Global Artisan C-Sink

Standard for Carbon Sink Certification for artisan biochar production

Developed by the Ithaka Institute for Carbon Strategies, 2024 - version 2.1A (15th June 2024)

The present standard is valid as of 15th June 2024. For already certified companies, a transition period until 31st December 2024 is applicable.

The geographical scope of the Global Artisan C-Sink is limited to Low-Income, Lower Middle Income and Higher Middle Income countries as defined by the World Bank classification of countries"

Abstract

To limit climate change, the carbon dioxide removal (CDR) from the atmosphere and storage of the extracted carbon is indispensable. Most negative emission technologies (NET), especially those that can be implemented rapidly at relevant scales, use plant photosynthesis to perform CDR. The CDR capacity of plants is highest under tropical and subtropical climates. Therefore, tropical agriculture must play a major role in achieving the removal and sequestration of at least 800 billion tons of CO_2eq by the end of the century, which is necessary to achieve the goals defined in the Paris Treaty. As smallholder farmers cultivate most tropical agricultural land, the certification of carbon sinks, i.e., the accumulation and storage of carbon in soil and biomass, must be organized in a generic and decentralized manner. Such carbon sinks may include temporary C-sinks (i.e., shade trees, soil organic carbon, biomass materials) or long-term persistent sinks (i.e., biochar produced from agroforestry residues).

The climate services provided through the establishment and maintenance of carbon sinks by smallholder farmers will have to be bundled into marketable products (i.e., global cooling services, CO_2 and CH_4 offsets), generating additional income for farmers and creating economic incentives for the upcoming carbon sink economy. Stringent monitoring, reporting, and verification (MRV) are needed to create trustworthy carbon sinks on smallholder farms, but also on larger estates, within farmers cooperatives, on public land, and in biomass processing industries. The C-sinks and the emissions caused by establishing the C-sinks must be transparently accounted for, controlled, and inscribed in the Global C-Sink Registry. The present Global Artisan C-Sink guidelines define how to certify biochar made in an artisanal way with endorsed low-tech pyrolysis. The guidelines regulate the (1) control procedures for sourcing biochar feedstock, (2) the training and exams for Artisan Biochar Producers, (3) the monitoring of biochar production, (4) the tracking of its applications, (5) the use of smartphone-based monitoring, and (6) C-sink registration.

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Glossary

The Global Artisan C-Sink certification system consists of the following five-party structure.

