong adsorber for PAHs, EBC-certified biochar will act in the urban environment as a net adsorber of those environmental toxins.

The limit values for **EBC-Materials** are stricter than the EU-REACH regulation for consumer products which bans all products containing more than 1 mg kg⁻¹ of one of the eight individual carcinogenic PAHs [1]. The EBC assumes it as consistent to use the same limit value of cancerogenic PAHs for soil, feed, food, water, ecosystem, and consumer product applications.

The limit value for $\Sigma 8$ EFSA PAHs in **EBC-Basic** is 4 mg kg⁻¹ because the biochar particles are embedded and firmly bound into mineral or polymeric matrices (e.g., concrete, asphalt, plaster, composites) and direct contact with living organisms can be avoided. This limit is mainly based on what can be regarded as harmless to employees handling the raw materials with adequate safety measures (packaging, storage, and ventilation) and suitable personal protective equipment.

Thanks to the above outlined requirements, all EBC certified biochars are compliant with the EU- REACH commission regulation [1]. Still, the $\Sigma 16$ EPA-PAH must be declared to CSI for all EBC certification classes.

It should be noted that due to the high adsorption capacity of biochar, most of the analytical methods used for example for soil analysis of PAHs are not suitable for biochar [19]. It is therefore strongly recommended to always use the service of EBC endorsed laboratories to perform PAH analyses even outside of the context of EBC certification.

The very low PAH limit values only allow an analytical accuracy of 40% for the 6 mg $\Sigma 16$ EPA PAHs kg⁻¹ limit value which implies an accuracy of ± 2.4 mg kg⁻¹ dm.

³ The COMMISSION REGULATION (EU) No 1272/2013 refers to Benzo[a]pyrene, Benzo[e]pyrene, Benzo[a]anthracene, Chrysene, Benzo[b]fluoranthene, Benzo[j]fluoranthene, Benzo[k]fluoranthene and Dibenzo[a,h]anthracene as PAHs that are classified as carcinogens. Compared to 8 EFSA PAH, which are a subset of the 16 EPA PAH, Indeno[1,2,3-cd]pyrene and Benzo[ghi]perylene are missing in the EU-regulation. However, Benzo[e]pyrene and benzo[j]fluoranthene are not part of either the 8 EFSA PAHs or the 16 EPA PAHs. Therefore, benzo[e]pyrene and benzo[j]fluoranthene have not yet been quantified in routine analysis of biochar but are added to the EBC-analyses since 2022 to guaranty conformity with the EU-REACH regulation.

8. Pyrolysis

8.1. Biomass pyrolysis must be operated in an energy efficient manner.

Except for the preheating of the pyrolysis reactor, the use of fossil fuels for heating the pyrolysis reactor is prohibited. The use of waste heat from other industrial processes, such as bio- digesters or cement production or the use of solar thermal energy is permitted. If the pyrolysis reactor is electrically heated, the use of renewable energy sources or the use of surplus electricity is required.

8.2. Homogeneity of biochar quality

The pyrolysis conditions must be adjusted such that a homogeneous quality of the biochar can be ensured throughout the entire batch.

8.3. The pyrolysis gases produced during pyrolysis must be recovered or burned. They are not allowed to escape into the atmosphere.

A significant portion of the global charcoal and biochar production is still made using obsolete technology [35] where most of the original feedstock carbon is released as toxic emissions to the atmosphere. Although the material quality of biochar produced in such kilns may meet EBC requirements, the environmental impact of such production techniques is highly negative.

However, if pyrolysis gases are trapped and are cleanly burned or used as bio-oil for the chemical industry, the environmental impact is neutral and even improved compared to biomass burning or natural decomposition. The EBC certificate guarantees that only climate positive biochar production technology is used and does not release unburned pyrolysis gases to the atmosphere.

8.4. Syngas combustion must comply with national emission limit values.

With emission limit values and regulations differing from one country to the next, any further definition of emission limit values for pyrolysis facilities would exceed the purpose and proportionality of these guidelines. Therefore, manufacturers must provide a guarantee that their facilities comply with national emission regulations. An annual, government-accredited emission measurement of the production plant is recommended.

For certification of the C sink potential of biochar, the pyrolysis unit must have an EBC type certificate (see Global Biochar C-Sink Standard) or provide endorsed emission measurements of the waste gas stream.

8.5. Biochar production must be energy efficient

For every batch of a certified pyrolysis unit, at least 60% of the sum of the energy contained in the biomass and all energy expenditures of the process must be recovered in the form of biochar, pyroil, refined chemicals, usable heat, or electricity.

Approximately 35 to 60 % of the energy contained in the biomass feedstock is eventually contained in the pyrolysis gas, which is usually burned in the pyrolysis unit. Part of the energy released during the combustion of these gases is often used to heat the biomass for pyrolysis. Excess heat must be used, e.g., for drying biomass, for district heating, for generating electricity or for similar sustainable purposes.

Alternatively, the pyrolysis oil and/or gas can also be captured and used for energy storage, e.g., to deliver peak loads in district heating in winter by burning pyrolysis-oil that was collected during summer. The material use of the bio-oil and/or the upgrading of the pyrolysis gas into basic chemicals such as methanol are also conceivable options to reach the required energy efficiency.

For a transitional period of a maximum three years after installation of the pyrolysis plant, an exemption for lower energy efficiency can be applied for. In the meantime, a solution for efficient waste energy recovery must be developed.

To calculate the energy efficiency, the energy contained in the biochar (E_{solid}), the total amount of used electrical and thermal energy, and the heating value of the marketed pyrolysis products are divided by the sum of the energy content of the biomass feedstock and the external energy used to produce the entire batch. For a more detailed outline of the energy efficiency calculation, please see the Global Biochar C-Sink Standard.

$$E_{eff} = \frac{E_{solid} + E_{pyrooil} + E_{fuelproducts} + E_{thermal} + E_{drying} + E_{electric} + E_{CO2pur}}{E_{feedstock} + E_{expenditures}}$$

Equation 11: Calculation of the energy efficiency (E_{eff}) using the energy content of the biochar (E_{solid}), the pyrolysis oil ($E_{pyrooil}$), the fuels produced by the pyrolysis process ($E_{fuelproducts}$), the produced thermal energy ($E_{thermal}$), the energy used for feedstock drying (E_{drying}), the electricity produced ($E_{electric}$), the energy value of separated CO_2 from the flue gas (E_{CO2pur}), the higher heating value of the feedstock ($E_{feedstock}$), and the energy expenditures for the entire pyrolysis facility ($E_{expenditures}$).

8.6. Certification of individual pyrolysis units

Each pyrolysis unit requires individual certification; it's not permitted to produce a single batch using separate units.

However, if multiple pyrolysis units are identical in design, share the same feedstock container, and discharge biochar into the same output container, a request to Carbon Standards may be submitted to consider these connected production lines as a single pyrolysis unit, thereby producing homogeneous biochar quality.

9. Work safety and health

- 9.1 Fire and dust protection regulations are to be complied with local and national regulations throughout the entire production, transportation, and user chain. An official operating permit or equivalent document must be presented.
- 9.2 All workers must be informed in writing about possible risks and dangers of and around the production facility and sign the document. This concerns, in particular, the self-ignitability of char dust, respiratory protection, contact with bio-oil and tars and possible gas leakage.
- 9.3 During transportation and bulk transfers, attention must be paid to the biochar being sufficiently moist to prevent dust generation or dust explosions (cf. chapter 7.7).
- 9.4 Workers must be equipped with suitable protective clothing and breathing masks where necessary.

10. Biochar for use as a feed additive

Biochar is a traditional feed additive that was often used to treat digestive problems of livestock. Since 2010, biochar is increasingly also used as an additive to daily feed mixtures. The use of biochar (i.e., vegetal carbon) as a feed additive is authorized by the EU-Feed regulation L 159 / 25 Nr . 575 / 2011 [2]. The EU provides different and additional limits for the use of biochar as feed compared to its use as a soil additive (Directive 2002/32/EC of 7 May 2002 on undesirable substances in animal feed [2] and Regulation (EC) No 396/2005 on maximum residue levels of pesticides in or on food and feed of plant and animal origin [36]. Therefore, the certification of EBC-FeedPlus requires the analysis and control of additional parameters compared to those presented in chapter 7 and Annex 1 of the EBC Guidelines⁴. Some analytical methods and calculations have to be adapted. The permissible test methods as well as the analytical methods for the individual parameters are detailed in Annex 2.

10.1. Approval as animal feed producer

Producers of EBC-FeedPlus certified biochars must mandatorily register as feed producers with the relevant authorities in accordance with applicable regional, national and/or EU regulations and submit proof of this to the EBC.

The aim of EBC-FeedPlus is to ensure that the biochar quality is suitable for animal feeding and that its production is sustainable. The equally important aspects of feed safety and hygiene during production, and especially storage and transport, can only be controlled by the EBC to a limited extent and thus not fully be guaranteed.

10.2. Biomass – only pure plant biomass feedstocks are permitted

When the original EBC-FeedPlus Certificate was introduced, only untreated trunk wood was approved as the source material for feed grade biochar production.

