



TAK

The first biochar standard with real-time digital monitoring

Technically Advanced Kilns – The Standard

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Impressum

These guidelines will be effective from 30th December 2026 for worldwide biochar certification.
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1 Introduction - The TAK Standard

The TAK standard is developed by those who made biochar production and CDR a global reality. With deep knowledge of the technology in all its stages, from highly automated to artisanal, we know how to certify it without overclaiming, without double counting, and without copy-pasting from other standards. The science that established pyrolytic carbon as a persistent C-sink, the flame-curtain kilns that carried biochar production to farmers on every continent, and the certification frameworks the industry now works from were developed here - by Carbon Standards International and the Ithaka Institute, across two decades of field work and open-access, peer-reviewed publications. Others apply that science, use those kilns, and adapt those frameworks; TAK breaks the trail.

Biochar has scaled from a niche practice to the largest carbon dioxide removal (CDR) method in operation today (2026). A wide range of pyrolysis technologies, biochar-based products, C-sink developments and trade has grown into a new industrial sector. Agricultural applications range from soil improvement, compound fertilizers and composting additives to manure treatment, animal bedding and feed additives. Beyond agriculture, biochar reaches construction, composite materials - including Olympic and World Cup-winning snowboards - plastics, paper and textiles. The decisive breakthrough for biochar use and carbon sinks came from smallholder farmers certified under the Global Artisan C-Sink Standard: within three years (2023–2025), artisanal production alone scaled to several million tons of CO₂e removed annually.

That growth ran through hundreds of thousands of farmers in India, Kenya, Brazil and many other countries, and it drove the emergence of robust industrial pyrolysis in regions where industrial production had been considered economically unviable. Those regions now lead global biochar production. Artisan production was, and remains, the bridge to technically advanced production: it trained the operators, built the feedstock chains and earned the market trust on which industrial pyrolysis now stands - conditions that simply did not exist five years ago. The TAK Standard was developed to accompany this evolution with a certification environment that is lean, closely monitored and safe, so that the professional pyrolysis industry can scale at the speed the climate requires.

TAK is the first biochar standard with real-time digital monitoring. Under all other biochar standards, a certificate rests on a sample analyzed once a year and on an audit that visits once a year; what happened in between is declared by the producer and trusted by the certifier. Under TAK, the pyrolysis reactor temperature, the flue-gas temperature and oxygen content, and the mass of biochar produced are measured continuously and transmitted online as they are measured, and the carbon content is determined daily. The certifier does not reconstruct production after the fact; it watches it as it happens, and a batch is certified only for the periods for which the complete record exists.

A certificate is only worth the proof behind it. Most carbon standards certify a snapshot - a sample, some hours of audit, a declaration - and trust the producer for everything in between. TAK does not: it is the first biochar standard to monitor production digitally and in real time. Every certified batch carries a continuous record: the pyrolysis and flue-gas temperatures logged in real time, the



latter read as a validated proxy for combustion quality and methane emissions; the biochar mass weighed continuously and transmitted online; the feedstock logged as it arrives; and daily in-house analysis of the parameters that actually vary, such as the carbon content of the biochar. These streams are cross-checked against each other, so the numbers must agree: the temperature record must be consistent, hour by hour, with the mass produced, the mass with the feedstock consumed, the carbon content with the temperature and the feedstock, the analysis with the declared class. Where the record is missing, the batch cannot be registered. A TAK certificate therefore certifies what it claims - that this biochar was made, with these emissions, from this feedstock, at this carbon content - and can show the measurement for every word of it. That is the standard's foundation, and it cannot be copied without the technology and the science that produce the data.

In issuing these guidelines, Carbon Standards presents an assessment mechanism grounded in the latest research and field practice. The TAK Standard ensures sustainable production of biochar and its application as a verified carbon sink: it gives buyers of registered C-sinks a reliable quality guarantee and gives producers a well-defined, internationally recognized set of parameters to demonstrate that their product meets it.

Biochar technology continues to develop rapidly. Research worldwide keeps extending what is known about biochar and its interactions with soil, materials, and the environment. The TAK Certificate and the European Biochar Certificate (EBC) are kept aligned with that research and revised as findings warrant — the standards evolve because their authors are the ones doing the science.

Most biochar certified under the TAK Standard is produced in order to establish carbon sinks. TAK certifies the production and quality of the biochar; the carbon sink it enables is quantified, monitored, and registered under the Global Biochar C-Sink Standard, for which TAK-certified biochar is eligible. What TAK contributes to this purpose is the integrity of its production data: mass, dry matter, and carbon content are monitored continuously and recorded as a closed chain of evidence, so that each registered carbon sink rests on a verified batch record rather than on a single spot analysis. Chapter 13 sets out how the two standards interlock, from the eligible biochar batch to the registered and tradable carbon sink.

The TAK Standard is part of the CS standards family and works closely with the EBC and the Global Artisan, Construction and Tree C-Sink standards, in the service of stringent international biochar quality norms, transparent monitoring, state-of-the-art science and analysis, and fair market development.

TAK-certified biochar can be produced and traded worldwide. The TAK guidelines are effective since **30th December 2026** for worldwide biochar certification.



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Glossary

Biochar	Biochar is a porous, carbonaceous material produced by pyrolysis of biomass. It is applied so that the contained carbon remains stored as a carbon sink or replaces fossil carbon in industrial manufacturing. Pyrolysis chars intended for energy generation are referred to as charcoal, biocoal, or biocarbon and are not covered by this standard. Biochar is produced by pyrolysis of biomass, a thermal conversion at temperatures typically well above 350 °C in a low- to no-oxygen atmosphere. Although torrefaction and hydrothermal carbonization are carbonization processes, their end products cannot be called biochar under this definition. Biochars are specific pyrolysis chars characterized by their material properties — such as a molar H/C_{org} ratio below 0.7 — and their usage features. Gasification, i.e., the partial thermal oxidation of biomass under a sub-stoichiometric supply of oxygen, is understood as part of the pyrolysis technology spectrum and can, if optimised for biochar production, be equally certified under TAK and EBC.
Biochar Processor	A company that uses certified biochar to produce biochar-based products (processed biochar) either through physical and/or chemical processing of the biochar (e.g., activation, granulation, or coating) or through blending it with other materials. A Biochar Processor must be TAK certified to register and label its products as TAK certified.
Biochar Trader	A company that trades bulk biochar or bulk biochar-based products or that fills biochar or biochar-based products into new packages and/or uses new labels. TAK certification as a Biochar Trader is required only when the traded products carry the TAK-certified label.
Certifier	The Certifier is a Carbon Standards' endorsed third party inspection and certification body (= Validation & Verification Body). In the present standard, the Certifier is synonym with the Validation & Verification Body (VVB).

C-sink	Non fossil derived carbon that is verifiably stored for more than one year (temporary C-sink), preferentially for more than 1000 years (geological C-sink)
C-sink matrix	Organic and mineral substrates to which biochar is mixed. The biochar to matrix ratio must be lower than 1:1 (v/v) to exclude that the biochar may burn unintendedly or might be recovered to be used in a way that the carbon could be emitted. See matrix positive list on the Carbon Standards' website.
C-sink owner	Owner of a C-sink material or, when applied to soil, owner of the climate effect of the C-sink.
C-sink potential	The pyrogenic carbon of a biochar that was not yet applied to a C-sink matrix but is temporarily stored in packing units, e.g., at the factory gate of a biochar production facility. Its unit is t CO ₂ e.
C-sink trader	An endorsed company or organization that trades the climate effect of a C-sink.
C-sink unit	A C-sink unit is the registered amount of a geo-localized biochar C-sink of the same TAK certified quality. The minimum size of a C-sink unit is 1 t CO ₂ e.
C-Sink_H	Annual average amount of biochar carbon sequestered over a time horizon of H years. For each year, the stored biochar carbon is evaluated. These annual carbon values from year 1 through year H are summed and then divided by H years to obtain the metric C-Sink_H, expressed in tons of annual CO ₂ e (t aCO ₂ e). Examples are C-Sink_100, C-Sink_20, or C-Sink_10.
Diffuse C-sink	Biochar C-sinks that was mixed to a C-sink matrix preventing the oxidation of biochar and which, due to the nature of the matrix, will be applied in small quantities well-distributed in space and time.
dMRV provider	A company that is endorsed to monitor and digitally track biochar from the production site to the C-sink site, assessing all occurring emissions, potential carbon leakages, and verifying the compensation and offsetting of those emissions.
Emission portfolio	Registered list of all GHG emissions caused by a production facility or a company or the entire production and establishment of a C-sink.

Endorsing agent	The Carbon Standards AG is in the role of endorsing agent. Carbon Standards (1) endorses dMRV provider, (2) endorses tracking and monitoring tools and IT systems used by dMRV provider, (4) conducts trainings for the certifier, (5) endorses the certifier, (6) verifies the reporting by the dMRV provider and the certifier, (7) endorses laboratories.
Geological C-sink	Non-fossil carbon that was applied to soil, sediments, the oceans, or the lithosphere and presents a persistence of more than 1000 years.
Global Cooling	The climate impact of a carbon removal and its storage, measured in tons of annual CO ₂ e, over a specified period. An amount of global cooling can compensate an equivalent amount of global warming for the duration that the persistence of the cooling effect is demonstrable.
Global C-Sink Registry	The Global C-Sink Registry contains all relevant information about a C-sink to ensure the corresponding climate service and prevent double counting.
GPC-Fraction	The portion of biochar carbon that is expected to persist for more than 1000 years and enters the geological carbon cycle.
Methane compensation	A temporary carbon sink that has the same or higher global cooling effect during 20 years as the absolute global warming effect of the methane emission over 100 years.
Negative Emission Technology (NET)	Negative Emission Technologies (NETs) are techniques that remove more carbon dioxide from the atmosphere than they emit, thereby reducing the atmospheric concentration of CO ₂ to mitigate the effects of climate change.
Non-fossil carbon	Non-fossil carbon refers to carbon originating from the atmosphere, which includes CO ₂ obtained from biomass, direct air-capture, and any biomass-derived material or substance. It excludes fossil carbon such as coal, lignite, peat and similar materials. It also excludes carbon in rocks, e.g. CO ₂ from calcination.
Persistence	Persistence refers to the duration that a defined fraction of biochar is stable in the environment or in a matrix to which the biochar was applied and does not degrade or decay and emit GHG emissions. Sometimes also referred to as “durability”.

Production Unit	One or more pyrolysis reactors registered together as a single entity in the CS Biochar Tool. A production unit may consist of a single pyrolysis reactor or of multiple small-scale pyrolysis reactors of the same certified TAK System that operate in parallel — for example, sharing a common combustion chamber and discharging into the same biochar storage. Each production unit must be located at a fixed, centralized production site and registered with a unique ID code, unless authorized as a mobile unit under Chapter 5.1.
SPC fraction	The semi persistent carbon (SPC) fraction of biochar is defined as the biochar-carbon fraction that is expected to decay within the first 1000 years after soil application.
Standard developer & holder	The Global Biochar C-Sink Standard was developed and is continuously updated by the Ithaka Institute. The Global Biochar C-Sink Standard is owned by Carbon Standards and can only be used under a licensing agreement. Carbon Standards is the standard owner managing the entire licensing and endorsement process of biochar producers, biochar processors and traders, dMRV providers, laboratories, the registry and C-sink traders.
TAK System Certificate	Certificate issued by CS attesting that a pyrolysis technology type is capable of meeting the requirements of this standard (Chapter 14). It does not certify biochar but the technology to produce certifiable biochar.
Temporary C-sink	Non-fossil carbon that is stored and/or used for a verifiable time of at least one year and preferably for more than 35 years as suggested by the EU for the carbon removal policy. Temporary C-sinks are a function of time given in years. The carbon contained in the temporary C-sink is calculated for each registered year as annual carbon (aCO ₂ e). The global cooling effect of the temporary C-sink depends on the year of the initial carbon removal and its expected decomposition.
Validation & Verification Body	Independent, internationally accredited organization endorsed by CS that does validation and verification of the carbon dioxide removal procedures and C-sink values before the issuance of C-sink certificates.