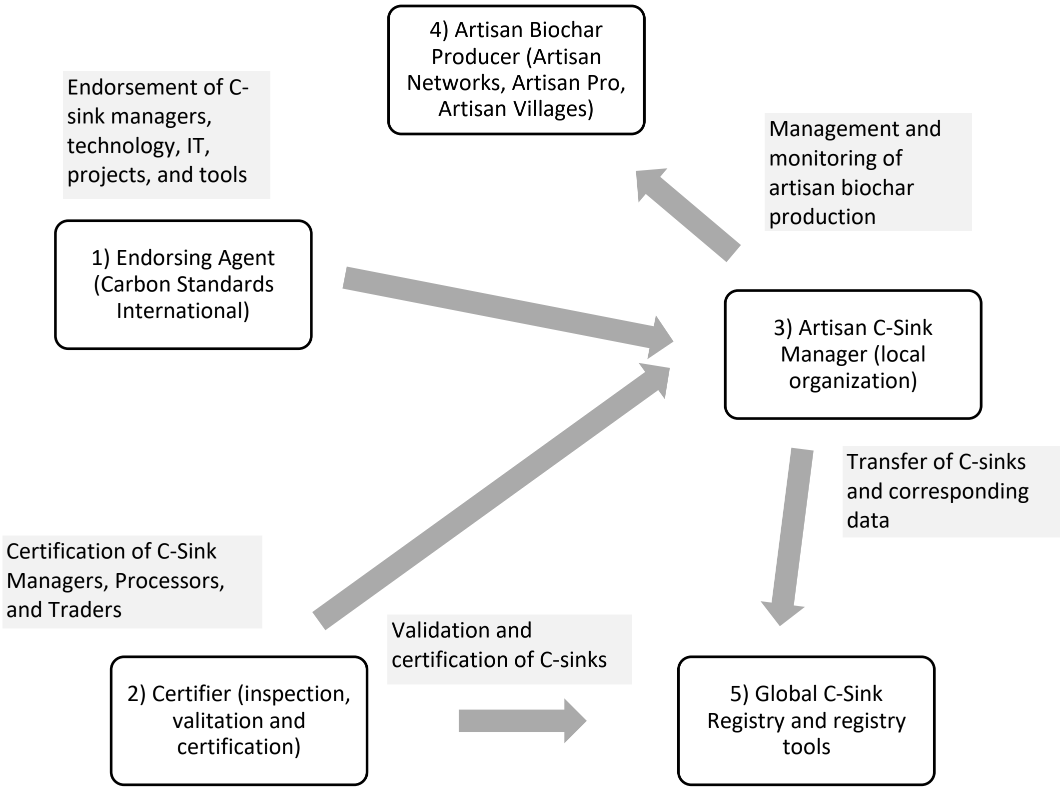

Figure 1: *The Global Artisan Biochar C-Sink is organized as a five-party structure. 1) The Endorsing Agent (Carbon Standards International), 2) The Certifier who is the inspection, validation and certification body, 3) The C-Sink Manager (in-country organization), 4) The Artisan Biochar Producers with C-Sink Networks, Artisan Pro, and C-Sink Villages, 5) The Global C-Sink Registry where all certified C-sinks are registered.*

Artisan App	A smartphone application endorsed by Carbon Standards, which enables the monitoring and collection of all data required for C-Sink certification.
Artisan Biochar Producer	An Artisan Biochar Producer prepares and controls the biomass feedstock and produces biochar manually using a Carbon Standards endorsed low-technology kiln. The Artisan Biochar Producer received qualified training in the craft of biochar production and succeeded in a final examen. The Artisan Biochar Producer can be a C-Sink Farmer or work within an Artisan Pro structure.
Artisan C-Sink Manager	The Artisan C-Sink Manager is an organization firmly anchored in the respective region and officially registered as a company or organization in the country of activity. They (1) organize the trainings and examens

	for the Artisan Biochar Producer, (2) monitor and control the biochar production of C-Sink Networks, C-Sink Villages, and Artisan Pro entities, (3) verify the quality and quantities of produced and traded biochar (4) track and verify the application of biochar; (5) prepare all data for the Global C-Sink Registry, (6) may trade registered global cooling services and GHG-offsets, (7) are responsible for equitable farmer payments, and (8) pay income taxes in the country of activity. The Artisan C-Sink Manager is controlled onsite and certified by the contracted Certifier. A company that acts as Artisan C-Sink Manager can become Artisan C-Sink Manager in several regions and countries but must be certified for each individual country.
Artisan Pro	Artisan Pro is a certification class for companies, cooperatives, or any other entity producing > 100 m^3 of biochar per year using diverse biomass feedstock not necessarily produced on the same farm where the biochar will be applied. The maximum production amount per year still covered under the Artisan Pro certification is 1500 m^3 of biochar.
Biochar Processor	A company or organization that collects, processes, trades, applies, and registers buys or collects biochar from C-Sink Cooks or Artisan Pro to create biochar substrates or products that eventually become C-Sink Units to be registered.
Biochar Trader	A Biochar Trader buys biochar from C-Sink Farmers, C-Sink Networks, C-Sink Cooks, C-Sink Villages, and/or Artisan Pro producers. They might process the biochar into biochar-based products and sell those or the pure biochar to farmers or industries (e.g., for construction materials). The traders must be certified under Global Artisan and are not allowed to trade biochar that is not certified under Global Artisan. C-sinks can only be certified when a full tracking to the C-sink matrix is provided.
C-Sink_100	Annual average amount of biochar carbon sequestered over 100 years. For each year, the stored biochar carbon is evaluated. These annual carbon values from year 0 through 99 are summed and then divided by 100 years to obtain the metric C-Sink_100, expressed in tons of annual CO_2e (t aCO_2e).
C-Sink Cook	A person or a family using TLUD stoves for cooking that produce biochar during the cooking process.