⁴ Version 10.4 of this standard contained an additional certification class, "EBC-Feed." Producers are granted a transition period until December 31, 2026, during which a batch can still be certified as EBC-Feed in accordance with the rules of standard version 10.4. As of 2027, no more batches will be certified with "EBC-Feed."

In the meantime, however, a sufficient number of scientific studies have been published [37], which show that biochar produced from other plant biomass had just as positive an effect on feed efficiency and animal health as wood based biochar. For this reason, all pure plant biomasses are approved since 2020 for the production of EBC-FeedPlus biochar according to the EBC feedstock list. Mineral additives are not permitted. Feedstocks with chemical additives, contaminations, or the risk of contaminations due to non-controllable source are excluded for the production of EBC-FeedPlus (e.g., chemically treated wood, paper sludge, green waste from municipal collection, etc.).

10.3. Separation of impurities

A significant risk to feed safety comes from possible impurities that can contaminate the biochar via the feedstock, the production process, or during storage. These are mainly pieces of metal, plastic, glass, and stones. Thus, rigorous control of the feedstock is necessary before it enters the pyrolysis process. To prevent metal and other impurities originating from the pyrolysis plant, it is necessary to regularly check the plant (check that no screws are missing, parts are broken or that abrasion occurs, etc.). To exclude the possibility of impurities entering the feed biochar after production, the biochar must be packaged and stored tightly sealed.

It is recommended to pass both the biomass before entering the pyrolysis unit and the biochar between discharge and packing through a magnetic metal separator. Also, stones and glass fragments pose a risk of injury to the animals if swallowed, mainly because of possible sharp edges and corners, and may also be present, for example, in source materials such as forest wood chips or crop residues otherwise commonly assumed to be clean. To at least eliminate this risk, in addition to using a stone separator, grinding the biochar to < 3 mm is recommended; silicate (glass) and stone per se are not toxic or harmful.

Feed manufacturers must be able to guarantee that marketed feed products are free of impurities following government requirements. According to Regulation (EC) 183/2005, a feed producer is responsible for feed safety. The EBC control processes (technical pre-audit, annual EBC inspection, visual inspection of random samples, laboratory analysis of a representa-

tive sample from each batch, reserve samples, documentation) provide assistance in this regard, but cannot replace the manufacturer's guarantee. In the event of complaints from users or other complaints and disputes, certification as an EBC-FeedPlus offer only limited security. To meet the responsibility for feed safety, EU Regulation 183/2005 strongly recommends that feed producers implement a Hazard Analysis and Critical Control Point (HACCP) system ("Feed business operators [...] shall put in place, implement, and maintain, a permanent written procedure or procedures based on the HACCP principles"). We therefore recommend additional external quality assurance by a certification body specialized in feed, such as GMP+ (<https://www.gmpplus.org>) or pastus+ (<https://amainfo.at/en/teilnehmer/futtermittel/pastus-zertifizierung/richtlinie-informationen>). Their certification process includes HACCP.

10.4. Pyrolysis temperature (HTT > 500 °C) and intensity ($H/C_{org} < 0.4$)

Although contaminated feedstock is not allowed within EBC-FeedPlus, trace contaminations, e.g., with pharmaceuticals or mycotoxins, can never be excluded completely. To assure the complete degradation of these organic micropollutants the pyrolysis temperature has to reach at least 500 °C for at least 10 min [38]. As these pyrolysis conditions are difficult to monitor and control, the H/C_{org} ratio is used as a proxy. The H/C_{org} ratio indicates the degree of aromatization of biochar carbon and thus the intensity of pyrolysis. If a biochar presenting an H/C_{org} ratio below 0.4, it is safe to assume that it was produced at temperatures above 500 °C for more than 10 minutes and is safe for animal consumption. The H/C_{org} ratio must not exceed 0.4 for EBC-Feed.

10.5. Heavy metals

According to feed regulations, the content of heavy metals including arsenic, lead, cadmium and mercury must be stated. The use of biochar as feed is based on the following limit values to be calculated on 88% of the dry matter content: arsenic: 2 mg kg⁻¹; lead: 5 mg kg⁻¹; cadmium 0.5 mg kg⁻¹ and mercury: 0.1 mg kg⁻¹.

10.6. PAHs

For EBC-FeedPlus, the limit value for the $\Sigma 8$ EFSA PAHs is set to 1 mg kg^{-1} and the $\Sigma 16$ EPA PAHs must not exceed 6 mg kg^{-1} (see chapter 7.12). To comply with the EU-REACH regulations, benzo[e]pyrene and benzo[j]fluoranthene must not be contained at higher concentrations than 1 mg kg^{-1} .

EBC-FeedPlus biochar fulfills all requirements of EBC-Agro and EBC-AgroBio. If EBC-FeedPlus biochar is applied as a feed supplement, bedding, and/or manure treatment, the manures resulting from these applications can be used as a soil amendment and for any other agronomic purposes such as composting, anaerobic digestion, and fertilizer production.

10.7. Dioxine, furane, dioxin-like PCB (WHO-PCB) and non-dioxin-like PCB (DIN- PCB).

The EU feed regulations prescribe strict limits for polychlorinated dioxins, furans and PCBs, which are well below the limits of the soil protection ordinance. Therefore, (1) each batch of feed biochars must be analyzed for these substances, and (2) the endorsed test method must have a lower detection limit. Consequently, special test methods and limit values for feed grade biochar apply here.

For PCDD / PCDF, a trigger value of $0.5 \text{ ng TE kg}^{-1}$ at 88% DM and a limit of $0.75 \text{ ng TE kg}^{-1}$ at 88% DM apply. For dl-PCB, a trigger value of $0.35 \text{ ng TE kg}^{-1}$ at 88% DM applies. For PCDD / PCDF + dl-PCB the limit value is $1.25 \text{ ng TE kg}^{-1}$ at 88% TS. For the sum 6 of DIN PCB, a limit value of $10 \mu\text{g TE kg}^{-1}$ at 88% DM applies.

10.8. Fluor < 150 mg kg^{-1} (88% TS)

The fluor content must be lower than $<150 \text{ mg kg}^{-1}$ (88% TS). However, fluorine salts are usually volatile in pyrolysis conditions and will rarely occur in biochars in significant concentrations.

10.9. Dry matter, crude ash, ash insoluble in hydrochloric acid

The specification of dry matter, crude ash content and HCl-insoluble ash are prescribed standard values of the EU feed regulations and must be stated on the product label. The content of the ashes must be determined by combustion at 550°C and given on an 88% dry matter basis.

10.10. Crude protein, crude fibre, crude fat

The indication of crude protein, crude fiber and crude fat contents are prescribed standard values of the EU feed regulations. Crude protein, crude fiber and crude fat are completely decomposed in the course of complete pyrolysis and are therefore no longer present in biochar. A biochar is considered to be completely pyrolyzed if the $\text{H}/\text{C}_{\text{org}}$ ratio is <0.4 , which is the prerequisite for EBC- FeedPlus certification. Thus, the analysis of crude protein, crude fiber and crude fat is not required and set by definition as 0 g kg^{-1} . The information is mandatory and must be stated on the product label.

11. Certification of companies that process biochar and manufacture biochar-based products

In agriculture and animal husbandry, biochar is rarely used in its pure form. More often it is part of a processed product such as a soil-amendments, potting soil, compost, fertilizer, bedding material, feed, or as an additive to anaerobic digestion or silage. In addition to the producers specialized in biochar manufacturing, a growing industry has developed, acquiring and processing biochar as a raw material for biochar-based products.

To guarantee and properly label products made with EBC-certified biochar, the entire supply chain, including production, processing, packaging, and labeling of the products, needs to be inspected and certified. Furthermore, this is a condition for C-sink registration.

Products containing biochar are only allowed to use the EBC logo and the inscription “Manufactured with EBC certified biochar” if the biochar processing company and their biochar-based products have also been certified according to the following guidelines.

11.1. Exclusive use of EBC certified biochar

The risks associated with the use of non-certified biochar in agriculture, livestock farming and in products ultimately destined for agricultural use, such as compost or biogas slurry, are very high, since in this case pollutants such as PAHs, dioxins and heavy metals may enter the human food chain and accumulate permanently in soils and the environment.

Therefore, products made with biochar can only become EBC-certified if the processing company uses exclusively EBC-certified biochar for their biochar-based products. The certified company may not use, store, or trade any biochar that is not EBC certified.

Without an exemption permit granted by Carbon Standards, no non-EBC or non-WBC certified biochar may be used, stored, and traded by the certified company.

11.2. Incoming goods inspection

All incoming biochar or biochar-based products must have the corresponding EBC certificate (EBC-FeedPlus, EBC-AgroOrganic, EBC-Agro, EBC-Urban, EBC-Materials, EBC-Basic) marked on the delivery documentation and labels. The incoming goods inspection must be documented.

Unlabeled biochar and biochar-based products without an EBC exemption permit must not be processed.

11.3. Storage

Biochar and biochar-based products must be stored in such a way that no contamination can occur. Particular attention should be paid to gaseous pollutants (for example engine exhaust gases) as these can be absorbed by the biochar. Biochar processors must ensure that neither different EBC certification classes nor different batches from different or the same manufacturers are mixed without documentation. The quality and origin of stored biochar as well as a traceable identification number and product name must be marked clearly visible on the storage or packaging material.