2 Summary of the TAK guidelines to prepare inspection

1. Scope of the TAK guidelines

1.1 The TAK guidelines are effective from 30.12 2026 for worldwide biochar certification.

2. Registration

2.1 Biochar producers can contact Carbon Standards via the website www.carbon-standards.com, where all relevant information and process updates are available. Following an initial online meeting, the company may register to start the certification process. A designated Carbon Standards contact person assists the registered company throughout the entire process that starts with the project endorsement and establishing the Project Design Document (PDD).

2.2 Only pyrolysis technology types holding a TAK Pyrolysis System Certificate (Chapter 14) can be certified for TAK production.

2.3 Once the biochar production unit is registered in the Biochar Tool and the technical documentation required for the technical pre-audit has been uploaded, an online meeting is arranged to conduct the pre-audit.

2.4 During the technical pre-audit, the remaining technical points of the company-specific dMRV system and quality assurance plan are finalized and documented in the biochar tool.

2.5 Once the technical pre-audit has been passed, the company information is forwarded to the appointed inspection and certification body (i.e., the VVB).

3. Production batch

3.1 A production batch starts with its registration in the Biochar Tool. The production batch receives a unique ID number and QR code.

3.2 A production batch may comprise a maximum of 1000 t biochar on a dry matter (DM) basis.

3.3 A production batch lasts a maximum of 365 days from the first day of production. If less than 50 t biochar (DM) are produced within these 365 days, the batch may be extended once to a maximum of 730 days, provided the feedstock and process parameters remain unchanged.

3.4 A batch is always linked to a specific production unit registered with its unique ID code.

3.5 Several pyrolysis reactors may be grouped and registered as a single production unit if they belong to the same certified TAK System pyrolysis type, process the same feedstock, share the same flue-gas monitoring, and discharge into a common biochar output. The grouped reactors then produce the same batch.

3.6 If a biochar producer registers a biochar production unit for the first time, a representative sampling has to be carried out within the first 10 production days after registration and sent for full TAK analysis to an endorsed laboratory.

3.7 Any change in feedstock composition must be declared in the Biochar Tool.

3.8 If the daily measured ash content (directly related to the carbon content) changes by more than 20%, a new batch must be registered.

3.9 Every 1000 t of biochar produced or every year, whichever comes first, the VVB takes a verification sample from the daily retention samples and sends it to an endorsed laboratory for full TAK analysis (cf. Chapter 8.4).

4. Sampling and sending the sample for analysis

4.1 The representative sample of a production batch must be taken in accordance with the sampling plan contractually specified during the technical audit.

4.2 If sampling is not carried out by cross-flow sampling, manual sampling must be fully documented by continuous video recording, including the sampling pile, all mixing stages, the filling of the sample bags, and their final sealing.

4.3 The sample must be registered in the Biochar Tool and sent with the TAK sample ID generated by the Biochar Tool to a CS-endorsed laboratory.

4.4 In addition to the samples taken for analysis, daily retention samples are required.

5. Permissible biomass for the production of biochar

5.1 All biomasses included in the TAK Positive List may be used individually or in combination as feedstock to produce TAK biochar.

5.2 Certain critical feedstocks, such as manures, biosolids, treated wood, or municipal waste, may be authorized but require individual permits by CS based on the technology, feedstock preparation and handling, emission testing, and intended biochar application. The pyrolysis of these materials requires a more comprehensive and frequent analytical program, as well as specific technology and monitoring.

5.3 Certain feedstocks may require additional quality management, as set out in the TAK Positive List.

5.4 Within a batch, the type and mixing ratios of biomass must not change significantly. If the daily measured ash content as fingerprint of the feedstock varies by more than 20%, a new batch must be started.

5.5 Feedstock humidity and composition influence biochar quality and emissions and must stay consistent within a batch. A change is reflected in the continuously recorded flue gas temperature, which responds to the varied calorific value of the feedstock; a marked shift indicates altered humidity or composition and must be investigated.

5.6 According to the TAK Positive List, mineral additives may add up to 10% of the mass. Higher mineral addition requires the written permit by CS.

6. Digital Monitoring, Reporting & Verification (DMRV)

6.1 TAK is the first biochar standard with real-time digital monitoring. It certifies each production batch on a continuous, closed chain of evidence rather than on periodic self-declaration. The recorded data streams must reconcile: feedstock consumed, running conditions, biochar mass,



and biochar carbon are cross-checked, and a batch is certified only to the extent that the chain is complete and consistent.

6.2 Each production unit records all monitoring data continuously and transmits them online to the CS Biochar Tool. The data comprise the pyrolysis reactor temperature (or, for flame-curtain systems, the combustion-zone temperature), the flue gas temperature, the flue gas oxygen content (lambda probe), and the biochar mass. The mass must be weighed continuously; a day-end total does not satisfy this requirement. Sensor types and positions are fixed during the technical pre-audit and documented in the CS Biochar Tool.

6.3 Received feedstock (date, volume, type) and produced biochar (dry mass, carbon content, number of packaging units) are recorded daily in the Biochar Tool.

6.4 A local dMRV system can be used to collect data on-site and perform initial checks. However, the data must be transmitted in realtime to the CS Biochar Tool.

6.5 A gap in any required continuous signal is treated as an interruption of production and excluded from the certified batch volume. Where the internet connection fails, timestamped data must be buffered locally and uploaded within 24 hours.

7. Specifications for emission control

7.1 Pyrolysis gases must be oxidized in a dedicated combustion chamber.

7.2 Flue gas temperature and O₂ content are continuously monitored as the basis for emission accounting and transmitted to the Biochar Tool (cf. Chapter 11).

7.3 Nationally defined emission limits must be complied with.

7.4 CO and CH₄ emissions must not exceed 50 g and 10 g per kg biochar, respectively.

7.5 The use of excess heat or the use of liquid and gaseous pyrolysis products is recommended.

7.6 Producers with limited or no waste-heat utilization are required to submit a public status report every two years detailing their efforts and progress toward improving the overall energy efficiency of their operation.

8. Properties of biochar

8.1 The biochar must be analyzed according to the TAK Basic Analysis Package by a CS-endorsed laboratory.

8.2 Daily measurements of dry matter weight and carbon content of the produced biochar are required (cf. Chapter 7).

8.3 The daily biochar production of each unit, on a dry matter basis, is automatically entered in the Biochar Tool from the continuous weight record (cf. Chapter 11)..

8.4 Limit values and declaration requirements listed in Table 1 must be observed.

8.5 Specifications, additional limit values, or more stringent limits that apply only to certain countries are or can be regulated in the respective Country Annex.

8.6 TAK biochar must be adjusted to a water content that prevents dust formation and spontaneous combustion (30% is recommended). CS may grant exceptions for material uses.



9. Health and safety

9.1 Fire and dust protection regulations must be complied with throughout the entire production, transportation, and supply chain.

9.2 The company must assess the possible health risks and dangers within the production and define technical, organisational, and personal protective measures.

9.3 All workers must be informed in writing and trained about the 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, tars, and possible gas leakage.

9.4 The company must equip workers with suitable protective clothing and breathing masks where necessary and ensure that employees follow the defined protective measures.

10. Application

10.1 TAK-certified biochar may be used in agriculture and in material applications.

10.2 For use as an animal-feed supplement, national regulations supersede the TAK Standard and must be fully respected.

10.3 For use in material applications, biochar may be supplied bone-dry, provided it is sold B2B and the purchasing company is adequately equipped to handle dusty and potentially self-igniting materials.

11. Labelling

11.1 The shipping label for unprocessed TAK biochar must indicate at least: carbon content (C_{tot}), dry weight, volume, and production date or, for large packaging units, the production period.

11.2 The QR code of the TAK-certified batch must be printed on the packaging and the delivery note. All relevant analytical parameters can be accessed via this QR code.

11.3 The CS Design Manual describes in detail how and when the TAK logo may be used for labeling and marketing purposes.

12. Controlling

12.1 At least one on-site inspection is conducted per year. The inspection service routinely reviews flue gas temperature, biochar carbon content, dry matter and further continuously recorded production records and may carry out unannounced inspections if irregularities are detected. In addition, at least 10% of all TAK-certified producers are controlled by unannounced visits annually.

13. C-Sink Certification

13.1 TAK certifies biochar production. The carbon sink itself is certified and registered under the Global Biochar C-Sink Standard, for which TAK-certified biochar is eligible.

13.2 The C-sink is quantified from the batch dry mass and organic carbon content. The persistence class follows the H/C_{org} ratio and, for the upper class, random reflectance (R_o) or the hydropyrolysis-resistant fraction (BC_{HyPy}). These analyses must be part of the certified batch analysis; separate sampling is not accepted.

13.3 All associated greenhouse-gas emissions must be offset, and each packaging unit tracked from the factory gate to its final C-sink, before the sink is registered in the Global C-Sink Registry.

13.4 The full procedure and checklist are given in Chapter 13.

Table1. Overview of the analytical parameters for TAK biochar

	TAK Agro & Material	
Elemental Analysis	Declaration of Ctot, H, ash	
H/C	< 0.7	
Physical Analysis	Dry matter (as received, not milled)	
	Standard density (@ particle size < 3mm) (Std)	
	Solid electrical conductivity (SEC)	
	Salt content	
	Water holding capacity (@ < 3 mm) (WHC)	
	pH	
Heavy metals. To be analyzed only once for the endorsement of the facility when only natural, non-treated plant biomass feedstock of risk class I is used. For feedstock of risk class II, analysis once per batch required	As	13 g t ⁻¹ DM
	Cd	1,5 g t ⁻¹ DM
	Cr	90 g t-1 DM
	Cu	100 g t-1 DM
	Hg	1 g t ⁻¹ DM
	Ni	50 g t-1 DM
	Pb	120 g t ⁻¹ DM
	Zn	400 g t-1 DM
Organic contaminants PAH	8 EFSA PAHs	< 1.0 g t ⁻¹ DM
	16 EPA PAH	declaration
Persistence	For H/C < 0.4: 75% PAC & 25% SPC. For H/C ≥ 0.4: 100% SPC For Ro > 3.8 and/or BC_HyPy > 90%: 90% PAC & 10% SPC.	



3 The TAK Certification System

TAK provides a robust framework for the safe use of biochar in agricultural, industrial, and consumer applications. It covers all common uses of biochar, including soil amendment; use in composting, anaerobic digestion, manure management, and potting substrates; and use as an additive in consumer products that may come into direct skin contact (e.g., textiles) as well as in industrial components (e.g., electronics, composite materials, building materials). TAK defines a single certification class that guarantees biochar quality for all permitted purposes.