C-Sink Farmer	A C-Sink Farmer produces biochar from feedstock of his farm and applies the biochar as biochar-based fertilizer on his farm. He participates in a C-Sink Network with other farmers in his region and is certified as part of the C-Sink Network. The maximum annual biochar production is 100 m^3. If he produces more he must be certified as Artisan Pro.
C-Sink Matrix	Organic or mineral substrates to which biochar is mixed at a ratio below 1:1 (vol) and which excludes that the biochar may burn unintendedly or might be recovered to be used in a way that the carbon oxidizes to CO_2. Find the C-Sink Matrix list here: https://www.carbon-standards.com/en/standards/service-505~global-artisan-c-sink.html
C-Sink Network	A C-Sink Network unites up to 1000 C-Sink Farmers managing land within a diameter of less than 50 km. Every participating C-Sink Farmer produces less than 100 m^3 biochar per year.
C-Sink Unit	A C-Sink Unit is the registered amount of geo-localized biochar C-sinks of the same controlled quality. For a C-Sink Network, the C-Sink Unit can comprise the monthly biochar-carbon production that was applied to the farm soils of the C-Sink Network under controlled conditions. For Artisan Pro a C-Sink Unit can comprise biochar from a same production batch that was applied during a maximum of one year to a geo-localized field or marketed as diffuse C-sink. For C-Sink Villages, the C-Sink Unit comprises the biochar that was produced by the C-Sink Cooks of the respective C-Sink Village collected and processed by a Biochar Processor for a maximum of one year and either marketed as a diffuse C-sink or applied geo-localized. The minimum size of a C-Sink Unit is 1 t CO_2e.
C-Sink Village	The grouping of more than 50 families from a same area producing biochar while cooking with TLUD stoves.
Certified Emission Reduction (CER)	Certified Emission Reduction (CER) units are credits issued by the Clean Development Mechanism (CDM) for emission reductions in developing countries, which can be traded and sold, and used by industrialized countries to meet a part of their emission reduction targets under the Kyoto Protocol.
Certifier	The Certifier is a Carbon Standards endorsed third party inspection and certification body. The Certifier (1) verifies on a regular basis the

	correctness and effectiveness of the Artisan C-Sink Manager's training and monitoring duties, (2) certifies the Artisan C-Sink Manager, (3) executes onsite and remote inspections, (4) certifies Artisan Biochar Producers, Biochar Processors, Biochar Traders, and C-Sink Traders. The certifier is accredited in accordance with ISO 17065:2012 or is in the process of accreditation. In the present standard, the Certifier is synonym with the Validation & Verification Body.
Diffuse C-Sink	Biochar C-sinks containing less than 1 t CO_2e where the biochar was mixed to a C-Sink Matrix preventing the oxidation of biochar.
Endorsing Agent	Carbon Standards International is in the role of Endorsing Agent. Carbon Standards (1) conducts trainings for the Artisan C-Sink Manager, (2) endorses the Artisan C-Sink Manager, (3) endorses tools and methods used by the Artisan C-Sink Manager, (4) verifies the reporting by the Artisan C-Sink Manager and the Certifier, (5) conducts trainings for the Certifier, (6) endorses the Certifier, (7) endorses the laboratories. Carbon Standards may (8) provide software for on-site control, tracking, certification, and registry of the produced biochar and C-sinks.
Kon-Tiki	Kon-Tiki is a generic name for all types of flame curtain or flame cap pyrolysis that are used by farmers worldwide. There is no restriction to metal kilns nor to the shape of it, it solely covers the principle of artisan biochar making using a flame curtain to protect the pyrolysis zone from combustion. The Kon-Tiki is not a brand name but the name for a method to produce biochar on-farm that is used in uncountable languages and facilitates farmer communication on a global scale.
Load	A load or production load is the production amount of one Kon-Tiki or one TLUD (from initial ignition to final quenching of one run).
Methane Offset	A temporary carbon sink (i.e., with a persistence of at least 20 years) that has the same global cooling effect during the 20 years as the global warming effect of the methane emission.
Negative Emission Technology (NET)	Negative Emission Technologies (NETs) are techniques that remove more carbon dioxide from the atmosphere than they emit, thereby reducing the overall concentration of CO_2 to mitigate the effects of climate change.
PAC Fraction	The persistent aromatic carbon (PAC) fraction of biochar is defined as the biochar carbon that persists longer than 1000 years in soil, it