11.4. Processing journal

Each processing step of biochar and biochar-based products must be documented in a processing journal. The quantity and quality of all processed biochar and the amount of biochar contained in the final products must be documented.

If the biochar or biochar-based products are merely repackaged or relabeled, the quantity and quality of the original and final products must still be listed in the processing journal.

The control of the flow of goods (balance between incoming biochar and biochar products, specific processing, and the outgoing biochar and biochar products) must be tracked and always documented.

12. Labeling and Advertising with EBC Certification

12.1. Trademark protection and compulsory information

12.1.1. Registered trademarks

Carbon Standards International owns the following EU trademarks:

- (1) EU guarantee mark No 018071838 'EBC' (word mark) and
- (2) EU guarantee mark No 018071835 'Certified Biochar EBC European Biochar Certificate (EBC)' (figurative mark), reproduction:



(hereinafter referred to as 'EU trademarks').

Each of the EU trademarks are registered in respect to the following list:

Class 01:

Chemical substances, chemical materials and chemical preparations and natural elements, in particular biochar, activated carbon activated adsorbents, activated carbon filters for the purification of gases, and activated carbon filters for the purification of liquids; Growth and fertilizers and chemicals used in agriculture, forestry and horticulture, in particular fertilizers (in part) consisting of biochar (biochar); Putties, fillers and glues for industrial purposes, in particular coal for filters for removing organic contaminants from water; Filter materials [chemical, mineral, vegetable and other raw materials], in particular activated carbon.

Class 04:

Fuels, in particular of biochar (charcoal, charcoal). Class 05: Biochemical feed additives made from biochar.

Class 19:

Building materials and components, not of metal, (partially) consisting of biochar.

Class 31:

Foodstuffs and animal feed (in part) consisting of biochar (biochar); Litter and bedding materials for animals (partially) consisting of biochar (biochar).

Class 40:

Production of coal by biomass pyrolysis; Processing of biochar (biochar) as a raw material for the production of various products.

(hereinafter referred to as 'the goods and services claimed')

12.1.2. Right to use the EU trademark

Carbon Standard International grants:

- (1) Manufacturers of EBC certified biochar, as well as of products containing EBC certified biochar,
- (2) Processors and traders of EBC certified biochar and products containing EBC certified biochar and
- (3) Users of EBC certified biochar (e.g., farmers, operators of composting plants, operators of biogas plants) as well as of products containing EBC certified biochar (e.g., farmers, gardeners, animal keepers).

the right to use these EU trademarks for the aforementioned goods and services under the following conditions:

The EU guarantee trademark No 018071838 "EBC" (word mark) may only be used alone or with the following additions

- (1) "Zertifikat" / "Certificate", or "Zertifizierung" / "Certification" or "zertifiziert" / "certified"
- (2) "Agro", "AgroOrganic", "AgroBio", "Feed", "Feed-Plus", "Urban", "Materials", "Basic"

The EU guarantee trademark No 018071835 “Certified Biochar EBC European Biochar Certificate (EBC)” (figurative mark) may only be used as registered. Additions or modifications are not permitted.

12.1.3. Advertising with laboratory analysis according to EBC standard

If an analysis of the biochar has been carried out by an endorsed laboratory (see list at www.carbon-standards.com/ebc) in accordance with the EBC standard, but no EBC certification was obtained, the lack of certification must be pointed out in a suitable form when advertising the analysis result. Misleading statements in this regard should be avoided in any case.

Permissible are for example formulations like “laboratory analysis after EBC standard*”, footnote: “not certified”.

12.1.4. Contractual penalty

If the user of the warranty marks culpably violates the statutes of these trademarks, he is liable to pay a fine of 500,– EUR to 10,000,– EUR to the Carbon Standards International. The amount of the fine to be paid shall be determined by Carbon Standard International at its reasonable discretion and, in the event of dispute, reviewed by a court of law as to its appropriateness.

Accordingly, Carbon Standard International deprives the user of the right to use the warranty marks.

12.2. Mandatory information on biochar

Each packaging unit must be labeled with at least the following parameters. Further requirements and details about labeling are provided in the CSI design manual, which must be followed:

- The certification class of the biochar (EBC-FeedPlus, EBC-AgroOrganic, EBC-Agro, EBC-Urban, EBC-Materials, EBC-Basic). The certification class is part of the EBC certification label.
- Organic carbon content (C_{org})
- H / C_{org} – ratio
- pH
- Dry weight
- Volume
- Production Date
- Batch ID

All other relevant analytical information, such as feedstock, pyrolysis temperature, elemental analysis, nutrient content, heavy metals, WHC, electric conductivity of the solid biochar, and $\Sigma 16$ EPA PAHs must be found via the QR-code of the batch printed on the packaging and the delivery note. The analytical parameters of the biochar uploaded by the endorsed laboratory can thus be accessed via this QR code attributed by the Biochar Tool.

If the packaging units are produced before the QR code is created – such as packaging for the end consumer – a company’s own QR code on the packaging unit can link the product to the company’s website, from where a permanent redirection to the EBC website of the certified batch must be set up before the packaging units are sold.

12.3. Mixing of biochars

If biochars of different EBC certification classes are used in one product, the end product may only bear the EBC certification class(es) whose requirements have been met by each individual biochar. The labeling requirements provided in the CSI design manual must be followed.

Certified resellers of biochar or biochar products do not need to name and identify the original company or production site of the biochar.

13. Control, quality management and certification

13.1. Principles of certification

The inspection is carried out on site at each production facility. It takes place once a year.

If a biochar producer desires to become EBC certified, their entire biochar production site must be inspected and certified, regardless of whether only one batch, several or all batches qualify for one of the EBC certificates.

Should an EBC-certified producer produce a batch that cannot be certified at least for EBC-Basic due to non-compliance with limit values, the producer must prove proper disposal of this waste materials according to local or national regulations. Otherwise, the certification of the plant may be permanently withdrawn.

Any manipulation of the biochar after its production is considered processing and requires inspection by the certification body. Manipulation includes blending biochar with additives such as compost and fertilizer, or cement and resin, activation through thermal processes (production of activated carbon), and enhancement by biological and/or chemical treatment, or mechanical processing such as milling. It further includes mixing of different biochars, repackaging, and relabelling.

Biochar processing companies may be exempted from the annual inspection visit to the production site if they can prove that they process less than 10 t of biochar per year. In such cases, compliance with the production and quality guidelines is evaluated by the inspection body by means of self-declaration and production protocols.

13.2. EBC-certified companies

For production, processing, and trade of EBC biochar, a distinction is made between four company types:

(a) Biochar producer (on-site inspection)

Biochar producers operate pyrolysis plants and manufacture EBC-certified biochar from biomass. Addition-

ally, they may grind, screen, and/or package biochar. Only biochar produced by the company itself may be stored on the premises, otherwise additional certification as a processing company and trader is required.

If the biochar is further processed by other, non-pyrolytic process steps (e.g., by charging it with nutrients, mixing it into compost, fermentation, activation, or blending with other products), an additional EBC certification as a biochar processing company is required.

A technical pre-audit by Carbon Standard International and an annual inspection visit by the inspection body are mandatory. The representative sampling must be carried out by an endorsed sampler.

Fundamental changes in operational procedures must be reported to Carbon Standards International and may lead to a new technical pre-audit.

(b) Processing companies and traders

The EBC is a mark of excellence that assures consumers of the quality of biochar within a product. This assurance is only valid if all stages of biochar processing are covered by the certification.

Processing companies that purchase EBC-certified biochar and use it to manufacture new, biochar-based products, must be EBC certified. Common processes are

- The blending of biochar with additives such as compost, digestate, fertilizer, cement, and asphalt,
- Activation by thermal processes (production of activated carbon),
- Enhancement by biological and/or chemical treatment,
- Mechanical processing such as milling
- Mixing of different EBC-certified production batches, which may also be purchased from different EBC-certified manufacturers
- Repackaging and relabelling of purchased biochar

The trade of unpackaged, loose goods (e.g., containers) is also subject to the inspection and certification obligation for biochar processing plants.

The initial audit is carried out by the inspection body, which also determines the processing protocols and the protocols for documenting the flow of goods with the processing companies. Audits by the certification body then take place every calendar year. CSI may order a specific adapted form of audit depending on the structure and production of the processing company.

(c) Trader of packaged goods – no certification needed.

The mere trade by third parties of pre-packaged biochar and biochar-based products labelled by the certified manufacturer according to EBC regulations is not subject to any further inspection and certification obligation.

Therefore, if a non-certified company or person sells EBC-certified biochar or biochar-based products, both the certified manufacturer and the unique ID number and QR code of the biochar batch must be clearly traceable. The certified manufacturer must therefore be named on the label and delivery note. Consequently, the label affixed by an EBC-certified company must not be altered, pasted over, or removed. If the original label is removed or covered over, the goods are no longer considered EBC certified. Additional labels, however, may be applied alongside the original labels. If the original manufacturer is not named on the packaging or the delivery note and the goods are thus relabelled, the company placing the goods on the market must then be EBC-certified, otherwise it may not label the goods as EBC-certified.