TAK certification is designed to exclude environmental and health risks such as:

1. Toxins entering the food chain through plant or animal uptake
2. Accumulation of contaminants in the environment
3. Ground- and surface-water pollution
4. Air pollution from production emissions and dust
5. Occupational and consumer health risks

TAK places strong emphasis on production monitoring and risk management. It is the first biochar standard to certify production on the basis of real-time digital monitoring rather than periodic self-declaration. Biochar analysis is performed in CS-endorsed laboratories. Selected parameters such as carbon content are analyzed onsite for daily production verification. Only part of the TAK analytical program can be performed by standard laboratories; most analyses are biochar-specific (e.g., heavy metals, PAH quantification, random reflectance) and require laboratory capacities currently available in only a limited number of countries. CS has therefore established a sample shipping service (c.f. chapter 8.6).

TAK threshold values generally match those of the EBC. However, the TAK analytical program includes fewer parameters to reduce recurring certification costs. Where TAK-certified biochar is produced or traded within the European Union or EFTA, the EU Annex applies, including the $\Sigma 16$ EPA PAH limit value, among other requirements. Certain countries regulate additional or more stringent limit values for soil amendments or biochar-based fertilizers; these are outlined in the respective Country Annex. Where national regulations permit less strict limit values than TAK, the TAK limits prevail.

TAK biochar must be produced from plant-based feedstocks. Permission for non-plant materials such as manure, digestate, or biosolids may be granted, but requires a specific technical audit by the Ithaka Institute to verify appropriate handling, monitoring, and emission control.

TAK biochar that is not dust-free must not be sold to private consumers (B2C) or directly to farmers. It may be sold only B2B, to companies able to ensure adequate protection against dust generation, self-ignition, inhalation exposure, and skin contact. Any such B2B sale requires prior approval from CS.



4 Biomass feedstock

- 4.1 Only biomass may be used to produce TAK biochar; fossil-carbon materials are not permitted.
- 4.2 Deliberate mixing of biomass with feedstocks containing fossil carbon (e.g., plastics) is prohibited.
- 4.3 The TAK Positive List (Appendix 1) specifies which biomasses are permissible for TAK biochar production and for which applications they may be used.
- 4.4 Impurities such as metals, construction waste, and composite materials must be reliably removed before pyrolysis.
- 4.5 Unavoidable and not reasonably separable contamination of biomass with plastics or rubber must not exceed 5% (m/m).
- 4.6 When using primary crops from agriculture and agroforestry (e.g., miscanthus, bamboo, short-rotation forestry), it must be ensured that the cultivation methods preserve or increase soil organic carbon (SOC). Measures such as soil cover, no-tillage, and mixed cropping combined with moderate, predominantly organic fertilization and plant protection are required and will be verified by the VVB. Supporting documents detailing the cultivation methods must be submitted to CS. SOC must be measured at least every five years.
- 4.7 TAK biochar must not be produced from primary forest logging. Wood-processing residues may be used only if they originate from forests demonstrably managed sustainably according to PEFC, FSC, or equivalent regional standards or laws. Biomass originating from clear-cutting of forests or forest sections is not permitted.
- 4.8 The pyrolysis of untreated human and livestock manure and manure-derived digestate may be admitted on a case-by-case basis, subject to a specific handling, monitoring, and analytical framework approved by CS. Industrial biosolids and mixed waste are not authorized under the TAK Standard as they require expanded analytical and monitoring measures, which are available only under the EBC
- 4.9 Mineral additives (e.g., rock powders, ashes, mineral salts) listed in the TAK Positive List may be used to control the pyrolysis process or biochar quality but require declaration and prior written approval from CS. CS may request additional controls for organic or inorganic contaminants.
- 4.10 All processed biomasses and additives, and any change in their composition or constitution, must be recorded in the CS Biochar Tool

Pyrolysis products derived from feedstocks not included in the TAK Feedstock Positive List are not considered biochar under this standard and must not be marketed using the TAK label. A producer wishing to include a new biomass or mineral additive in the TAK Positive List must submit a formal application to CS. The CS Scientific Committee will review the request and either approves the inclusion or publishes the reasons for refusal.



5 Pyrolysis Technology, Energy and Emissions

5.1 Minimum technical requirements

The TAK Standard covers professional pyrolysis equipment operated at an industrial level at a fixed, centralized production site. In specific cases, mobile pyrolysis units may be authorized by CS, provided they are equipped with the same real-time dMRV system. Open-flame kilns (e.g., open Kon-Tiki units) do not qualify for TAK certification and are referred to the Global Artisan C-Sink Standard.

Continuous operation with continuous feedstock input and biochar output is preferred, as it tends to produce more homogeneous biochar and gas quality while allowing monitoring to be more readily standardized and automated. Manual or semi-manual feedstock input and batch pyrolysis may equally be authorized. In every case, whether continuous or batch, TAK production shall meet the following conditions. Whether a given pyrolysis technology can meet them is established once per technology type in the pyrolysis system endorsement (Chapter 14); the technical pre-audit then verifies their implementation for the individual installation.

- (1) Pyrolysis gases are channelled into a combustion chamber and the flue gas is released through a duct or chimney. The combustion chamber shall be dimensioned and operated to approach a gas residence time of 2 seconds at 850 °C in the burnout zone; the producer shall document the design basis on which this is pursued.
- (2) The temperatures of the flue gas and of the pyrolysis kiln as well as the oxygen content of the flue gas are continuously measured and directly accessible to the VVB via the CS Biochar Tool.
- (3) The flue-gas temperature is used as a validated proxy for combustion quality and methane emissions. The correlation underlying this proxy must be established by the Ithaka Institute as part of the TAK System Certificate (Chapter 14). Depending on kiln type and data availability, Ithaka may apply a calibration derived from the specific installation, a calibration transferred from an equivalent kiln type, or conservative default values.
- (4) Emissions during start-up and shut-down are not significantly higher than during regular operations and are documented and included in the batch emission calculation.
- (5) The dry weight of the biochar produced is measured either continuously - at the biochar outlet in continuous systems, or from the kiln weight in batch systems – or daily through sampling.

Small-scale units and networks of mobile units for which real-time monitoring and representative sampling cannot be ensured should be certified under the Global Artisan C-Sink Standard.

5.2 Biomass pyrolysis must be operated without fossil fuel-based energy

Except for the initial preheating phase of the pyrolysis reactor, the use of fossil fuels for reactor heating is prohibited. The utilization of waste heat from other industrial processes, such as anaerobic digesters, cement production, or similar facilities, as well as the use of solar thermal energy, is permitted. If the pyrolysis reactor is electrically heated, the electricity must be



generated on site from renewable sources or sourced from certified renewable energy (e.g., via guarantees of origin or equivalent national certification schemes).

5.3 Pyrolysis gases must not escape into the atmosphere

A significant portion of global charcoal production still relies on obsolete technology, in which most of the original feedstock carbon is released as unburnt, toxic emissions. Although the material quality of charcoal produced in such kilns may meet biochar requirements, the environmental impact of these production methods is unacceptable and therefore incompatible with TAK certification.

Pyrolysis gases must be fully combusted, captured for material use (e.g., as bio-oil for chemical applications), or otherwise prevented from escaping into the atmosphere. The technical and monitoring requirements that give effect to this are set out in 5.1.

If pyrolysis gas is condensed to pyrolysis oil and wood vinegar, the non-condensable fraction (syngas) must likewise be collected or passed through the oxidation zone: the requirement that no pyrolysis gas escapes untreated applies to all gaseous products, whether or not the condensable fraction has been separated.

The TAK certificate guarantees that pyrolysis gases are not released untreated and that the environmental footprint of biochar production is substantially improved compared with artisanal biochar and traditional charcoal production.

5.4 Emission limits

Pyrolysis gases must be combusted such that CO emissions do not exceed 50 g and CH₄ emissions do not exceed 10 g per kg of biochar produced. These TAK-specific limits apply in addition to national and state emission regulations, which must also be respected. N₂O emissions from biomass pyrolysis are typically negligible and are therefore not regulated under this standard.

Compliance with the emission limits must be verified by at least one CS-endorsed emission measurement for each pyrolysis type, feedstock class, and production site. Direct emission measurement is not feasible for every batch, so TAK relies on a proxy: the combustion conditions that determine emissions are monitored continuously, and the endorsed measurement calibrates the emissions against them. Three parameters are recorded continuously for this purpose - the flue-gas temperature, the oxygen content of the flue gas (λ), and the gas residence time in the oxidation zone, for which the combustion chamber is designed and operated to approach two seconds at 850 °C. Temperature and residual oxygen together characterize the completeness of oxidation, the conditions under which methane and CO are destroyed: a flue gas held sufficiently hot, with sufficient excess oxygen, for a sufficient time corresponds to low and predictable CH₄ and CO emissions.

During the endorsed measurement, the CO and CH₄ emissions are recorded together with these simultaneously logged parameters, which calibrates the relationship for the specific installation. This correlation, established by the Ithaka Institute (Lotz et al., 2026), then allows continuous



verification between campaigns: the continuous temperature and oxygen records demonstrate that the calibrated combustion conditions are maintained batch by batch, and the emissions accounted for each batch are those derived from them.

Because batch-level methane is accounted from the flue-gas temperature proxy rather than from direct measurement, a safety margin of 20% is added to the proxy-derived methane emissions before they are accounted for offsetting. Provided the pyrolysis technology and operating conditions remain unchanged, the endorsed emission measurement must be repeated only every five years.

5.5 Energy efficiency and waste-heat utilization

Approximately 35–60 % of the energy contained in biomass feedstock is released in the form of pyrolysis gas and oil, which are normally combusted in the pyrolysis unit. A portion of this energy is used to heat the reactor and sustain the pyrolysis process.

Wherever feasible, surplus heat should be utilized for sustainable purposes such as biomass drying, district heating, electricity generation, or similar applications. However, in many subtropical and tropical regions with large biomass potentials, there is often no meaningful or economically viable use for waste heat. Requiring waste-heat utilization may impose undue constraints and impede the scale-up of the biochar industry in regions where it is most needed for carbon dioxide removal. For this reason, the TAK Standard permits biochar production even when no waste-heat utilization is possible.

Nevertheless, every producer must actively explore options to make productive use of the energy released during pyrolysis. Producers with limited or no waste-heat utilization are required to submit a status report to CS every two years, detailing their efforts and progress toward improving the overall energy efficiency of their operation. CS will provide a blueprint for the report which should be publicly available.

Alternatively, pyrolysis oil and/or gas may be captured and stored for later energy use - for example, to meet peak demand in district heating during winter months using pyrolysis oil produced in summer. The material utilization of pyrolysis oil or the upgrading of pyrolysis gas into basic chemicals such as methanol are additionally recommended pathways to increase carbon and energy efficiency.

The use of bio-oil has so far been implemented only on a limited scale. In principle, bio-oil may contain any pollutants that formed during pyrolysis but were prevented from condensing onto the biochar surface through careful process control. Special attention must therefore be paid to occupational safety during production, storage, and use. Operators wishing to condense liquid fractions from pyrolysis gas must submit a brief dossier to Carbon Standards that (a) describes the planned process, (b) outlines the known properties of the condensate specific to the feedstock and process conditions, (c) details the planned storage and use, and (d) specifies the occupational safety measures related to the condensation and handling of the liquid products.