	corresponds to portion of biochar carbon bound in clusters of more than seven aromatic rings as analyzed by the hydro pyrolysis method.
Persistence	Is the time that a defined fraction of biochar is stable in the environment or in the matrix to which the biochar was applied and does not degrade or decay. Sometimes also called: “durability”.
Region	A certification region is a defined region of a country or an entire country but cannot cover more than one country.
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. At least 50% of the SPC fraction still remains after 50 years in the registered soil C-sink.
Standard Developer, Standard Owner & Standard Manager	The Global Artisan C-Sink standard was developed and is continuously updated by the Ithaka Institute. The Global Artisan C-Sink standard is owned by Carbon Standards and can only be used under a licensing agreement. Carbon Standards is the Standard Manager coordinating the entire licensing and endorsement process.
Global C-Sink Registry	The Global C-Sink Registry contains the physical location of each C-sink, the year of the carbon removal, the date of application, applied amount of carbon, the carbon persistence, and the C-sink owner.
TLUD	A Top-Lit-Up-Draft stove (i.e., a micro-gasifier) that uses pyrolysis and gasification methods to transform biomass into cooking gas and biochar producing less GHG and particulate emissions than traditional cooking over fire.
Verified Emission Reduction (VER)	Verified Emission Reduction (VER) is a carbon offset representing a reduction of one metric ton of CO_2 emissions, which is independently verified against a recognized standard but not certified under an international convention like the Kyoto Protocol.

1. Introduction

Since 2020, carbon sinks created by industrial production of biochar and its subsequent application in agriculture or durable materials can be certified according to the Global Biochar C-Sink standard (former EBC C-Sink) to create tradeable climate services (Schmidt et al., 2020). The underlying requirements, e.g., the tracking of the biomass from its source to the pyrolysis plant or of the biochar from the production site to its final application site, have been adapted to the situation in Europe. Here, biochar is mainly produced by biomass recyclers, municipalities, and industries with large heat demand. The biochar is partly processed by specialized manufacturers and/or is distributed via the agricultural wholesale trade throughout Europe. Moreover, Global Biochar C-Sink requires the EBC or WBC certification of the pyrolysis plant to guarantee the sustainability of both biomass sourcing and the pyrolysis process, compliance of biochar properties with relevant regulations, and the availability of precise and load-specific data on biochar characteristics like carbon content and hydrogen to carbon ratio, which requires representative sampling and recurring analysis in endorsed laboratories.

High investment and maintenance costs of industrial pyrolysis plants and low profitability in markets with low prices for thermal energy and biochar explain why no such industrial biochar production facilities exist in most tropical countries yet. However, biochar can also be produced with low-cost methods, e.g., in Kon-Tiki type kilns or TLUD stoves (Chapter 3). Here, the biochar is produced manually, e.g., from farm residues like straw, leaves, kernels, husks, pruning wood, or shade tree biomass. The process is less controlled than in industrial facilities and not mechanized, but when done correctly, the resulting biochar is of high quality, and emissions tend to be low compared to biomass decay or uncontrolled combustion. (Cornelissen et al., 2023; Gerard Cornelissen et al., 2016; Karananidi et al., 2020; Smebye et al., 2017). Such low-tech artisanal biochar can be certified as a carbon sink under the following conditions:

1. The biomass was procured sustainably, e.g., farm residues, derived from biomass processing waste streams, or disaster debris but no forest wood except for C-sink cooking (Chapter 6).
2. It was dried and/or aerated to avoid decomposition during storage and subsequent greenhouse gas emissions during pyrolysis (Chapter 8).
3. The pyrolysis was done with care by trained artisans to reduce the formation of non-CO_2-greenhouse gas emissions during pyrolysis to a minimum (Chapter 4 and Chapter 5)
8. The methane emissions caused during production are offset through equivalent emission avoidance, certified tree plantations, or other certified temporary carbon sinks (Chapter 14).
    9. The biochar was applied to the soil or C-sink eligible materials and not burnt or sold for burning (Chapter 7).
    10. The carbon sink was registered in the Global C-Sink Registry (Chapter 10).