The relabelling of closed packaging of certified biochar and biochar-based products or the sale under an own trade name without mentioning the actual manufacturer is subject to the certification obligation as a private label trader.

(d) Private Label Traders (remote inspection)

If the biochar and biochar-based products are manufactured, packaged, and labelled by the manufacturer for another company, and the name and contact information of the manufacturing company do not appear on the packaging, the retailer marketing the goods under its brand name must be EBC certified as private label trader. Otherwise, the own brand retailer may not label the goods as EBC certified.

This also applies if closed packaged biochar goods are purchased from other manufacturers or distributors and then relabelled in such a way that the manufacturing company and its contact data are no longer recognizable as such. The company placing the goods under its own brand must necessarily be EBC certified. Otherwise, he may not label the goods as EBC-certified.

Provided there is no repackaging of the goods, EBC certification of private label traders does not require on-site inspection; it can be done via online declaration and remote assessment.

13.3. Registration for certification

To register for certification, please contact Carbon Standards International (www.carbon-standards.com). The team of Carbon Standards International will assist you throughout the entire certification process.

Carbon Standards International AG

Ackerstrasse 117
5070 Frick Switzerland
Tel. +41 (0) 62 552 10 90
service@carbon-standards.com

13.4. Technical pre-audit of pyrolysis units

Every pyrolysis unit is subject to a technical pre-audit carried out by Carbon Standard International. The aim of the technical pre-audit is to obtain a detailed understanding the thermochemical process to identify potential problems for the certification and quality management. During the technical pre-audit, the standard method and frequency of endorsed sampling, the type of retained samples, the determination of dry weights, and the plant's own quality control program may be adapted, if necessary. All adaptations and precisions of the usual certification and quality management procedures, are documented in the audit report.

The technical pre-audit of biochar producers includes the following steps:

- The company uploads the detailed technical description and flow charts of the production process to the Biochar Tool.
- During a video conference, the documents are reviewed, the system is checked for technical suitability, and company-specific details are discussed.

All detailed technical information shared between the production company, the Ithaka Institute, Carbon Standards International, and the certification body are subject to strict confidentiality and are protected by data protection law. If desired, a non-disclosure agreement (NDA) can be signed between Carbon Standards International and the company to be certified.

Fundamental changes in operational procedures must be reported to Carbon Standards International and may lead to a repetition of the technical pre-audit. The certification body may also order a new technical pre-audit due to operational changes that prevent the inspection visit from being carried out in a meaningful way.

Processors and traders of biochar are subject to an initial audit by the certification body, but do not need a separate technical pre-audit.

13.5. EBC instruction manual

The present EBC guidelines describe the basic requirements for EBC certification. For biochar producers, an EBC instruction manual based on these guidelines provide the exact implementation of these rules where necessary. This includes:

- Organization of the operating documentation,
- Requirements for occupational health and safety
- Flow charts for representative sampling
- Flow chart and documentation for taking and storing the retention samples
- Additional analyses of critical or strongly varying parameters (e.g., PAH, heavy metals, contamination or impurities of biomasses, etc.).
- Determination of the dry matter content for each individual packaging unit.
- The EBC instruction manual is a contract between the EBC-certified company and Carbon Standards International. The instruction manual is treated confidentially by the certification body and Carbon Standard International.

Processing companies and biochar traders do not receive a separate instruction manual.

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Annex 1

Analytical Methods for EBC-biochar Basic Package

The current issue date of the respective standard is applicable. Descriptions in this annex may contain deviations and/or concretizations regarding the listed methods. If no ISO method is applicable to the biochar matrix, the required analytical method is described below the parameter. For further reference, corresponding non-ISO methods are listed.

Sample preparation (ISO 13909-4, DIN 51701-3):

After homogenization, the sample is divided representatively into portions. This subsampling is done by quartering (quarter method) of the homogenized sample. At least 1000 g of the original sample is needed for all analyses and, if necessary, several replicates.

A portion of the sample is dried at 40 °C and is divided into some subsamples after drying and homogenization. Approximately 250 g of the 40 °C dried and uncrushed sample is used to determine the salt content, pH, bulk density as delivered, and BET surface area of the material. Approximately 50 g of the 40 °C dried sample is finely ground in a vibratory mill. After homogenization, the fine material is subsampled for further analysis (i.e., PAH, ash, CHNOS, trace, and major elements, conductivity). Unless otherwise specified, the particle size of the analytical samples is specified by the respective methods and standards.

Bulk density for ground particle sizes < 3 mm (ISO 17828, analog VDLUFA-Method A 13.2.1): To calculate bulk density, a dried, water-free sample of at least 300 ml is poured into a graduated cylinder, and the mass is determined by weighting. The volume of the sample is read after 10 times compression by means of falling. The bulk density (on dry matter base) in kg / m³ is calculated from the mass and the volume of the sample.

Bulk density of the unground sample as delivered (DIN EN ISO 17828):

Only for particle sizes between 0.3 mm and 30 mm. The sample is analyzed as delivered, not dried, not milled.

NOTE: The bulk density of freshly produced biochar is subject to fluctuations due to several factors, such as vibrations, shocks, pressure, drying, and humidification. The measured bulk density may, therefore, have been altered by transport, storage, or handling.

Salt content (electrical conductivity of leachate) – in analogy to DIN ISO 11265:

Add 20 g of the sample to 200 ml of desalinated water and shake it for 1 hour, followed by filtration of the solution. The conductivity is then measured using the filtrated water. The temperature correction is automatically done on the measuring device. The electrical conductivity is given for a solution at 25 °C. The salt content is calculated using the factor 52.8 [mg KCl/l]/[10⁻⁴/cm] and is given in mg KCl/l. This is based on the conductivity (14.12 * 10⁻⁴ S/cm) of a 0.01 molar KCl solution.

pH-value DIN ISO 10390 (CaCl₂):

A minimum of 5 ml of the air-dried sample is placed in a glass vessel. Five times the volume (25 ml) of a 0.01 M CaCl₂ solution is added. The suspension is overhead rotated for 1 h. The suspension obtained is directly measured with a pH meter.

Water content according to ISO 589, DIN 51718, specified as follows:

Method A / two-step method (Reference method for coal)

Raw moisture

The sample (100 to 1000 g) is spread evenly in a drying bowl crucible, weighed with 0,1 g accuracy and dried in an oven at $(40 \pm 2) ^\circ\text{C}$ until the mass is constant. If necessary, the sample is divided and dried in more than one crucible.

Analysis: raw moisture (FG) in %

$$FG = \frac{m_E - m_R}{m_E} * 100$$

FG = raw moisture in %

m_E = mass of the sample before drying in g

m_R = mass of the sample after drying in g

Hygroscopic moisture

Hygroscopic moisture is the moisture held firmly within the pore structure of biochar. Measuring hygroscopic moisture will lead to an understanding of a particular biochar's ability to hold and release moisture.

A subsample of the air-dried and crushed (grain size $< 1 \text{ mm}$) sample is weighed immediately after the subsampling into a TGA crucible and is dried in a nitrogen atmosphere at $(106 \pm 2) ^\circ\text{C}$ to constant mass.

Evaluation: hygroscopic moisture (FH) in %

$$FH = \frac{m_E - m_R}{m_E} * 100$$

FH = hygroscopic moisture in %

m_E = mass of the sample before drying in g

m_R = mass of the sample after drying in g

Water content

Evaluation: water content (Wt) in %

$$W_t = FG + FH * \frac{100 - FG}{100}$$

W_t = water content in %

FG = raw moisture in %

FH = hygroscopic moisture in %

Ash content (550 °C) ISO 1171, DIN 51719:

To determine the ash content in biochar two programs of the TGA (30 or 60 min) could be used. The weight determination of the crucible is carried out automatically. Enter the sample number for corresponding crucible position. Add 1.0 g of the sample to the ceramic crucible and spread the substance evenly in the crucible. Weighing is done automatically relative to the crucible position.

Runs the following heating program in the oven:

heating with a rate of 5 K / min to 106 °C under a nitrogen atmosphere to constant mass ($\Delta m < 0,05\%$).

- temperature increase with 5 K / min to 550 °C under oxygen atmosphere,
- hold this temperature for 30 or 60 min to constant mass ($m < 0,05\%$).

The ash content is automatically determined and calculated for the sample used.

Carbonate CO₂ according to ISO 925, DIN 51726:

1 g of pre-dried and ground sample is weighed to 0.2 mg and placed in the decomposition flask. The device consists of an absorption tower, which purges the air of carbon dioxide, the decomposition flask with an attachment to add the decomposition acid, and three connected washing bottles. The carbon dioxide freed air is sucked through the system. After the system is purged and the washing bottles are filled with an absorbing solution of BaCl₂ and NaOH solution, 30 ml decomposition acid (hydrochloric acid with HgCl₂ as a catalyst and a wetting agent) are added to the decomposition flask. The content of the decomposition flask is boiled for about 10 minutes. The inert gas flow transports the carbon dioxide produced through the acidic solution in the first wash bottle in the other two wash bottles. In the second wash bottle, the carbon dioxide dissolves under the consumption of base and is precipitated as barium carbonate. If something precipitates in the third wash bottle, the measurement must be repeated with a lower initial mass. The consumption of base in the second wash bottle is determined by pH-titration using hydrochloric acid. The carbonate content of the sample is calculated from the base consumption and is calculated as CO₂.