6 Definition of biochar batches and their registration

Batch definition and limits

- 6.1 A batch consists of the amount of biochar produced from the same feedstock or feedstock blend, operated within the declared pyrolysis temperature range, and resulting in consistent biochar properties.
- 6.2 The maximum production quantity of one batch is 1000 t biochar on a dry matter (DM) basis.
- 6.3 A production batch may run for a maximum of 365 days after its registration.
- 6.4 A production batch can be interrupted for maintenance or to produce another batch (e.g., from other feedstock or using other pyrolysis parameters). Regardless of the number and duration of interruptions, the batch ends no later than 365 days after its initial registration or when the production of 1000 t biochar (DM) is reached. However, if less than 50 t biochar (DM) are produced within these 365 days, the batch may be extended once to a maximum of 730 days, provided the feedstock and process parameters remain unchanged.
- 6.5 A production batch is considered completed or interrupted once either the temperature tolerance (chapter 6.11) or the feedstock-type (chapter 6.13) changed. A new batch — with updated parameters — must then be registered immediately via the Biochar Tool.

Registration and traceability

- 6.6 Each production batch must be registered in the Biochar Tool and receives a unique ID number with a corresponding QR code. These identifiers ensure the traceability of the biomass feedstock, the production conditions, and biochar quality.

Production units and facilities

- 6.7 A batch is always linked to a single production unit.
- 6.8 Multiple small-scale pyrolysis units operating under the same TAK System Certificate type may be grouped as a single production unit (e.g., if six pyrolysis reactors of the same construction type run in parallel using the same combustion chamber and fill the same biochar storage). The maximum production amount per batch is still 1000 t biochar (DM) regardless of how many pyrolysis reactors are grouped under a single production unit.

Process tolerances

- 6.9 The pyrolysis temperature is a decisive parameter for biochar quality and emission control. While it is practically impossible to measure the temperature of the charring particles, the flue gas temperature and the temperature of the pyrolysis reactor correlate to the pyrolysis temperature depending on the design of the pyrolysis device. Both, the flue gas and reactor temperature must be logged continuously and made accessible online to the VVB via the CS Biochar Tool.
- 6.10 If the pyrolysis temperature measured via reactor or flue gas proxies, deviates by more than 15% from the declared setpoint for more than 30 minutes, the biochar produced during the



deviation must be separated from the batch. It may not be sold under the batch's certification.

- 6.11 The share of each feedstock type in the mixture must not deviate by more than 20% relative to its declared proportion, and the proportions of all feedstocks must sum to 100% at all times. For example, if a mixture is declared as 20% grain husks, 30% nut shells, and 50% landscape-conservation wood, the permissible ranges are 16%–24% for grain husks, 24%–36% for nut shells, and 40%–60% for wood. Any actual mixture must fall within all three ranges simultaneously and sum to 100% (e.g., 22% grain husks, 30% nut shells, and 48% wood). All feedstock variations must be registered in the CS Biochar Tool.
- 6.12 Biochar whose production conditions did not fall within the tolerance limits of a batch (e.g., during plant start-up and shut-down) must be separated and may not be labeled and sold under the batch's certification class.
- 6.13 Biochar that was disqualified by the batch parameters may be mixed into fresh feedstock and re-pyrolyzed.

Sampling

- 6.14 If a biochar producer registers a biochar production batch, a representative sampling has to be carried out within the first ten production days after registration following the CS-endorsed sampling plan.
- 6.15 If a production batch is produced with the same parameters as the preceding batch, the new sample must be taken from the monthly sealed daily retention samples after every 1000 t biochar or one year production time (see chapter 11.X)



7 Production Monitoring

Production monitoring is where the TAK certificate earns its meaning. Biochar analysis, feedstock selection, emission measurement, energy efficiency and worker safety are all necessary, but each is a snapshot, and a snapshot can be arranged. Continuous monitoring removes the gaps between snapshots in which a producer's word would otherwise stand in for a measurement. Repeated unannounced inspection is neither practical nor affordable at the scale biochar now operates; smart, real-time digital monitoring, introduced by TAK as the first biochar standard to require it, achieves the same assurance permanently and at lower cost.

The principle is a closed chain of evidence. Every certified batch is defined by data streams that must agree with one another: the continuous temperature and oxygen records fix when and how the kiln was running; the continuous weight record fixes how much biochar was made, and when; the daily feedstock log fixes what went in; and daily carbon analysis fixes what came out. Each stream constrains the others: the mass produced cannot exceed what the feedstock and the running hours allow, the declared class cannot contradict the analysis, and the accounted emissions cannot contradict the temperature and oxygen records. The certificate certifies the batch only to the extent that the chain is complete and consistent. Data that are missing, or streams that do not reconcile, are not certified: the corresponding production is excluded, not assumed. This is the foundation on which TAK can state plainly that it certifies only what it can prove.

7.1 Daily recording of received feedstock and produced biochar amounts

All feedstock delivered to the production site must be recorded by date, volume, and feedstock type in the CS Biochar Tool, and the record must be current at the end of each production day. The measurement effort must stay practical: aggregate figures - for example whole lorry or container loads - are sufficient, and total volume need only be accurate to within a few cubic metres. For the mass balance, recorded volumes are converted to dry mass using standard density values assigned to each feedstock type. This level of precision is acceptable because the resulting feedstock mass is cross-checked against the measured biochar production, where gross discrepancies surface; and during on-site inspection the recorded volumes and feedstock types must correspond to what is present.

The biochar production of each unit is weighed continuously and transmitted online (7.3); the daily total, with dry mass, carbon content, and number of packaging units, is registered in the CS Biochar Tool.

7.2 Continuous measurement of temperature and flue gas oxygen

To monitor consistent production conditions and verify the plausibility of total production amounts, every pyrolysis unit must be equipped with a temperature sensor that continuously records the temperature of the pyrolysis reactor. For systems in which the pyrolysis gas is combusted directly in or above the reactor (e.g., flame-curtain pyrolysis), the temperature in the combustion zone may be accepted as an alternative. A second temperature sensor must be installed in the exhaust stack to record the flue-gas temperature.



In addition, an oxygen sensor (λ probe) must be installed in the exhaust stack to record the oxygen content of the flue gas continuously. Together with the flue-gas temperature, this signal characterizes the completeness of combustion and forms the basis of the emission proxy defined in 5.4.

The type and positioning of all sensors must be determined during the technical pre-audit and documented in the Project Design Document (PDD).

The records must be transmitted online to the CS Biochar Tool; where the internet connection fails, the timestamped data must be buffered locally and uploaded no later than twenty-four hours afterwards. Missing data for any required signal will be treated as an interruption of production, with the corresponding period excluded from the batch's certified production volume.

7.3 Continuously weighing the produced biochar

Every TAK production unit must weigh its biochar output continuously and transmit the mass online, whatever the kiln type. The weight is more than a production figure: it is the independent evidence that biochar was actually produced, in the quantity and at the time claimed, and it is the mass signal against which the temperature, oxygen, feedstock, and carbon records are cross-checked. The continuous production weight measurement is the key in the monitoring system of TAK. A production period without a continuous weight record cannot be reconciled and cannot be certified.

In closed batch systems such as Kon-Tiki type kilns, the reactor shall stand on load cells throughout the burn. The mass is logged continuously and read automatically at the end of pyrolysis, before quenching, so that the batch yields its dry mass directly, without moisture correction.

In continuous systems such as auger and rotary kilns, continuous weighing is achieved by an automatically tared and emptied weigh-bin at the outlet: each fill is weighed and discharged, and the successive fills form a continuous mass record. The weighed output is a fresh, quenched mass, and its conversion to dry mass follows in Chapter 7.4 from the daily sample.

The weight is transmitted online to the CS Biochar Tool in the same way as the temperature and oxygen signals (7.2). Where the internet connection fails, the timestamped data must be buffered locally and uploaded no later than twenty-four hours afterwards. As with the other continuous signals, a gap in the weight record is treated as an interruption of production, and the corresponding period is excluded from the certified production volume.

Weighing the biochar only at the end of the day, for instance by weighing filled bags or containers, does not satisfy this requirement: a day-end total confirms a quantity but not the course of production, and cannot be correlated with the continuous process signals. The weighing method, its accuracy, and its safeguards are fixed generically for each technology in the pyrolysis-system endorsement and specifically for each installation in the PDD.



7.4 Measuring dry mass and carbon content

Dry mass and carbon content are by far the most decisive parameters for C-sink certification: together they determine how much accountable carbon a sink contains. Yet despite large efforts to make biochar the most reliable C-sink in the CDR field, both have often been measured poorly.

Dry mass has frequently been assessed without a proper understanding of how biochar holds water - and twenty-four hours in an unventilated oven, or simply drying in the sun, is not enough to determine dry mass to better than 20 %. Carbon content, meanwhile, has typically been analyzed only once a year, on a more or less representative sample. But carbon content is not a fixed property of a production line: it depends on parameters such as feedstock composition, pyrolysis temperature and intensity, and the efficiency of gas-solid separation, all of which vary to some degree even in well-controlled industrial operations. A single annual analysis cannot capture that variation and applied to a production of 1,000 tons it turns the certified carbon into an essentially random quantity. It also leaves the door open to fraudfully sending an unrepresentative, carbon-rich sample to the laboratory.

Together, an imprecise dry mass and an unrepresentative carbon value are a significant source of C-sink overclaiming. Daily assessment of both parameters is therefore a prerequisite for C-sink certification, not a refinement of it. It is the most important methodological advance TAK introduces.

The dry-matter fraction and the carbon fraction are determined from a single representative sample of the day's production (c.f. Chapter 8.2), drawn as specified in the PDD (Annex 1), so one daily sampling serves both. The milled sample is dried in a thermogravimetric moisture analyzer; the drying yields the dry-matter fraction directly. Following the thermogravimetric drying step, the dried sample is directly used in a dedicated incinerator for carbon assessment via ash analysis.

The reference method for organic carbon is elemental analysis, which remains the anchor for periodic calibration and audit; but an elemental analyzer is expensive, fragile, and demanding in expertise, and is not suited to routine daily use in a semi-industrial environment. For the daily measurement TAK therefore uses a robust proxy. As long as the feedstock type does not change within a batch, the ash content of the biochar correlates closely with its organic carbon content, and ash is simple and cheap to determine on site.

The ash content is measured by combustion at 550 °C (carbonates are not oxidized at that temperature, so that the derived carbon is organic carbon). It is converted to organic carbon through a linear relationship whose coefficients depend on the biochar's H/C ratio, which is both feedstock- and process-determined. The H/C ratio is taken from the annual elemental analysis and used to assign the biochar to an H/C class. Each H/C-class carries its own calibrated ash-to-carbon regression, together with a conservatism margin scaled to that class's calibration uncertainty. The daily measurement thus supplies the ash value, while the annual elemental analysis fixes which conversion applies and how large a margin it carries. Because the annual sample calibrates every daily measurement, its carbon level must remain consistent with the daily ash record; a departure flags the calibration for review. The regressions, their H/C class boundaries, the associated margins, and their validity limits are given in Annex 2.



The determination is carried out once per day. The resulting carbon content is applied to the day's dry mass, and the dry mass and carbon content are registered for the day's production in the CS Biochar Tool. For example, one tonne of biochar at 65 % dry matter and 80 % carbon contains $0.65 \times 0.80 \times 1 \text{ t} = 0.52 \text{ t C}$, a carbon sink of 0.52 t C (equivalent to 1.9 t CO₂e).