11. The artisan members of a C-Sink Network or Carbon Village are paid directly for the climate service, and the amount the artisans and cooks receive is transparently communicated.
12. The country where the biochar was produced counts among the Low-Income, Lower Middle Income, and Higher Middle-Income countries as defined by the World Bank classification of countries (https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html)

If proven that the above principles and conditions are met, the biochar carbon sink and its climate service can be assessed, certified, and traded as an asset.

2. Definition of Biochar Artisan, C-Sink Farmer, C-Sink Cook, Artisan Pro, and Artisan C-Sink Manager

The Artisan Biochar Producer (i.e., the Artisan) prepares and controls the biomass feedstock and produces biochar manually. The Artisan Biochar Producer himself or an internal auditor appointed by the Artisan C-Sink Manager documents feedstock provision, biochar production, and its application via a smartphone app.

The Artisan selects the feedstock, prepares the correct feedstock sizes, and controls feedstock humidity. The pyrolysis kiln or TLUD stove is fed manually. The Artisan controls the biochar-making process, maintains the pyrolysis temperature, avoids the evolution of smoke, and proceeds with the quenching and post-pyrolysis treatments. The Artisan or a dedicated auditor registers all necessary data and images into the Carbon Standards' endorsed artisan App.

Artisan production is further defined by the fact that the biomass feedstock used for biochar production is either crop residues from a farm (e.g., straw, pruning, leaves, empty fruit bunches, shells, etc.), dedicated biomass production sites (e.g., bamboo plantation), biomass feedstock from fallow crop rotations, natural disaster biomass (e.g., after a tornado), or residues from crop processing (e.g., nut shells, coffee parchments, sawdust, pomace, etc.). C-Sink Cooks may also use forestry biomass.

Artisanal produced biochar is preferentially used on the farm or in the garden from where the biomass feedstock originated. When direct application is not feasible or useful, the biochar or biochar-based materials may be collected for selling. If the biochar is applied and sold outside of the farm or garden, the intermediary who collects, processes, and trades the biochar must be certified as a biochar processor and/or trader to track the biochar with an App to the eventual carbon sink site or have it registered as diffuse C-sink.

An Artisan C-Sink Manager is a company or organization (e.g., NGO, non-for-profit foundation, farmer association) which is managing Artisan Biochar Producer, C-Sink Networks, Artisan Pros, and C-Sink Villages. The Artisan C-Sink Manager is legally registered in the specific country where he manages artisan operations. The Artisan C-Sink Manager pays income taxes in the country of its artisan activities and is the legal entity guaranteeing that the property rights of C-sink owners are respected.

If an Artisan C-Sink Manager is an international organization or company that is active with Artisan C-Sink projects in several countries, the Artisan C-Sink Manager must register a subcontractor or subsidiary company as full legal entity in each country of its Artisan C-Sink activities.

Artisan C-Sink Manager can coordinate several C-Sink Networks, C-Sink Villages, and Artisan Pro producers.

The biochar application must be documented with georeferenced photos. This is no longer necessary if the biochar is already incorporated into a non-combustible matrix like compost, liquid fertilizer, digestate, or manure (except where manure is dried for fuel use) and documented as diffuse C-sink. If untreated biochar (i.e., biochar that still could be dried and burned) is sold as biochar fertilizer on the market and the Biochar Trader does not document the biochar application, the C-sink cannot be certified.

An artisan is an artisan if he/she excels in his/her craft which means he/she prepares the biomass, pyrolyzes it, and applies, stores, or sells the biochar. We consider that an artisan can produce at maximum 5 m^3 biochar per day on 300 days per year which adds to a maximum of 1500 m^3 of biochar per year. Exceeding the production of 1500 m^3 biochar per year, the production reaches an industrial scale, and more professional production equipment should be considered.

Within this regulatory framework, the Global Artisan C-Sink distinguishes the following options for artisanal biochar production:

(1) C-Sink Farmer & Artisan Network: The C-Sink Farmer is an Artisan Biochar Producer who produces up to 100 m^3 of biochar per year from residues of her/his farm and applies this biochar back to his/her soil. Exceptionally, biomass from neighboring farms or debris can be used, and biochar can be sold to other farmers when correctly tracked. C-Sink Farmers are grouped in Artisan Networks with a maximum of 1000 participating farmers managed by an Artisan C-Sink Manager. The total annual C-sink production of an Artisan Network may a C-Sink Unit to be registered in the Global C-Sink Registry (Fig 2).