CHN according to ISO 29541, DIN 51732:

The use of TruSpec Micro or comparable devices is recommended. The sample is combusted in a stream of pure oxygen. Resulting CO₂, H₂O and nitrogen oxides are quantified to calculate the elemental composition.

Sulphur according to ISO 19579, DIN 51724-3:

The pre-dried and crushed sample is weighed in a ceramic crucible. At high temperatures (> 1300 °C), the sulfur is oxidized in an oxygen stream with the aid of a V₂O₅ catalyst layer. The resulting SO₂ is detected in an Infrared cell and calculated with the sample mass as total sulfur content.

Oxygen (calculation) according to ISO 17247, DIN 51733:

The oxygen content is a parameter derived from calculations. It is assumed that the biochar sample consists essentially of ash, carbon, hydrogen, nitrogen, sulfur, and oxygen. If one subtracts the ash, carbon, hydrogen, nitrogen, and sulfur content in percent from 100 %, the result will be the oxygen content in percent.

C_{org}, molar H/C and molar O/C (calculation):

Other quantities and ratios can be calculated from the determined data.

C_{org} is derived from the total carbon content minus the inorganic carbon content (CO₂) in the sample. The H content is analyzed through CHN-analysis (see above). To calculate molar ratios, the determined mass fractions of the elements must be converted into molar quantities. To do this, the value must be divided by the respective molar mass (carbon: 12.001 g mol⁻¹, hydrogen: 1.008 g mol⁻¹, oxygen: 15.999 g mol⁻¹).

PAH according to DIN EN 17503 (extraction method 10.2.3 using toluol)

Currently, no ISO method exists for the analysis of PAHs in biochar. Therefore, the following method based on DIN EN 17503 must be used. A 2.5 g sample of pre-dried and crushed biochar is extracted with at least 100 ml of toluene using Soxhlet extraction for **six hours**. The extract is then concentrated to a volume of 10 ml, and an internal standard is added. An aliquot of the extract is measured using GC-MS or an equivalent measurement method.

Trace metals after microwave-assisted digestion according to EN ISO 12846, DIN 22022-1, DIN 22022-7, DIN EN ISO 17294-2 / DIN EN 1483:

(Pb, Cd, Cu, Ni, Hg, Zn, Cr, B, Mn, As, Ag)

Microwave digestion currently, no ISO method exists for microwave digestion of biochar)

The pre-dried and crushed sample is weighed and placed into the reaction vessel of the microwave. 10 ml of nitric acid and 2 ml of hydrofluoric acid are added. The reaction vessel is sealed and placed in the microwave.

Program flow of the microwave pressure digestion:

- heating (room temperature to 240 °C) for 15 min
- holding time at 240 °C for 20 minutes
- free cooling

additional only for ICP-OES:

Program flow of the fluoride masking (Boric acid, adding 5 ml of saturated solution):

- heating (room temperature to 160 °C) in 8 minutes
- holding time at 160 °C for 7 minutes
- free cooling

After complete cooling, the reaction vessels are opened, and the digestion solution is transferred to a 50 mL plastic volumetric flask and filled with deionized water.

The diluted solution is measured by ICP-MS (DIN EN ISO 17294-2).

To determine the levels of mercury DIN EN ISO 12846, DIN 22022-4, DIN EN ISO 17294-2, and DIN 22022-7 can be used.

Main elements after melting digestion according to ISO 23380, DIN 51729-11, DIN EN ISO 11885 / DIN EN ISO 17294-2: (P, Mg, Ca, K, Na, Fe, Si, S):

The melting process is performed on the biochar ashes. 200 mg of the fine ash is weighed into a platinum crucible and thoroughly mixed with 2 g of lithium metaborate.

The platinum crucible is placed in a digestion oven. The digestion remains at least 15 minutes at 1050 °C in the oven. The melt is dissolved in hydrochloric acid and filled to 500 ml.

The samples are measured with ICP-OES (DIN EN ISO 11885) or ICP-MS (DIN EN ISO 17294-2).

Declaration of the nutrient content

The content of nitrogen, phosphorous, magnesium, calcium and potassium must be stated in g kg⁻¹ of nitrogen, P₂O₅, MgO, CaO and K₂O, respectively, referring to dry matter of biochar. It is recommended to provide all main elements (for P, Mg, Ca, K additionally) as g kg⁻¹ (element, not oxide) and the results of elemental analysis and calculation (CHNSO, C_{org}, carbonate) in % of dry matter of biochar.

Water holding capacity (WHC) according to DIN EN ISO 14238, annex A

Water-holding capacity. This can be measured using the method DIN EN ISO 14238, annex A. The test consists of soaking the 2mm fraction of the material in a water-filled test tube for a period of 24 hours. After this, the test tube should be covered with filter paper and placed upside-down on a dry sand bed for 2 hours to remove free water. The saturated material should then be weighed and then dried at 40 °C in a compartment dryer. After drying, the material should be weighed again to estimate the water-holding capacity.

Electrical conductivity of the pyrogenic solid

To determine the conductivity of the solid biochar, it is first necessary to compress the finely ground biochar under standardized pressure. The defined compression is usually done in the EBC-endorsed Black Gauß I device (c.f., <https://zenodo.org/records/8197758>), where the electrical resistance is then measured vertically through the test specimen. Based on the measured resistance of the biochar and the geometry of the compacted matter, the specific conductivity can be determined using the following formulas:

$$\Omega_{specific} = \Omega_{electric} * \frac{A}{h}$$

$$LF = \frac{1}{\Omega_{specific} * 100}$$

$\Omega_{specific}$ = specific resistance in Ohm * cm

$\Omega_{electric}$ = electric resistance in Ohm

A = Area of the compressed biochar = contact area of the electrode in cm²

H = Height of the compressed biochar in cm

LF = Conductivity in mS/cm

For the determination of the conductivity, a device for compressing the biochar, a multimeter with the capability of 4-wire measurement and a measuring construction in which the biochar can be compressed and the electrical resistance can be measured at the same time are required. The measuring construction consists of a pressure flask whose bottom and lid each consist of corresponding copper electrodes. The electrodes used are to be connected to an external multimeter.

In an exemplary setup, for example, a sample chamber volume of 10 cm³ results in a relevant weighing range of 1-2 g of a sample dried at 40 °C and finely ground for analysis. A pressure in the range of 10 – 50 kN must be applied to this test setup using a hydraulic press (e.g., toggle press). When the specified target pressure is reached, the resistance is immediately read on the multimeter and converted using the above formulas. The average conductivity is obtained from the mean value of the solid conductivities under 10, 20, 30, 40 and 50 kN pressure.

This method was developed by the Ithaka Institute and Eurofins. The necessary measuring equipment can be obtained from Eurofins. The establishment of an ISO standard for this measurement method is currently being attempted.

Annex 2

Analytical Parameters for EBC-Feed

The current issue date of the respective standard applies. Further descriptions in this annex may contain deviations and/or concretizations with regard to the mentioned standard. The explanations in italics are only intended to provide the reader with basic information; the implementation is based exclusively and precisely on the standard referred to.

Trace metals As, Pb, Cd, Hg **DIN EN 15763**

For microwave digestion, 0.1 g to 1 g of the dried, ground, and homogenized material is weighed into a plastic cup (PTFE, PFA) or quartz cup. After addition of 65% nitric acid in a ratio of 1+5 (sample+acid) and after addition of 30% hydrogen peroxide in a ratio of 1+2.5 to 1+10 (sample+hydrogen peroxide), digestion is performed at the maximum permissible temperature for the system (usually 190 °C). Heating phase: 15 min; holding time: 30 min.

After cooling, transfer quantitatively to a polypropylene vessel with a volume marker and fill it to the mark with 0.1 M nitric acid. The measurement is carried out by ICP-MS or ICP-OES. For mercury, cold vapor AAS or atomic fluorescence spectrometry is used.

PCB **DIN EN 16167, DIN EN 16215**

The material is crushed into powder (<1 mm) and dried at a maximum of 35 °C. Alternatively, it can be dried chemically or by freeze-drying. 5-10 g of sample are extracted by Soxhlet extraction with toluene for 6 h with the addition of suitable internal standards. Alternatively, an ASE extraction can be used. The extract is concentrated and purified according to VDLUFA VII 3.3.2.2 with silica gel column chromatography. The quantification of the purified extract is done with GC-MS or GC-ECD.

PCDD/PCDF/coplanar PCB **DIN EN 16190, DIN EN 16215, Commission Regulation (EC) No 152/2009 (modified by No 2017/771) – HRGC/HRMS method**

The material is crushed into powder (<1 mm) and dried at a maximum of 35 °C. Alternatively, freeze-drying can be used. After the addition of isotope-labeled standards, 2 g of sample material are extracted with toluene in a Soxhlet for 20 h. Alternatively, special hot extractors such as the ASE can be used. After concentration, the extract is purified by multiple column chromatography and can be divided into different fractions. At this point it is also possible to obtain the DIN-PCB fraction. Finally, the components are measured with GC-HRMS.