7.5 Documentation

Complete production records must be kept, providing detailed descriptions, dates, and locations of any production problems or stoppages.

8 Biochar Sampling

8.1 Representative batch sample

The representative biochar samples sent to the endorsed laboratory for the batch analysis must be taken by a CS-endorsed automatic cross-flow sampling device. Cross flow sampling should be automatic, but it can also be done manually when a reliable protocol and documentation are put in place and endorsed by CS. If cross-flow sampling cannot be carried out (e.g., in batch pyrolysis), the producer must submit an equivalent sampling method to CS for endorsement prior to the technical pre-audit (cf. Annex 3).

The cross-flow sampling device must be configured so that for every ton of biochar produced, at least 1 litre of biochar is retained as a composite sample. This composite must consist of at least 10 incremental extractions distributed evenly over the production of that ton. The sample sent for full laboratory analysis must consist of at least 20 liters, representative for a production of 20 tons.

The representative sample must be registered in the Biochar Tool and assigned a unique ID. Only samples registered via the Biochar Tool can be considered as sample for batch analysis.

8.2 Representative daily sample

The representative daily sample must be taken from at least ten incremental cross-flow extractions. If no cross-flow sampling is possible, ten subsamples of the entire daily production must be collected from ten different spots of the production pile. The composite sample must have at least a volume of 1 liter after milling.

8.3 Retention sample

The daily sample remaining after the daily dry mass and carbon analysis must be collected in containers of at least 60 liters. Each container must be sealed once it has reached its capacity or once the corresponding production volume has been completed, whichever comes first. The sealed container must be labelled with the batch ID and the corresponding production period and stored dry and protected for at least two years. These sealed containers constitute the retention samples for the batch.

8.4 VVB verification sample

During its annual inspection or any unannounced visit, the VVB draws one verification sample of at least 20 litres per batch from one of the sealed retention containers, breaking and documenting the seal. The VVB seals the sample with a tamper-proof closure and labels it with a CS-ID. The VVB or the producer sends the sealed sample to an endorsed laboratory.



8.5 Sampling plan

The detailed sampling plan, cross-flow protocol, and methods must be submitted to Carbon Standards before the technical pre-audit. Any subsequent modification of the sampling plan requires prior approval by Carbon Standards.

8.6 Shipping samples

To keep transport and analytical costs as low as possible, CS helps producers collect samples locally and forward them to its endorsed laboratories. For this purpose, producers may contact the local offices of CS and of the EASY-CERT group, which are present in more than 50 countries worldwide and can be contacted in the local language.

8.7 Reporting of results and use of analytical data

The endorsed laboratory shall send the results of the analysis to the biochar producing company and a copy to the accredited inspection body, Carbon Standards, and the Ithaka Institute. By applying for TAK certification, the producer agrees that Carbon Standards and the Ithaka Institute have the right to use the results of TAK analyses in anonymised form for statistical and scientific purposes.



9 Biochar Analysis, Properties, and Thresholds

The TAK Standard applies a streamlined analytical programme focused on the parameters most relevant for environmental protection, safe handling, and sustainable use. These selected parameters enable robust characterisation of biochar to ensure product safety. The basic analytical programme as detailed in Annex 3 is performed once per batch; the daily dry-mass and carbon determinations of chapter 7 are additional to it. If an unannounced on-site inspection is carried out, a second sample is taken and submitted for the same analytical program; discrepancies between the two results are handled under the non-conformity procedure of the VVB.

Numerous additional analytical methods exist to characterize and classify biochar in greater detail. However, many of these lie beyond reasonable cost limits and require highly specialised laboratory capacities available only in a limited number of countries. TAK analyses the parameters that determine safety and correct carbon accounting, and omits those that add cost without adding protection.

The limit values mentioned in the following chapter are only valid in conjunction with the permissible test procedures and analytical methods performed in an endorsed laboratory. These are detailed for the individual parameters in Annex 3 and 4.

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

Solid residues from pyrolysis or gasification of biomass that exceed TAK limit values must be considered toxic waste and shall be disposed of in accordance with local, national, or international waste regulations.

9.1 Carbon content

The organic carbon content of biochar varies typically between 25 % and 95 % of dry matter, depending on the feedstock and the pyrolysis conditions. For TAK eligible feedstock, the expected range is 40 to 95 %. For example, the carbon content of pyrolysed straw is usually between 40 % and 60 %, and that of wood and nutshells between 70 % and 90 %. TAK does not define a minimum organic carbon content but reserves the right to exclude biochar whose properties are highly atypical of the declared feedstock, following a plausibility check with the producer. Such cases may include, for example, highly oxidized gasifier ash being declared as biochar.

Only organic carbon is used for carbon sink certification, as the long-term permanence required for C-sink accounting can only be reliably calculated and ensured for pyrogenic organic carbon, not for mineral carbonates, which are vulnerable to dissolution under acidic conditions.

9.2 H/C_{org} molar ratio must be below 0.7

The molar H/C_{org} ratio indicates the degree of carbonization and, therefore, of biochar stability. The ratio is one of the most important characterizing features of biochar. For TAK-eligible feedstocks, the H/C_{org} ratios depend mainly on the pyrolysis conditions.



H/C_{org} values exceeding 0.7 indicate non-pyrolytic chars or pyrolysis deficiencies, regardless of the feedstock (Schimmelpfennig and Glaser, 2012).

Only biochars presenting molar H/C_{org} ratios below 0.4 are eligible for certification of a geologically persistent carbon (GPC) fraction (cf. Global C-Sink Standard). Less pyrolyzed biochars (i.e., with an H/C_{org} between 0.4 and 0.7) are more likely to degrade in soil within a 1,000-year timeframe.

For biochars intended for use as feed additives, certifiers should apply more stringent limits. H/C_{org} ratios higher than 0.4 should not be authorized, in order to ensure full decomposition of potential organic feed contaminants (e.g., fungal spores in waste hay). The H/C_{org} ratio < 0.4 is used here as a proxy for reaching pyrolysis temperatures > 500 °C (Hagemann et al., 2025).

9.3 Nutrient contents

The nutrient content of biochar depends mainly on the feedstock selection and can account for up to a third of the total mass. It should be noted that these nutrients are only partially available to plants due to their incorporation into stable aromatic structures (especially nitrogen) and the high adsorption capacity of the biochar and may only be reincorporated into biological cycling 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 the availability of potassium can reach 50 % (Camps-Arbestain et al., 2015). The plant availability of phosphorus and potassium can be improved by optimizing the pyrolysis conditions and the use of additives (Buss et al., 2020; Rathnayake et al., 2023).

Given the generally low biochar nutrient content and plant availability, nutrient analysis is not required under the TAK Standard but recommended on a voluntary basis. In agriculture and animal husbandry, nutrient information may be legally required in some countries. For material applications, nutrient content is generally less relevant. However, higher levels of calcium, potassium, and magnesium may influence certain material properties, which would be a reason to declare nutrient content where available.

9.4 Heavy metals (potentially toxic elements)

Contamination with potentially toxic elements (PTE), commonly referred to as heavy metals, arises in biochar either from the biomass feedstock or from metal abrasion within the pyrolysis unit. The latter typically results in elevated contents of chromium and nickel, which are common components of steel alloys. To rule out contamination originating from the pyrolysis unit, a complete heavy metal analysis must be carried out prior to certification for every production unit before the facility is permitted to produce biochar under the TAK Standard.

Regarding feedstock-derived heavy metals, it should be noted that these elements are inherent components of all ecosystems. Even in natural soils with minimal anthropogenic influence, plants absorb more than 50 geogenic elements — including all essential micronutrients. Their potential toxicity depends on the specific element, its concentration, and its bioavailability. Importantly, the



bioavailability of heavy metals in biochar is typically lower than in the original feedstock or in many other soil amendments such as compost.

With the exception of a few elements that are volatile or semi-volatile at pyrolysis temperatures (e.g., mercury), the heavy metals contained in the biomass remain in the biochar. As biomass loses more than half of its mass during pyrolysis (primarily in the form of carbon, hydrogen, and oxygen compounds), the non-volatile heavy metals become correspondingly concentrated in the final product.

Although the permissible feedstock for TAK biochar is restricted, unexpected contamination can occur — for example, when woody biomass is sourced from roadsides or other locations with elevated environmental pollution or high geogenic background concentrations. A complete heavy metal analysis is therefore required for each production batch as part of the annual batch analysis.

The limit values of the TAK Standard are aligned with existing values in the EBC and IBI, ensuring international harmonization.

Table 2: Limit values for heavy metals according to the TAK Certificate.

Heavy metals	As	13 g t ⁻¹ DM
	Cd	1,5 g t ⁻¹ DM
	Cr	100 g t ⁻¹ DM
	Cu	140 g t ⁻¹ DM
	Hg	1 g t ⁻¹ DM
	Ni	50 g t ⁻¹ DM
	Pb	120 g t ⁻¹ DM
	Zn	420 g t ⁻¹ DM

9.5 Physical parameters: bulk density, dry-matter content, salt content, and pH

The pH value of biochar is an essential criterion for its targeted use in substrates and for the fixation of minerals in soil and industrial products. The salt content, measured via the electrical conductivity of a biochar leachate, may indicate salt contamination of the feedstock or excessive oxidation during pyrolysis, and should therefore be measured. Moreover, it is an important factor when using biochar substrates as young plants are particularly sensitive to high salt levels.

Bulk density of biochar milled to a standardized particle size of < 3 mm is a useful specification for trading and comparing biochars.

TAK biochar must be adjusted to a water content that prevents dust formation and thus also spontaneous combustion, unless an exemption for B2B trade has been granted by CS. TAK recommends a water content of 30 % for this purpose. Appropriate storage must prevent the biochar from drying.



If an exemption is granted to trade dry biochar for material uses, the manufacturer and trader must indicate the associated hazards in accordance with relevant standards and local, national, and international requirements. This includes but may not be limited to spontaneous ignition, dust explosion, and the health hazards from fine dust inhalation. Producers must indicate appropriate safety precautions accordingly.

9.6 Water holding capacity (WHC)

Water holding capacity (WHC) is a relatively simple yet informative measure of the porous structure of biochar and is therefore a valuable indicator of overall biochar quality. It provides practical guidance for mixing biochar with liquids such as liquid fertilizers, digestate, or stormwater, and is a key parameter for assessing biochar's effectiveness in increasing soil water retention and buffering moisture in the root zone. It is likewise useful for evaluating the moisture uptake and buffering properties of construction materials and other biochar-based composites.

To ensure reproducible and comparable results, WHC must be determined on biochar milled to a particle size of < 3 mm.

9.7 Solid state electrical conductivity (SEC)

The solid-state electrical conductivity (SEC) of biochar arises from condensed aromatic carbon structures containing delocalised π -electrons, analogous to materials such as graphite and carbon black (Hagemann et al., 2025). For a given feedstock, SEC increases exponentially with pyrolysis temperature and correlates strongly with the H/C molar ratio, which is a widely used indicator of biochar aromaticity and recalcitrance (Grafmüller et al., 2026; Hagemann et al., 2025). SEC, therefore, serves as a practical proxy for biochar carbon persistence. Research has demonstrated a strong correlation between SEC, the hydropyrolysis-resistant carbon fraction (BC_HyPy), and the H/C molar ratio across biochars produced at 400–800 °C (Hagemann et al., 2025).