A group of more than 1,000 farmers would be hardly manageable in the internal control system. An Artisan C-Sink Network with 1,000 farmers, each producing 100 m^3, would produce a total of approximately 20,000 t biochar per year, which is significantly more than most fully EBC-certified industrial companies. For this reason, we do not expect to raise this limit of participants per Artisan C-Sink Network any time soon. The Certifier must inspect annually the Artisan C-Sink Manager.

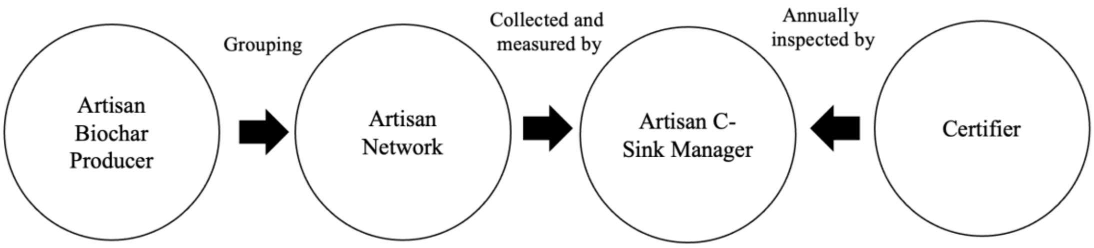

Figure 1. The diagram of Artisan Network

(2) C-Sink Cook, C-Sink Village, and Biochar Processor: The C-Sink Cook is usually a family or household that uses one or several TLUD pyrolysis stoves for cooking, producing an average 30 kg (DW) of biochar per month. Well-trained TLUD cooks using dried woody feedstock produce biochar qualities that meet WBC-Agro certification standards. The Biochar Processor collects, controls, and measures the biochar every few weeks. The biochar is usually delivered to a central processing location where it is mixed with a C-sink matrix and transformed into biochar-based fertilizer or other biochar-based materials. C-Sink Cooks are grouped in C-Sink Villages that may contain as many C-Sink Cooks that live within a radius of 10 km. Preferably, the biochar is applied as biochar-based fertilizer in the gardens and farms of the C-Sink Village, although, in most cases the biochar is collected by a Artisan Biochar Processor who trades biochar-based products in- and outside the C-Sink Village.

The Certifier must inspect annually the biochar processor on-site and randomly select at least 1% of the C-Sink Cooks to control during the annual inspection visit. The application of the biochar products prepared by the Artisan Biochar Processor need site-specific monitoring and on-site inspection.

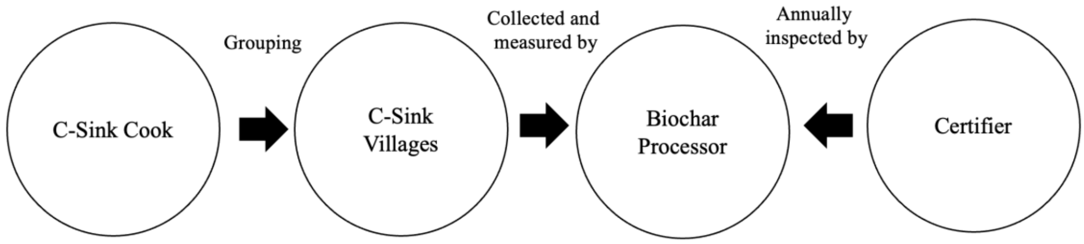

Figure 2. The diagram of C-Sink Cook and Biochar Processor

(3) An Artisan Pro is a registered company or part of a registered company. An Artisan Pro may have several production units and artisans that run these.