Fluor **ISO 11724, VDLUFA III 17.3.2, VDLUFA VII 2.2.2.1, DIN EN 16279 (ion selective electrode; according to VDLUFA VII 2.2.2.1), BAFU F-7 2017 (DIN 38405-4):**

The dried and ground material is ashed and digested with sodium hydroxide. The cooled digestion is dissolved in hydrochloric acid with the addition of a complexing agent (TISAB). A pH value of 5.5 is then adjusted, and the fluoride content is determined using an ion-sensitive electrode.

Dry matter

Permitted test methods: dry matter: ISO 589, DIN 51718, VDLUFA III 3.1:

A minimum of 50 g of the sample is taken and crushed as necessary, avoiding changes in moisture content. 5 g of biochar are weighed (± 1 mg) and dried at 103 °C for 4 h. After loading the oven, the drying time does not start until 103 °C has been reached exactly. After cooling in the desiccator, it is weighed back (± 1 mg).

Crude ash

Permitted test methods: analog to ISO 1171, DIN 51719, VDLUFA III 8.1m HCl-insoluble ash: VDLUFA III 8.2m, specified as follows:

Approximately 5 g of sample is weighed to the nearest 1 mg into an annealed and tared ashing dish. The dish is placed in a muffle furnace and left at 550 °C ± 5 °C until no char particles are visible. After cooling in the desiccator, the sample is weighed back to 1 mg. For difficult samples, ammonium nitrate treatment is carried out according to method VDLUFA 8.1.

Annex 3

Additional Parameters

Producers are not required to obtain the additional parameters outlined in Annex 3 for EBC certification; however, these parameters provide valuable data for further biochar characterization. Descriptions in this annex may contain deviations and/or concretizations regarding the listed methods. If no ISO method is applicable to the biochar matrix, the required analytical method is described below the parameter. For further reference, corresponding non-ISO methods are listed.

Gross calorific value / net calorific value according to ISO 1928, DIN 51900:

To determine the calorific value, a bomb calorimeter that fulfills the requirement of the stated standard is used. 0,3 to 0,8 g of pre-dried and ground sample is weighed into a combustion bag, capsule, or crucible. The sample is mounted in the combustion bomb with an ignition wire and 10-20 ml of eluent in the bottom part of the bomb. The bomb is placed into the calorimeter. The oxygen filling, the ignition, and the measurement are done automatically. After combustion, the bomb must be checked for signs of incomplete combustion. The gross calorific value is calculated using the calibration and measurement data. With further corrections, the net calorific value is calculated.

Ash content (815 °C) ISO 1171, DIN 51719:

The ash content at 815 °C is determined after determining the ash content at 550 °C by rising the temperature from 550 °C with 5 K / min to 815 °C and holding until constant weight (mass difference $\pm 0,05\%$) is reached.

Volatile matter according to ISO 562, DIN 51720:

1,0 g of the pre-dried and ground sample is placed into a crucible (with lid). The sample must form a uniformly thick layer on the bottom of the crucible. The crucible is placed in the oven preheated at 900 ± 5 °C. After 7 minutes (± 5 sec), the crucible is removed from the oven and reweighed after cooling to room temperature. The volatile matter content is calculated from the mass loss of the sample.

PCB

VDLUFA VII 3.3.2.2 (DIN-PCB; hot extraction, GC-MS) DIN EN 16167 (use extraction method 2 with Toluol and not with light petroleum), DIN 38414-20 and DIN EN 16215. No ISO method for biochar PCB exists, use the procedures as follows:

The sample is crushed into powder (<1 mm) and dried at a maximum of 35 °C. Alternatively, it can be dried chemically or by freeze-drying. 5-10 g of sample are extracted by Soxhlet extraction with toluene for 6 h with the addition of suitable internal standards. Alternatively, an ASE extraction can be used. The extract is concentrated and purified according to VDLUFA VII 3.3.2.2 with silica gel column chromatography. The quantification of the purified extract is done with GC-MS or GC-ECD.

PCDD/PCDF/coplanar PCB according to DIN EN 16190:2019-10, DIN EN 16215, Commission Regulation (EC) No 152/2009 (modified by No 2017/771) HRGC/HRMS method, No ISO method for biochar PCDD/PCDF/coplanar PCB exists, use the procedures as follows:

The sample is crushed into powder (<1 mm) and dried at a maximum of 35 °C. Alternatively, freeze-drying can be used. After the addition of isotope-labeled standards, 2 g of sample material is extracted with toluene in a Soxhlet for 20 h. Alternatively, special hot extractors such as an ASE can be used. After concentration, the extract is purified by multiple-column chromatography and can be divided into different fractions. At this point, it is also possible to obtain the DIN-PCB fraction. Finally, the components are measured with GC-HRMS.

Specific surface area according to DIN ISO 9277 (BET):

The samples should be dried at 40 °C and milled to a particle size < 3.15 mm. Nitrogen is used as the adsorption gas. Degassing temperature and time are set to 150 °C and 2 hours. The degassing has to be done under a vacuum. The multipoint BET method should be applied.

Chrom(VI)

DIN EN 16318. No ISO method for biochar Chrom(VI) exists, use the procedures as follows:

Chromium cannot be oxidized during pyrolysis and is instead reduced during pyrolysis, i.e., Cr(VI) is converted into less mobile and dramatically less toxic Cr(III), which is already regulated as the total Cr content of biochar. Nevertheless, this method is offered to provide analytical evidence of compliance with the requirements of the EU Fertilizer Product Regulation, if required.

Particle size distribution ISO 1953

Particle size distribution is determined by sieving according to DIN 66165 or ASTM D2862, based on local preferences and equipment availability. For this purpose, suitable sieves with ascending mesh sizes are stacked on top of each other. The sample is placed on the uppermost, widest-meshed sieve, and then the apparatus is operated for a defined time so that the biochar is sieved dry by shaking or shaking and tapping. After that, the oversize on each sieve is weighed.

Biochar that has been pre-sieved to less than 2 mm or ground appropriately can also be analyzed for particle size distribution using laser diffraction according to ISO 13320. The specifications of the instrument must be adhered to so that the technically largest possible biochar particles can also still be measured.

Annex 4 – Sampling

A4. Representative sampling

In order to obtain a biochar sample as representative as possible (in terms of accuracy and precision), a batch must be sampled within the first seven days of production according to the following exact methodology. An incremental cross-stream sampling guarantees the most representative sampling of the product.

A. Pyrolysis systems with continuous production

1. On three consecutive days, 8 samples of 3 liters each are taken at intervals of at least one hour directly at the discharge of the freshly produced material. This sampling can also be done by an appropriately adjusted automated cross-stream sampler.
2. The 24 subsamples are combined to form a composite sub-sample.
3. The taking of each of the 24 samples (= 3 x 8 daily samples) as well as the homogenisation and sample division must be documented with the exact sampling times in the sampling protocol delivered by the certification body.

B. Systems with non-continuous production processes

1. The quantity of biochar from which a representative sample is to be taken from must be at least equal to the production volume of one day.
2. The biochar pile to be sampled must first be thoroughly mixed by moving it from one pile to another three times with a front loader or shovel.
3. At 24 different spots of the pile, samples of 3 liters each are taken.
4. The 24 subsamples are combined to form a composite sub-sample.
5. The sampling has to be documented in the sampling protocol delivered by the inspection body.

C. Homogenizing and dividing of the sample

The mixed sample of 24 x 3 liters = 72 liters can either be sent directly to the endorsed laboratory where it shall be homogenized and divided into a representative analytical sample or the company proceeds as follows to produce a small representative analytical sample on its own.

1. If the particle size of the composite sub-sample is larger than 3 mm, it should be milled to < 3 mm, otherwise no representative sample division is possible.
2. The milled composite sub-sample is either divided by a mechanical sample divider to 2 to 2.5 l or homogenized according to the following instructions:
3. The milled composite sub-sample (total 72 liters) is poured onto a clean surface and then shoveled three times from one pile to another.
4. A sub-sample of 1.5 l is then taken at 15 spots in the mixed pile.
5. The 15 subsamples are again poured together.
6. The new 22.5 l subsample has then to be homogenized thoroughly by turning and piling it 3 times up-side-down.
7. From the mixed pile of the 22.5 l subsample, 15 subsamples of 150 ml each shall now be taken at 15 different spots in the pile and united.

The samples to be sent to the endorsed laboratory have to be labeled with the QR code generated on the EBC website.

The expected uncertainties in regard to accuracy and precision were described in detail by Bucheli et al. [40] and will be taken into account by the EBC when evaluating the results. The aim of the prescribed sampling method is to achieve a well-characterized cross-sectional sample.

A5. Country Annex: Sweden

The Swedish appendix considers Swedish legal requirements and relevant Swedish certificates regarding limit values for potential pollutants. The Swedish appendix overrules the respective EBC limit values as presented below.

EBC-certified biochar that is sold on the Swedish market must meet all requirements of the respective certification class of the European Biochar Certificate and the Swedish annex. The Swedish annex applies together with European Biochar Certificate, is an addition to the EBC, and shall therefore not be read as a standalone document.