SEC must not be confused with the electrical conductivity of an aqueous biochar suspension, which is used to estimate salt content. The two parameters describe fundamentally different properties: SEC reflects the electronic conductivity of the solid carbon matrix, while the leachate conductivity reflects ionic content dissolved in water.

9.8 Polycyclic aromatic hydrocarbons (PAH)

The pyrolysis of organic materials inevitably leads to the formation of polycyclic aromatic hydrocarbons (PAH) (Fagnäs et al., 2012). PAH are primarily generated in the gas phase and are generally degraded to innocuous compounds (mainly CO₂ and H₂O) during the combustion of pyrolysis gases. However, depending on the design and operating conditions of the pyrolysis reactor, varying amounts of PAH may condense onto the biochar surfaces and into its internal pore structure when the biochar cools below the boiling point of the respective PAHs while still in contact with pyrolysis gases in the reactor or during discharge (Thomas D Bucheli et al., 2014; Buss et al., 2016). The efficient separation of biochar and pyrolysis gases during discharge is therefore essential for minimizing PAH contamination.

Appropriate production technologies - including both artisanal and modern pyrolysis reactors – can, when properly designed, reliably produce biochar with very low PAH content, as demonstrated by Kon-Tiki flame curtain kilns (Cornelissen et al., 2016) and all EBC-certified biochar companies since 2012. The type of biomass feedstock has been shown to have only a negligible influence on the PAH content of the resulting biochar (Bucheli et al., 2015a). However, some industrial pyrolysis and gasification technologies have resulted in biochars with elevated PAH levels (Hilber et al., 2012), indicating unsatisfactory or unsuitable production conditions (Bucheli et al., 2015b).

Tab. 3: PAH limit values for the TAK biochar.

		TAC
Organic contaminants PAH	Σ8 EFSA PAH	< 1.0 g t ⁻¹ DM
	Σ16 EPA PAH	declaration

The significance of PAH as a proxy for total pyrolytic condensates

The PAH content of biochar is important not only because of the direct toxicity of individual PAH compounds, but because the regulated PAHs - whether the most commonly used 16 compounds selected by the U.S. Environmental Protection Agency (16 EPA) or the eight compounds suggested by the European Food Safety Authority (8 EFSA) - serve as proxies for the total content of pyrolytic condensates on the biochar. Pyrolysis gases contain more than 500 identified aromatic compounds (Achten and Andersson, 2015a), including alkylated PAHs, oxy- and nitro-PAHs, and heterocyclic aromatic species, the vast majority of which are not individually regulated and whose toxicity is largely unknown. A low PAH content, therefore, indicates effective separation of pyrolysis gases from the biochar product and, by extension, low total condensate contamination. Conversely, elevated PAH levels signal broader condensate contamination that extends well beyond the measured compounds.

Toxicity and bioavailability

Individual PAHs differ widely in their toxicity (WHO, 2016). The type and degree of toxicity (e.g., genotoxicity, carcinogenicity, ecotoxicity) depend on molecular structure, concentration, bioavailability, exposure route, and duration of exposure. Critically, the bioavailability of biochar-bound PAHs is extremely low (I. Hilber et al., 2017a). As shown by Hilber et al. (I. Hilber et al., 2017b; Isabel Hilber et al., 2017a), biochar amended to soil acts more as a sink than a source of PAHs. When compared with compost, digestate, fertilizer, atmospheric depositions, or hay - all of which are significant entry points of PAHs into agronomic systems (Honda and Suzuki, 2020; Patel et al., 2020; WHO, 2016; Wu et al., 2019) - PAH bioavailability from biochar is the lowest among these sources. Studies confirm very low bioavailability of biochar-bound PAHs when contents remain below the TAK limit values (Isabel Hilber et al., 2017b).



Choice of PAH indicator: $\Sigma 8$ EFSA PAHs

Historically, PAH thresholds in standards such as the EBC and IBI were based on the 16 individual PAHs compiled by the U.S. Environmental Protection Agency. These compounds were selected from among hundreds of PAHs (Achten and Andersson, 2015b) based on environmental relevance, toxicity, and measurability. However, the adoption of the EPA-16 list and the use of very low limit values were not originally grounded in biochar-specific science or risk assessments. They were borrowed from regulatory thresholds established for other soil amendments — such as compost, digestate, plant substrates, and even contaminated soils — across various countries.

Using a limit value based on the sum of the 16 EPA PAHs assigns equal weight to all individual compounds, although they can be divided into two groups: eight PAHs for which there is insufficient or no evidence of carcinogenicity, and eight with confirmed carcinogenic properties (Achten and Andersson, 2015b). TAK defines its limit values based on the sum of the eight carcinogenic PAHs ($\Sigma 8$ EFSA PAHs), following the European Food Safety Authority's recommendation to evaluate safety by monitoring these eight compounds [23]. The TAK limit value of $1 \text{ mg } \Sigma 8 \text{ EFSA PAHs kg}^{-1} \text{ DM}$ is as protective as thresholds applied to food products. However, as the $\Sigma 16$ EPA PAHs are a proxy for general pyrolysis gas condensation, the $\Sigma 16$ EPA must be declared. By scanning the QR code on the packaging, on delivery notes, or in other contexts, $\Sigma 8$ EFSA PAHs and $\Sigma 16$ EPA PAHs are available to customers and regulators.

Analytical considerations

Due to the high adsorption capacity of biochar, analytical methods developed for PAH analysis in soil or water are not suitable for biochar (Hilber et al., 2012). It is therefore required to use the service of TAK-endorsed laboratories to perform PAH analyses.

9.9 Limit Values for PCB and PCDD/F

In modern pyrolysis plants, only minimal quantities of polychlorinated biphenyls (PCB) and polychlorinated dibenzo-p-dioxins and furans (PCDD/F) are produced (Grafmüller et al., 2024). Significant contamination with these compounds can occur only when pyrolysis gases condense on the biochar surface — a process that would simultaneously result in exceedingly high PAH contamination (Grafmüller et al., 2024). As established in Section 7.9, the regulated PAHs serve as proxies for the total content of pyrolytic condensates, including chlorinated aromatic compounds. For this reason, routine quantification of PCB and PCDD/F is not required for TAK biochars. Any biochar that meets the TAK PAH limit is automatically exempt from PCB and PCDD/F testing.

Regardless of this exemption, the following limit values for PCB and PCDD/F apply under TAK:

- PCB: $0.2 \text{ mg kg}^{-1} \text{ DM}$
- PCDD/F: $20 \text{ ng kg}^{-1} \text{ I-TEQ (WHO)}$

If PCB or PCDD/F contamination is suspected - for example, due to anomalous PAH results or the use of feedstock from potentially contaminated sources (e.g., biomass from urban areas or contaminated soils) - the VVB or CS may require their quantification at any time.



10 Safety and health

- 10.1** Fire and dust protection must comply with local and national regulations throughout the entire production, transportation, and supply chain.
- 10.2** All workers must be informed in writing about the possible risks and dangers of and around the production facility. This concerns, in particular, the self-ignitability of char dust, the need for respiratory protection, contact with bio-oil and tars, and possible gas leakage. Each worker must sign an acknowledgement confirming that they have received and understood this information.
- 10.3** The certified biochar producer must equip workers with suitable protective clothing and breathing masks where necessary, and must ensure that employees follow the defined protective measures.
- 10.4** Adequate first-aid equipment must be available at the production site at all times. The company must establish and maintain emergency procedures covering fire, gas leakage, and personal injury. All workers must be trained in these procedures, and emergency drills must be conducted at least once per year.



11 Storage and processing of biochar

11.1 Storage

Biochar and biochar-based products must be stored in a manner that prevents contamination. Special attention must be given to gaseous pollutants (e.g., engine exhaust gases), which can be adsorbed by biochar. Suitable storage include filling big bags and keeping them under a roof, loading into covered containers, or storing in other protected environments.

Producers must ensure that TAK biochar is never mixed with non-TAK-certified biochar. Any mixing of TAK biochars from different batches—whether from the same producer or from different TAK-certified producers—must be documented. The quality, origin, traceable identification number, and product name must be clearly visible on all storage units or packaging.

11.2 Processing

In agriculture, biochar is rarely used in its pure form. It is typically incorporated into processed products such as soil amendments, potting substrates, compost, fertilizers, bedding materials, or additives for anaerobic digestion. Alongside specialised biochar producers, a growing industry processes purchased biochar as a raw material for biochar-based products.

To ensure correct application and labelling of products containing TAK-certified biochar, the entire supply chain - from production to processing, packaging, and labelling – should be certified.

However, within the scope of the TAK Standard, the market for biochar-based products is still at an early stage, and the volume of processed biochar remains comparatively small. Requiring certification of external processors and traders would place a disproportionate burden on this nascent industry. TAK therefore does not currently require certification of external, independent processors or traders beyond the tracking of the biochar to the C-sink or to the C-sink matrix (cf. Global Biochar C-Sink Standard, Chapter 10). Consequently, biochar-based products manufactured by such non-certified companies must not carry the TAK logo. If the processor prints the batch number and the registered packaging unit ID on the packaged product, it may state: "Contains biochar certified under the TAK Standard, batch [ID], packaging unit [ID]."

If warehouse keepers, processors, and/or traders wish to use the TAK label in their marketing and labelling of products, they must be registered with CS and certified in accordance with the applicable requirements.



12 The TAK C-Sink Certification and Registration

12.1 The relation between TAK and the Global Biochar C-Sink Certification

The TAK Standard certifies the production and quality of biochar. The biochar only becomes a carbon sink when it is (1) stored in an approved matrix, (2) its stored carbon is quantified over time, (3) all associated greenhouse-gas emissions are offset, and (4) the C-sink is registered. These monitored and certified steps are governed by the Global Biochar C-Sink Standard, hereafter "the C-Sink Standard".

The present chapter describes how TAK-certified biochar becomes a registered carbon sink and how the TAK and the Global Biochar C-Sink standards interlock. It is deliberately short. It restates none of the C-Sink Standard's methodology and reproduces none of its equations. For every calculation, threshold, and procedure, the C-Sink Standard is the governing document, and the relevant chapter is cited. Where the two standards address the same object, the C-Sink Standard prevails on carbon accounting and registration, and the TAK Standard prevails on production and monitoring.

12.2 Position of TAK in the C-sink certification chain

A biochar carbon sink is the result of three steps: removal of CO₂ from the atmosphere through biomass growth, transformation of the removed carbon into a stable form through pyrolysis, and verifiable storage of that carbon (C-Sink Standard, Chapter 1). TAK certifies the transformation step and the data that describe it. The removal, expressed as feedstock carbon neutrality, and the storage, meaning application to soil or to a material matrix, are assessed under the C-Sink Standard.

TAK- and EBC-certified biochar are equally eligible for Global Biochar C-Sink certification. TAK certification establishes the production quality, the analytical characterization, and the batch-accurate production record that the C-Sink Standard requires as the starting point of every C-sink calculation. TAK is the production layer; the C-Sink Standard is the accounting and registration layer built upon it. The eligibility clause of the C-Sink Standard (Section 1.3) will become aligned with this change at its next update.