Artisan Pro biochar is professionally produced using all sorts of eligible biomass found within a radius of 30 km from the production site. Artisan Pro biochar is not necessarily applied back to the fields where the biomass was grown but is mostly traded to other farms and industries. Artisan Pro biochar is produced at a registered production site with registered production equipment. It can be produced by several trained Artisan Biochar Producers (i.e., employees of the certified company), though they work at the same site with the same equipment. The maximum annual biochar production still considered artisanal is 1500 m^3 per year. The production of larger amounts requires World Biochar Certification (WBC) or an exemption approval as outline below.

Artisan Pro production sites and entities cannot be certified under the simplified certification procedure for C-Sink Farmers but need site-specific monitoring and verification through regular, at least annual on-site inspections. The annual production of an Artisan Pro producer using the same feedstock class may be considered to be of the same quality and is entitled to be used as uniform biochar for the establishment of C-Sink Units to be registered in the Global C-Sink Registry.

Artisan Pro companies need to estimate their annual production. If they expect to produce more than 1500 m^3 of biochar per year, the Artisan C-Sink Manager must submit to Carbon Standards a justification, why no industrial pyrolysis plant (burning pyrolysis gases under controlled and monitored conditions with heat usage or electricity production or pyrolysis oil recovery) can be installed yet. This must include a timeline for the development towards industrialization of the biochar production. The Artisan C-Sink Manager must also explain why the certification as Artisan Pro instead of under the WBC standard is still preferred. Carbon Standards must approve the justification and explanation. The approval may include deadlines for re-evaluation.

The Certifier must inspect each Artisan Pro at least once a year at the production site.

Artisan C-Sink Managers are inspected on-site at least once a year by the Certifier.

3. Basic Principles of Certification

The basic principles of certification are the same as for the Global Biochar C-Sink guidelines (2023) that are applied to industrial biochar production:

- All emissions occurring due to biomass sourcing, biochar production and application must be accounted and need to be adequately offset by registered carbon sinks.
  - In the case of methane emissions, the increase of standing biomass and the avoidance of methane emission from crop residue burning or decomposition may be used for offsetting. Also, the SPC-fraction of the artisanal biochar C-sink maybe used for offsetting.
  - Other emissions need to be converted into CO_2e and must be offset by registered persistent (geological) carbon sinks (e.g., by the PAC fraction of biochar with a persistence > 1000 years).
- The production of biochar and the establishment of the final, physical C-sink must be monitored and verified by the Artisan C-Sink Manager. The Artisan C-Sink Manager must follow the present standard and be certified through the Certifier.

Creating biochar-based C-sinks is a negative emission technology (NET). It is not considered a certified emission reduction (CER) or verified emission reduction (VER). However, the production and application of biochar can lead to significant emission reductions (e.g., reduction of methane emissions from rice fields or from the uncontrolled decomposition of farm residues, nitrous oxide emissions from fertilizer applications). Those emission reductions are not accounted for in the present C-sink assessment. The individual Artisan Biochar Producer or the Artisan C-Sink Manager may take advantage and monetize these co-benefits of biochar production and application when scientific evidence and/or suitable controlling is available for the specific case, but not under the umbrella of the Global Artisan C-Sink standard. However, if the monetization of these co-benefits is done negligently and without sufficient evidence, the Certifier may withdraw or restrain the Global Artisan C-sink certification.

Producers under the Global Artisan C-Sink must not seek additional third-party certification for other forms of C-sink and CDR occurring on the same land area registered for Artisan C-Sinks (c.f., Chapter 19).

4. Eligible Technology

While industrial biochar making is quickly picking up in some countries (mainly in North America, Middle and Northern Europe, and Australia), most of the biochar used worldwide is made using flame curtain pyrolysis, i.e., in Kon-Tiki type pyrolysis kilns. The Kon-Tiki flame curtain pyrolysis combines the simplicity of the traditional kiln with sufficient combustion of pyrolysis gases and avoids the need for external fuel.

4.1. Flame Curtain Pyrolysis (the Kon-Tiki method)

The Kon-Tiki was established in 2014 by the Ithaka Institute in Switzerland and spread rapidly by open-source technology transfer to farmers all over the world. However, the Ithaka Institute did not invent flame curtain pyrolysis (i.e., the Kon-Tiki), which is a simple method that ancient people most probably used already thousands of years ago. Also, Kelpie Wilson had presented on her most valuable Backyard Biochar website (https://wilsonbiochar.com/) examples of the Japanese Moki-Kiln, the Australian Moxham Kiln, Kelpie Wilson's own Pyramid Kiln, and new cone and pyramid designs by Michael Wittman, Gary Gilmore, Josiah Hunt, and others before Ithaka’s open access promotion and scientific investigation of flame curtain pyrolysis under the generic name of Kon-Tiki (Schmidt and Taylor, 2014). Other names like ring of fire, trough kiln, or fire cap are also commonly used.