A5.1 List of requirements EBC Swedish appendix

The deviations and additions from/to European Biochar Certificate, made in the present Swedish appendix, concern only the certification classes EBC-Agro and EBC-AgroOrganic.

A5.2 EBC-Agro

EBC sets limit values for lead (Pb) and cadmium (Cd) but, for EBC-certified biochar sold on the Swedish market, these limit values are replaced according to the table below.

EBC-reference	Analysis parameter	Value	Comment / reference
Chapter 7.6	Lead (Pb)	100 mg kg ⁻¹ (DM)	Limit value taken from SNF1998:944 and industry standard SPCR152.
Chapter 7.6	Cadmium (Cd)	1 mg kg ⁻¹ (DM)	Guide value taken from EU-Ecolabel, industry standard SPCR 120 and SPCR 152

A6. Country Annex: Austria

The annex for Austria considers the current Austrian quality standard for biochar as defined by ÖNORM S 2211. This annex overrules the respective EBC limit value as presented below.

Biochar that is sold with an EBC-certificate on the Austrian market must meet all requirements of the respective EBC certification class plus the Austrian annex. The Austrian annex applies together with European Biochar Certificate (EBC), is an addition to the EBC, and shall not be read as a standalone document.

A6.1 List of requirements for EBC country annex Austria

The deviations and additions from/to the EBC in the present Austrian annex concern only the certification class EBC-Agro.

A6.2 EBC-Agro

EBC sets a limit value for lead (Pb) but, for EBC-certified biochar sold on the Austrian market, this limit value is replaced according to the table below.

EBC-reference	Analysis parameter	Limit value	Comment / reference
Chapter 7.6	Lead (Pb)	100 mg kg ⁻¹ (DM)	Limit value taken from ÖNORM S 2211

A6.2 EBC-Urban

Biochars certified with EBC-Urban must present $\Sigma 16$ EPA-PAH below 6 mg kg⁻¹, which is the same threshold as for EBC-Agro.

A7. Country Annex: Switzerland

Switzerland was the first country in Europe to approve the use of EBC-certified biochar in agriculture. The framework conditions for its approval have been revised multiple times since then. With the updated Fertilizer Ordinance (DüV, Annex 2) and the Ordinance on the Reduction of Risks relating to the Use of Certain Particularly Dangerous Substances, Preparations and Articles (Chemical Risk Reduction Ordinance (ORRChem)), biochar is listed under section 2.2.2.3 as “Materials obtained through pyrolysis or gasification (CMC14).” The following regulations go beyond the general requirements of the EBC standard.

A7.1 Authorized Feedstocks for the Production of Biochar for the Application Classes EBC-Agro and EBC-Agro-Bio:

The Swiss ordinance expands the previously authorized feedstocks and is newly aligned with EU Regulation EU2019/1009.

Authorized feedstocks:

- Virgin wood and wood products, including bark and leaves from trees
- Plant waste from the food industry and fibrous plant waste from the production of virgin pulp and paper production
- Residues from the production of bioethanol and biodiesel
- Biowaste from separate collection of biowaste
- Animal by-products, provided the end of the waste ordinance has been reached
- Additives necessary to improve process performance or environmental compatibility of the pyrolysis or gasification process

A7.2 PAH Limit for the Application Classes EBC-FeedPlus, EBC-Agro, and EBC-AgroBio

According to the Swiss Chemical Risk Reduction Ordinance (ChemRRV [13]), a limit of 4 mg kg⁻¹ DM applies to the sum of the 16 EPA PAHs. This limit also applies to all biochars that are permitted for use in agriculture (EBC-Agro, EBC-AgroBio, EBC-FeedPlus).

The very low limit of 4 mg of 16 EPA PAHs per kg of biochar (DM) is extremely difficult to analyze and can only be guaranteed with an accuracy of 50%. For certification purposes, this means the limit is 4 ± 2 mg kg⁻¹ (DM).

EBC-Chapter Analytical Parameter	Value	Certification Class	Comment/Reference
7.12 16 EPA PAHs	4.0+2.0 g t ⁻¹ (dm)	EBC-FeedPlus EBC-Agro EBC-AgroOrganic	Limit value from Chemikalien Risikoverordnung 814.81, Bern 2022

A7.3 Further Requirements and Regulations

Upon approval, the Federal Office for Agriculture (FOAG) issues conditions. These include, among others:

- Reporting obligation for the quantities of biochar placed on the market at the end of a calendar year, as well as the submission of a copy of the EBC certificate, if available.

For EBC-certified companies, CSI, in consultation with the FOAG and with the permission of the producers, assumes the annual reporting obligation.

- If no EBC certificate is available, at least 4 pollutant analyses must be carried out in the first year of production, in accordance with Annex VI, Module D1, Chapter 5 of Regulation EU 2019/1009, for an annual production volume of up to 3,000 tons. These analyses must be performed as per ChemRRV (SR 814.81), Annex 2.6, Section 2.2.2.3. If the required limit values are undershot by 50%, the number of analyses can be reduced to 2 after the first year of production. If the feedstocks for the pyrolysis process change by at least 20%, a new pollutant analysis must be provided. All pollutant analyses must be submitted to the FOAG at the end of a calendar year.
- The pyrolysis temperature must be at least 500 °C for a minimum of 10 minutes.
- Limit values for inorganic and organic pollutants are defined in Annex 2.6 of the ChemRRV.
- The FOAG can prescribe the frequency of analysis in the approval.
- For products containing biochar, such as fertilizers, composts, and digestates, the biochar content must be indicated on the label.
- The maximum application rate per hectare is 1 t per year and 10 t over 20 years (Annex 2.6 ChemRRV).
- A mixture of an approved fertilizer with already approved biochar does not require new approval. The mixture is subject to a registration requirement (cf. Art. 20 para. 3).

A8. Country Annex: Denmark

The annex for Denmark considers the Danish Ordinance on the use of waste for agricultural purposes (Bekendtgørelse om anvendelse af affald til jordbrugsformål, BEK nr 1001, 27/06/2018). This annex defines the application of EBC Basic biochar in Danish agriculture considering that:

1. the requirements of BEK nr 1001 are fully met,
2. levels of PAHs in biochar are compliant with EBC-Agro,
3. the biochar is labeled as specified in this annex.

The regulation BEK nr 1001 allows the application of defined, sanitized wastes in agriculture, gardening, and forestry. In an advisory opinion⁵ the Danish Environmental Protection Agency⁶ concluded that pyrolysis at a minimum temperature of 500 °C for a minimum of 3 minutes fulfills the criteria for sanitization. Still, the pyrolysis product in this specific case is legally still considered a waste. Its application to agricultural soil is regulated by BEK nr 1001, which defines limit values for potentially toxic elements in pyrolysis feedstock and in the soil prior to application.

This annex is optional and only applicable to biochars for the Danish market that are produced from manure, sludge from ponds and aquaculture, municipal organic waste, municipal sewage sludge, digestates, industrial sewage sludge, and animal by-products. Any biochar produced exclusively from biomasses not included in the above list shall only be sold for agricultural applications when certified as EBC-Agro, EBC-AgroOrganic or EBC-FeedPlus as specified in the main document of the European Biochar Certificate (EBC).

The Danish annex applies together with EBC, is an addition to the EBC, and shall not be considered a standalone document.

A8.1 Prerequisite for using EBC-Basic biochar in Danish agriculture

The deviations and additions from/to the EBC certification guidelines in the present Danish annex concern the labelling and intended use of EBC-Basic, which fulfil the criteria specified below.

A8.1a Permissible biomass

This annex only applies to biochars produced in whole or in part from the following feedstocks (feedstock identifiers / ID refer to the EBC Positive list of permissible biomasses for the production of biochar):

- | | |
|---|-------------------------------------|
| • manure | (feedstock-ID AB-02) |
| • sludge from ponds/aquaculture | (feedstock-ID WW-02 or AB-03) |
| • municipal organic waste | (feedstock-ID R-10) |
| • municipal sewage sludge | (feedstock-ID WW-01) |
| • digestates and industrial sewage sludge | (feedstock-ID WW-02, AD-01 – AD-04) |
| • animal by-products | (feedstock-ID AB-01, AB-03) |

⁵ A „vejledende udtalelse” published by “Miljøstyrelsen” (Danish Environmental Protection Agency), which is part of the Miljøministeriet (Danish Ministry for the Environment), is an interpretation of the already existing, relevant set of rules and only indicative. It has no legal effect.

⁶ „Pyrolyse som metode til kontrolleret hygiejnisering iht. affald til jord- bekendtgørelsen”, Danish Environmental Protection Agency (J.nr. 2021-60803, Ref. CASCg, June 22, 2022)

A8.1b Limit values for potentially toxic elements (PTE) in biochar

EBC does not include limit values for potentially toxic elements for EBC-Basic. However, for use in Danish agriculture, the limit values for PTE listed in Table 1 must not be exceeded.