12.3 Feedstock carbon neutrality and additionality

Only carbon-neutral biomass may be used for TAK production. Under the C-Sink Standard (Chapter 5) a feedstock is carbon-neutral if it is the residue of a biomass processing operation, or if its removal did not, over the relevant reference period, reduce the total carbon stock of the system in which the biomass grew. Biochar made from biomass whose harvest destroyed or depleted a natural carbon sink, for example clear-cut forest or drained peat soil, renders no climate service and cannot be certified as a C-sink. The emissions of cultivation, such as fuel, nitrogen fertiliser, and pesticides, do not in themselves break neutrality; they are carbon expenditures recorded in the emission portfolio and must be offset (13.5).



Feedstock is grouped into the ten classes of the Biochar C-Sink Standard, from crop and forest biomass to processing residues, manure, and biosolids. Most classes rest on the producer provided evidence of neutrality. Forest wood is the exception: its neutrality must be demonstrated at forest level, through the country's LULUCF reporting, a PEFC, FSC, or Global Tree C-Sink certification, or an accredited assessment of the forest's carbon balance. The year of CO₂ removal, which fixes the start of the C-sink's persistence curve, is set per class and is likewise defined in Chapter 5 of the standard.

Beyond neutrality, the biomass must be additional: the C-sink must not displace a more carbon-efficient use of the same biomass that would otherwise have occurred. High-value material uses, such as construction timber, are more carbon efficient than pyrolysis and are, thus, preferred, while residues, damaged wood, and wood residues from demonstrably sustainable forestry remain eligible feedstock. The producer submits a risk assessment for activity shifts and market transformation; it is evaluated by Carbon Standards in the technical audit and verified by the certifier. TAK does not re-decide feedstock eligibility. It inherits these conditions from the C-Sink Standard, and a batch produced from ineligible biomass cannot become a registered C-sink however well it is produced and monitored.

12.4 Quantifying the carbon sink

The size of a biochar C-sink at the moment of application is the product of its organic carbon content and its applied dry mass (C-Sink Standard, Chapter 2.1, the quantity C-Sink₀). Its evolution over time is a function of the biochar's persistence in the given matrix. TAK supplies the two primary production quantities: the dry mass of biochar produced per batch and its organic carbon content.

The C-Sink Standard then partitions the carbon into a geologically persistent pool (GPC) and a semi-persistent pool (SPC), whose relative sizes follow the biochar's persistence class (Chapter 3). For soil-applied biochar the class is set by the molar H/C_{org} ratio and, where available, by random reflectance (Ro) and the hydropyrolysis-resistant fraction (BC_{HyPy}): 90% GPC for the upper class, 75% for the lower class, and 100% SPC for biochar with H/C_{org} above 0.40. The time-averaged sink is expressed through the CINK_H metrics. TAK does not reproduce these definitions; it ensures that the analyses on which they depend are part of the certified batch analysis (see 13.5).

12.5 Emission portfolio and offsetting

Every C-sink carries an emission portfolio: the sum of all greenhouse-gas emissions caused from biomass provision through pyrolysis, handling, transport, and application to the final matrix (C-Sink Standard, Chapter 4). These emissions must be offset before the C-sink can be registered.

TAK contributes the production-side entries of this portfolio directly from its monitoring system: the energy and fuel consumption of the process, and the methane emissions of the pyrolysis unit derived from the continuously monitored flue-gas signals. Emissions occurring after the factory gate are tracked separately by the dMRV provider (C-Sink Standard, Chapters 4 and 10). The offsetting rules, namely CO₂ and N₂O against geologically persistent carbon and methane against



a temporary C-sink delivered over a 5-to-20-year horizon, are set out in the C-Sink Standard and are not repeated here.

12.6 Analyses required for C-sink classification

The persistence class of a soil-applied biochar depends on analytical values that go beyond routine production control. The organic carbon content and the H/Corg ratio are always required. Random reflectance (Ro) and the hydropyrolysis-resistant fraction (BC_HyPy) are required to reach the upper persistence class.

Under the C-Sink Standard these analyses are accepted only when requested as part of the endorsed batch analysis; separate sampling is not accepted (C-Sink Standard, Sections 1.3 and 3.7). The sample used for persistence classification must therefore be the representative batch sample taken under TAK. TAK's role is to guarantee that this sample is representative of the continuously monitored batch and that its identity to the batch is documented.

12.7 Tracking from the factory gate to the C-sink

Once a packaging unit leaves the production site, its carbon can still be lost, whether to combustion, to industrial reduction, or to any use that re-emits the carbon. From this point the sink is protected by post-production dMRV, described in Chapter 10 of the C-Sink Standard. Each packaging unit carries a scannable identifier linked to its batch, and every transport, change of ownership, processing step, and final application is registered until the carbon reaches a soil or material matrix from which it can no longer escape. The sink is then geo-localised, or, for finely distributed applications, registered as a diffuse C-sink (Chapter 11).

TAK's own dMRV ends at the factory gate. The post-gate chain is the responsibility of the C-sink owner, processor, trader, or dMRV provider, as defined in the C-Sink Standard. The same batch identifier generated for TAK carries through into this post-production tracking, so that the production record and the post-gate record remain a single, continuous chain of evidence.

12.8 Registration in the Global C-Sink Registry

A certified C-sink becomes a tradable climate service only once it is registered in the Global C-Sink Registry operated by Carbon Standards (C-Sink Standard, Chapter 13). Registration records the owner, the location, the batch and its analyses, the amount of carbon and its persistence curve, the emission portfolio and its compensation, and the project documentation. The full set of registered data is listed in Chapter 13 of the C-Sink Standard and is not reproduced here.

Several roles interact in this process. The producer holds the TAK certification and generates the production data. A dMRV provider, endorsed by Carbon Standards, tracks the biochar and prepares the monitoring report. An independent validation and verification body (VVB) verifies the removal and the C-sink value. Carbon Standards acts as the endorsing agent for dMRV providers, tools, laboratories, and certifiers. The project documentation, comprising the Project Design Document (PDD), the monitoring report, the validation report, and the verification report, is published in the registry together with the C-sink.



12.9 Interface between TAK monitoring and C-sink accounting

The value that TAK adds to C-sink certification lies in the quality of its production data. Under conventional certification, the dry mass and carbon content of a batch rest on a single representative analysis. Under TAK, the produced mass is weighed continuously, the dry mass and carbon content are determined daily, and all signals form a closed chain of evidence in which missing data is excluded from the certified volume. The starting quantity of the carbon sink is therefore established from a real-time, tamper-evident production record rather than from a single point measurement. This raises the integrity of the registered C-sink and reduces the uncertainty that the C-Sink Standard's safety margins are designed to cover.

12.10 Carbon efficiency (indicative)

Carbon efficiency is the fraction of feedstock carbon that a pyrolysis operation preserves in a storable form rather than releasing it as CO₂ (C-Sink Standard, Section 8.1). Carbon efficiency of a C-sink is not a threshold, but appears on the C-sink certificate as an indicative and comparative value. It expresses how much atmospheric carbon a given quantity of biomass ultimately delivers to storage, and it therefore lets buyers and traders compare the resource efficiency behind otherwise equivalent carbon credits.

For most TAK systems the potential to raise carbon efficiency is low. The typical TAK design combusts the pyrolysis gases directly, so its products are biochar, CO₂, and heat. While in most regions where TAK systems are employed, there is no use of extra heat except for drying, CO₂ capturing for such small-scale facilities is not yet economically viable. The carbon efficiency therefore sits at the biochar level only, but here, the feedstock to biochar carbon turnover rate decreases with temperature while persistence increases with temperature. Therefore, there is no significant leverage to increase C-efficiency in TAK. The higher-efficiency trajectories of the C-Sink Standard, namely sequestration of pyrolysis oil or capture of the combustion CO₂, are generally not available to these designs. The realistic improvement for a TAK operation is to use the recovered heat, for example to dry the incoming feedstock. This raises the energy value of the process and is registered as a step forward, but it does not change the indicative carbon efficiency, which counts only carbon preserved in a sink.

Carbon efficiency is the quantitative form of the additionality principle (C-Sink Standard, Section 5.2; see 13.3). Biomass carbon should be preserved as fully as the technology allows, and a higher carbon efficiency means less biomass carbon squandered per ton of registered sink. Reporting it, even without a threshold, keeps this comparison visible to the market.

12.11 Checklist: From TAK batch to registered C-sink

This checklist maps the path in the order it occurs and names the governing document for each step. It is a reference, not an additional requirement; every item is ruled by the TAK Standard or by the cited chapter of the C-Sink Standard.



Step	Governing document
Production (biochar producer)	
Biochar produced and certified under TAK: batch definition, feedstock, emission control, and continuous monitoring	TAK
Feedstock carbon-neutral and additional; activity-shift and market-transformation risk assessed and submitted	C-Sink Ch. 5
Biomass storage emissions assessed where moist biomass is stored beyond one month	C-Sink Ch. 6
Batch dry mass and organic carbon content determined by continuous weighing and daily measurement	TAK; C-Sink 2.1 and 9.2
Persistence analyses requested within the certified batch analysis: H/Corg always, Ro and/or BC_HyPy for the upper class	C-Sink 1.3, 3.5 to 3.7
Production emission portfolio compiled: energy, fuel, and pyrolysis methane, with pro-rata allocation for co-products and the margin of safety	C-Sink 4.2, 4.4, 4.6, 4.7
Fossil-emission reduction plan submitted and updated annually	C-Sink 4.5
Carbon efficiency reported as an indicative value	C-Sink 8.1; TAK 13.10
Packaging units labeled with the identifier linking to the Global Biochar Tool	C-Sink 9.1
Post-gate handling (C-sink owner, processor, trader, dMRV provider)	
Each unit tracked from the factory gate to the final C-sink; transport, ownership changes, and processing emissions recorded	C-Sink Ch. 10
Application conforms to an approved use and matrix; biochar not exceeding 50% of matrix volume unless a matrix exception applies	C-Sink Ch. 12
C-sink geo-localized, or registered as a diffuse C-sink for finely distributed applications	C-Sink Ch. 11
For soil application, landowner or tenant consent to the passage of carbon to geology	C-Sink 11.1
Registration (C-sink owner, VVB, Carbon Standards)	
Full emission portfolio offset before validation	C-Sink Ch. 4 and 13
Project documentation complete: Project Design Document, monitoring, validation, and verification reports	C-Sink 13
C-sink value verified by the VVB and registered in the Global C-Sink Registry	C-Sink 13



13 Labeling and advertising with the TAK trademark

13.1 Trademarks

Carbon Standards owns the following trademark:



13.2 Right to use the TAK trademark

Carbon Standards grants:

- (1) Manufacturers of TAK certified biochar, as well as of products containing TAK certified biochar,
- (2) Traders of TAK certified biochar,
- (3) Manufacturers of pyrolysis systems holding a TAK System Certificate, for the certified technology type only.

the right to use the TAK trademark for the aforementioned goods and services. The TAK trademark may only be used as shown in chapter 13.1. Additions or modifications are not permitted.

The trademark "TAK" (word mark) may only be used alone or with the following additions:

- (1) "Certificate", "Certification", or "certified"
- (2) "real-time monitored"
- (3) "TAK System certified" (only for certified pyrolysis technology)

For more detailed guidelines on the use of the TAK trademark, please refer to the Carbon Standards Design Manual.

13.3 Mandatory information on biochar

In addition to the QR code related to the certified batch, the shipping label for unprocessed TAK biochar must indicate at least the following information about the biochar:

- Organic carbon content (C_{org})
- Dry weight
- Water content
- Volume



All other relevant analytical information, such as feedstock, pyrolysis temperature, H/C_{org} ratio, pH, salt content, elemental analysis, nutrient content, heavy metals, WHC, electric conductivity of the solid biochar, $\Sigma 8$ EFSA and $\Sigma 16$ EPA PAHs, can be found via the QR code of the certified batch. **The QR code of the TAK certified batch must be printed on the packaging and the delivery note.** The analytical parameters of the biochar uploaded by the accredited laboratory can thus be accessed via this QR code.

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 TAK biochar tool of the certified batch must be set up before the packaging units are sold.

13.4 Production date

In addition to the QR code of the biochar batch, the production date must be noted on each packaging unit. For large packaging or storing units whose contents are produced over several days, the production period must be marked. The production date combined with the QR allows the buyer to access the exact carbon content of the respective packaging unit.



14 The TAK System Certificate

The TAK System Certificate attests that a pyrolysis technology, as a design, is capable of meeting the requirements of this standard. It is issued once per technology type, before any installation of that type can be certified, and it is the foundation on which the site-specific certification is built: the system certificate qualifies the technology in general, the Project Design Document (PDD) then applies it to a particular installation. Several requirements of this standard are deliberately not fixed as universal numerical rules, because the appropriate realization depends on the pyrolysis technology; the system certificate is where those technology-dependent requirements are defined for each type.

The system certificate certifies the technology, not the biochar. It does not certify any producer, installation or batch, and it does not entitle the manufacturer or the operator of a certified system to label biochar as TAK certified; it entitles the manufacturer to label the technology as "TAK System certified"

14.1 Scope of the system certificate

The system certificate establishes, for a given technology type, that the design can meet the following requirements, and how it does so:

The gas-handling and combustion geometry (5.1). The system certificate confirms that the combustion chamber is dimensioned and operated to approach a gas residence time of two seconds at 850 °C, and records the design basis on which this is pursued: the chamber geometry, the secondary-air arrangement, and the resulting burnout zone.

The emission measurement and proxy calibration (5.4). The system certificate defines how the CO and CH₄ emissions of the technology are measured, and how the flue-gas temperature and oxygen signals are calibrated against them to serve as the continuous emission proxy. It fixes whether the technology uses an installation-specific calibration, a calibration transferred from an equivalent unit, or conservative default values, together with the associated safety margin.

The weighing architecture and mass safeguards (7.3). The system certificate specifies how the technology weighs its biochar output continuously and online, i.e. load cells for closed batch systems and a tared weigh-bin at the outlet for continuous systems, the accuracy this achieves, and the safeguards against mass not attributable to biochar.

The sampling arrangement for dry matter and carbon (7.4). The system certificate defines how a representative daily sample is drawn from the technology's output for the dry-matter and carbon determinations, including the cross-flow or equivalent method appropriate to the discharge configuration.

14.2 System certificate and PDD

The system certificate operates at the level of the technology type; the PDD operates at the level of the individual installation. The system certificate establishes that a design can meet the standard; the PDD establishes that a specific site, using a certified technology, does so. An



installation cannot be certified under a technology type that holds no system certificate, and a PDD cannot relax a requirement that the system certificate has fixed for the type.

14.3 Issuance and evidence

The TAK Pyrolysis System Certificate is issued by CS, with the Ithaka Institute responsible for the scientific and technical assessment. It is granted on the evidence that the design meets each requirement in scope: the combustion and residence-time basis, the emission measurement and proxy calibration, regularity of production conditions, the weighing and sampling architecture. The evidence may include engineering documentation and calculation, an emission measurement campaign by the Ithaka Institute or an endorsed emission-testing laboratory, and, where required, measurements on a reference installation of the type. Certified technology types are listed on the CS website.

14.4 Label

The manufacturer of a certified technology type may use the designation "TAK System certified" and the corresponding label for that type, in accordance with Chapter 14 (Labeling) and the CS Design Manual. The label may be used only for the certified type and only as long as the certificate is valid.

14.5 Validity and revision

A system certificate remains valid as long as the certified design is unchanged. A material change to the design, to the combustion chamber, the gas handling, the weighing arrangement, or any element affecting emissions, mass balances, or mass determination, requires the certificate to be reviewed and, where necessary, re-issued. This mirrors the recalibration trigger of 5.4: a material change in combustion geometry invalidates the proxy calibration, and the same change invalidates the certificate that rested on it. CS may also review a system certificate when the underlying requirements of the standard are revised.



15 Control, quality management and certification

15.1 Principles of certification

The inspection of the TAK Certificate is coordinated by one of the endorsed inspection and certification bodies (i.e., the VVB). An annual on-site inspection is conducted at each production facility.

The VVB routinely reviews the continuous on-site measurements (i.e., flue gas temperature and oxygen, pyrolysis temperature, production weight, dry mass, C-content) and production records. If there is any indication of non-compliant production practices or deviation from quality protocols, the inspection service will carry out an unannounced on-site inspection. Producers are, therefore, obliged to keep their production records up to date at all times to be prepared for unannounced control visits.

Every year at least 10% of all TAK-certified producers are controlled by unannounced visits in addition to the annual audits.

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

Should a TAK-certified producer produce a batch that cannot be certified under TAK due to non-compliance with the standard, the producer must demonstrate to the VVB either (a) proper management of the non-compliant material in accordance with local or national regulations, or (b) that the non-compliant biochar has been mixed with biomass feedstock and re-pyrolysed.

Only biochar produced by the certified facility itself or purchased from other TAK-certified producers may be stored on the premises and labeled as TAK biochar. If the company produces or trades additional biochar certified under other CS standards (e.g., EBC or Global Artisan C-Sink), the annual audit includes an in-depth product-flow audit covering all certified material on site.

15.2 Registration for certification

To register for certification, please get in contact with Carbon Standards, which will assist you throughout the entire certification process.

Carbon Standards AG

Ackerstrasse 117

5070 Frick

Switzerland

Tel. +41 (0) 62 552 10 90

info@carbon-standards.com



15.3 Technical pre-audit of biochar producers

Every production unit is subject to a technical pre-audit carried out by Carbon Standards. The pyrolysis technology type of the production unit must hold a TAK System Certificate (Chapter 14) before the pre-audit can be completed. The aim of the technical pre-audit is to obtain a detailed understanding of the thermochemical process to identify potential problems for certification and quality management. During the technical pre-audit, the company-specific quality assurance plan — including the sampling method and frequency, the type of retention samples, and the determination of dry weights — is established and, if necessary, adapted to the particularities of the production process.

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.
- The company-specific quality assurance plan, including the sampling method and frequency, the type of retention samples, the determination of dry weights, and the positioning of temperature sensors, is finalized. The Project Design Document (PDD) is concluded on this basis after the pre-audit.

All detailed technical information shared between the production company, the Ithaka Institute (acting on behalf of CS for the scientific evaluation), Carbon Standards, and the VVB is subject to strict confidentiality and protected by applicable data protection law. If desired, a non-disclosure agreement (NDA) can be signed between Carbon Standards and the company to be certified.

Fundamental changes in operational procedures — such as the installation of a new reactor type, feedstock drying, changes to the gas-handling system, or modification of the temperature sensors — must be reported to Carbon Standards and may lead to a repetition of the technical pre-audit. The VVB may also require a new technical pre-audit if operational changes prevent the annual inspection from being carried out in a meaningful way.

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Annex 1

Analytical Methods for TAK-biochar

Basic Package

Descriptions in this annex may deviate from or further specify the listed methods. If no ISO method is applicable to the biochar matrix, the required analytical method is described below the parameter. Corresponding non-ISO methods are listed for reference.

The laboratories endorsed by CS are qualified to perform the following analytical methods. For C-sink certification, additional analyses by random reflectance and/or hydropyrolysis (HyPy) are required; they are described in the Global Biochar C-Sink Standard. The analyses for biochar quality and for C-sink classification can be performed on the same sample in a single run.

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 to a state where it can be milled. The water loss is measured. After drying and homogenization, the sample is divided into subsamples. 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. After homogenization, the milled material is subsampled for further analysis (i.e., PAH, ash, CHNOS, trace and major elements, and conductivity). Unless otherwise specified, the particle size of the analytical samples is specified by the respective methods and standards. To avoid metal contaminations from the mill, non-abrasive mills without Chromium and Nickel must be used for diminution.

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 weighing. 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 (ISO 17828, DIN EN ISO 17828):

Only for particle sizes between 3 mm and 30 mm. The sample is analyzed as delivered, not dried, not milled. Procedures as described above for Bulk density for ground particles.

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 ISO 11265, 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 ISO 10390 (CaCl₂), 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 ± 2) ° 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 < 3 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 BaCl_2 and NaOH solution, 30 ml decomposition acid (hydrochloric acid with HgCl_2 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 CO_2 .

CHN according to ISO 29541, DIN 51732:

The sample is combusted in a stream of pure oxygen. Resulting CO_2 , H_2O 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 ($> 1300^\circ\text{C}$), the sulfur is oxidized in an oxygen stream with the aid of a V205 catalyst layer (following the Dumas method). The resulting SO_2 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 (CO_2) 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 ISO 12846, EN-ISO 12856, DIN 22022-1, DIN 22022-7, DIN EN ISO 17294-2 / DIN EN 1483:

(Pb, Cd, Cu, Ni, Hg, Zn, Cr, B, Mn, As, Se, 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-C) in % of dry matter of biochar.

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

Water-holding capacity. This can be measured using the method DIN EN ISO14238, 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:

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

$$LF = \frac{1}{\Omega_{specific} * 1000}$$

$\Omega_{specific}$ = 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 (<https://zenodo.org/records/8197758>). Eurofins sells the necessary measuring equipment. An ISO standard for this measurement method is currently being attempted.

Annex 2

Additional Parameters

Producers are not required to obtain the additional parameters of Annex 2 for TAK certification; however, these parameters offer valuable data for further biochar characterization.

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.

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

VDLUF A 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 ground into powder (<1 mm) and dried at a maximum of 40 ° 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 ground into powder (<1 mm) and dried at a maximum of 40 ° 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 ISO 9277, DIN ISO 9277 (BET):

The samples must be dried at 40°C and milled to a particle size < 3 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) according to 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 according to 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 3

A4.1 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 ten days of production according to the following exact methodology. An incremental cross-stream sampling guarantees the most representative sampling of the product. If that is not implemented, the following procedures can be used:

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 VVB.

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 VVB.

C. Homogenizing and dividing of the sample

The mixed sample of 24 x 3 liters = 72 liters can either be sent directly to the accredited 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 than to be homogenized thoroughly by turning and piling it 3 times upside-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 accredited laboratory have to be labeled with the QR code generated in the CS Biochar Tool.

The expected uncertainties in regard to accuracy and precision were described in detail by Bucheli et al. (Thomas D. Bucheli et al., 2014) and will be taken into account by CS when evaluating the results. The aim of the prescribed sampling method is to achieve a well-characterized cross-sectional sample.



Annex 4

For the exact description of the methodology and procedures that applies to in-house analysis of DM, C content, and SEC, please refer to [Annex 4](#).