Table 7.1: Limit values for EBC-Basic biochar to be used in Danish agriculture according to the Danish Annex to the European Biochar Certificate. (P_{tot} = total phosphorous, dm = dry matter)

EBC-reference	Analysis parameter	Limit value	Comment / reference
Chapter 7.6	Lead (Pb) ¹	5000 mg kg ⁻¹ P _{tot}	BEK nr 1001, Annex 2
Chapter 7.6	or Lead (Pb)	60 mg/kg kg ⁻¹ DM	BEK nr 1001, Annex 2
Chapter 7.6	Cadmium (Cd)	100 mg kg ⁻¹ P _{tot}	BEK nr 1001, Annex 2
Chapter 7.6	or Cadmium (Cd)	0,8 mg/kg kg ⁻¹ DM	BEK nr 1001, Annex 2
Chapter 7.6	Copper (Cu)	1000 mg kg ⁻¹ DM	BEK nr 1001, Annex 2
Chapter 7.6	Nickel (Ni)	2500 mg kg ⁻¹ P _{tot}	BEK nr 1001, Annex 2
Chapter 7.6	or Nickel	30 mg kg ⁻¹ DM	BEK nr 1001, Annex 2
Chapter 7.6	Mercury (Hg)	200 mg kg ⁻¹ P _{tot}	BEK nr 1001, Annex 2
Chapter 7.6	or Mercury (Hg)	0,8 mg kg ⁻¹ DM	BEK nr 1001, Annex 2
Chapter 7.6	Zinc (Zn)	4000 mg kg ⁻¹ (DM)	BEK nr 1001, Annex 2
Chapter 7.6	Chromium (Cr)	100 mg kg ⁻¹ (DM)	BEK nr 1001, Annex 2
Chapter 7.6	Arsenic (As) ¹	25 mg kg ⁻¹ (DM)	BEK nr 1001, Annex 2

¹: For lead and arsenic, BEK nr 1001 defines two different limit values; The stricter limits for home garden applications are applied in this annex.

A8.1c Limit values for polycyclic aromatic hydrocarbons (PAH) in biochar

EBC defines a limit value of 4 mg kg⁻¹ for the 8 EFSA PAH for EBC-Basic. However, for use in soil according to this annex, levels of PAHs in biochar must be compliant with EBC-Agro, i.e.:

- - Limit value of 6±2.4 mg kg for the 16 EPA PAH, and
- - Limit value of 1 mg kg⁻¹ for the 8 EFSA PAH

must not be exceeded. For more information on this topic, see Chapter 7.12 of the EBC guidelines.

A8.1d Limit values for the feedstock

According to the advisory opinion of the Danish Environmental Protection Agency, the limit values for potentially toxic elements are to be applied to the feedstock in its initial state. In principle, most trace elements are not volatile in pyrolysis and thus accumulate through mass loss in pyrolysis. However, others, such as mercury, and to a certain extent also cadmium, are volatile, so that an analysis of the biochar does not provide sufficient information about the feedstock. Therefore, the biochar feedstock must also be analyzed in accordance with national requirements to demonstrate compliance with the following limit values. If feedstocks are mixed, e.g., when sewage sludge from different wastewater treatment plants is treated in a single pyrolysis plant, the different sewage sludges must be examined individually according to the relevant standards for sewage sludge analysis.

Table 7.2: Limit values of feedstock to produce EBC-Basic biochar to be used in Danish agriculture according to the Danish Annex to the European Biochar Certificate. (P_{tot} = total phosphorous, DM = dry matter) Limit values apply for individual feedstock prior to mixing feedstock from different sources.

Analysis parameter	Limit value	Comment / reference
Lead (Pb) ¹	10000 mg kg ⁻¹ P _{tot}	BEK nr 1001, Annex 2
or Lead (Pb)	120 mg/kg kg ⁻¹ DM	BEK nr 1001, Annex 2
Cadmium (Cd)	100 mg kg ⁻¹ P _{tot}	BEK nr 1001, Annex 2
or Cadmium (Cd)	0,8 mg/kg kg ⁻¹ DM	BEK nr 1001, Annex 2
Copper (Cu)	1000 mg kg ⁻¹ DM	BEK nr 1001, Annex 2
Nickel (Ni)	2500 mg kg ⁻¹ P _{tot}	BEK nr 1001, Annex 2
or Nickel	30 mg kg ⁻¹ DM	BEK nr 1001, Annex 2
Mercury (Hg)	200 mg kg ⁻¹ P _{tot}	BEK nr 1001, Annex 2
or Mercury (Hg)	0,8 mg kg ⁻¹ DM	BEK nr 1001, Annex 2
Zinc (Zn)	4000 mg kg ⁻¹ (DM)	BEK nr 1001, Annex 2
Chromium (Cr)	100 mg kg ⁻¹ (DM)	BEK nr 1001, Annex 2

A8.2 Labelling of the product

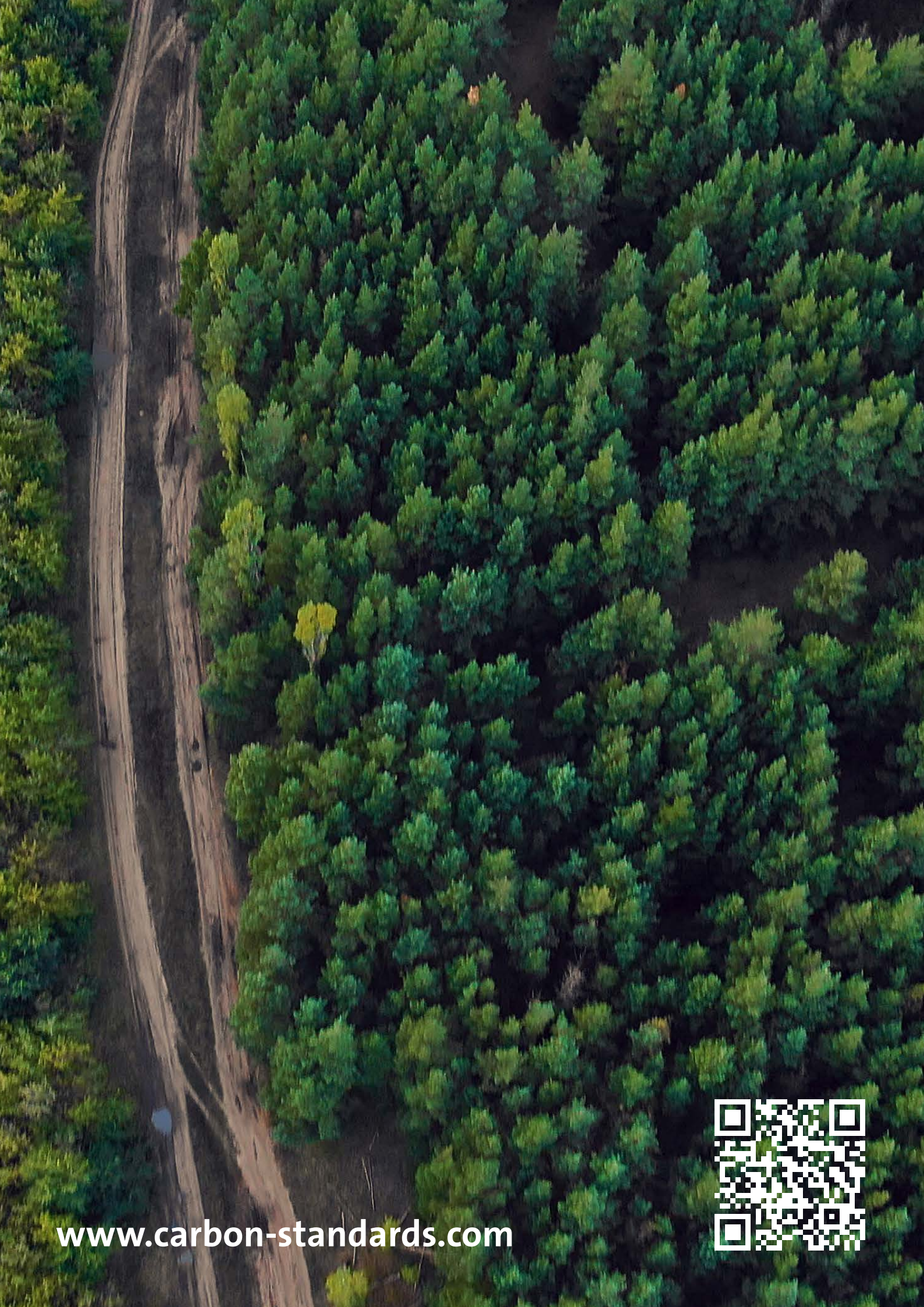
Biochar certified as EBC-Basic for the Danish market that fulfills the criteria as detailed in A7.1 may be sold for the use in agriculture. However, the application is restricted according to the regulation BEK nr 1001. This includes:

- Maximum application rate of 7 tons of dry matter per hectare per year, calculated as a 10- year average in agriculture and 15 tons per year in parks, forests and where no perishable crops are grown.
- Only to be applied on soils not exceeding the trace metal content specified in annex 4 of BEK nr 1001

Therefore, a clear reference on the packaging and/or delivery bills and accompanying documents is mandatory:

“only for soil application in Denmark according to BEK nr 1001”

The notice may be linguistically adapted and should be noted in Danish and English. Furthermore, the rules of chapter 12 of the EBC (Labeling and Advertising with EBC Certification) do apply.



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