One run of a 2 m^3 conical flame curtain kiln with an upper diameter of 2.4 m produces 500 kg of biochar (dry matter basis) and close to 2 MWh of heat from shrubs, husks, straw, pruning and other organic farm waste in about three hours needing one worker to maintain and control the process. The cost per kiln varies with design, construction material and country but is within a range of 30 € (soil pit shield) to 5,000 €. The cheapest way is a mere conically shaped soil pit which would essentially be for free.

The principle of flame curtain pyrolysis consists of pyrolyzing biomass layer by layer in a conically-, polygonal-, rectangular-, or cylindrical-formed metal, concrete, or soil kiln. A fire is started in the kiln, and the embers spread to form a first layer on the bottom of the kiln. A thin layer of biomass is then added on top of the embers, heats quickly and starts outgassing. The rising pyrolysis gas is caught in the flame curtain and reacts with combustion air entering the kiln from the top. When ash appears on the outside of the carbonizing biomass, the next layer of biomass is homogenously spread on top. Convective and radiant energy from the flames above and from the hot pyrolyzing layers below heat up the fresh biomass layer, which starts to pyrolyze (Schmidt et al., 2015).

The biochar below the upper pyrolysis layer is shielded from oxygen access by the fire curtain itself. The combustion zone thus forms a flame curtain that protects the underlying biochar from oxidizing and cleanly burns all pyrolysis smoke and gases as they pass through this hot fire front. It is important to spread each new biomass layer at the right time and rate determined by monitoring the flame, smoke, and ash formation. Too much feedstock will smother the flame (producing smoke and gas emissions), and too little feedstock will not maintain a full curtain of flame to protect the biochar from oxidizing (forming ash) and to completely combust the pyrolysis gases (avoiding smoke). The manual layering of biomass is repeated until the metal kiln or soil pit is filled. The pyrolysis process is then actively ended by quenching with water or a nutrient solution (e.g., diluted urine, dissolved fertilizer) which is fed into the kiln from below if possible or, where water is not easily available, by snuffing with a layer of soil.

The temperature in the main pyrolysis zone just below the flame curtain is 680°C to 750°C (Schmidt and Taylor, 2014) and cools down slowly below the main pyrolysis zone when new feedstock layers are added to 150–450°C depending on the duration of a production load before final quenching. When snuffed with a metal lid and soil, biochar temperature may be maintained at above 400°C for more than 24h depending how tight the snuffing layer and kiln are (Gerard Cornelissen et al., 2016).

There is no restriction to the size of the kiln. Small backyard kilns with a volume of less than 100 liters or giant 15 m^3 kilns can all make high quality biochar if the artisan biochar maker knows his/her trade.

The Kon-Tiki type pyrolysis is well investigated today (Bursztyn Fuentes et al., 2020; Cornelissen et al., 2023; Dahal et al., 2021; Flesch et al., 2019; Kalderis et al., 2020; Karananidi et al., 2020; Kiong Kong and Sing Sii, 2019) in regard to biochar quality, organic contaminants, and emissions.

4.2. Pyrolysis Cook Stoves (TLUD micro gasifier)

Traditional open-fire cooking is associated with low feedstock efficiency, high greenhouse gas (GHG) emissions per meal, and adverse health effects, particularly among women and children. TLUD stoves offer a more environmentally friendly alternative by pyrolyzing dried, mostly woody feedstock and utilizing the resulting pyrolysis gas for cooking. This method is significantly cleaner than using a simple wood fire or wood-burning stoves is more feedstock efficient (Adeniyi et al., 2023; Birzer et al., 2014; Obi et al., 2016), and still produce some biochar with every run.

The biochar production process in TLUD stoves differs from flame curtain pyrolysis. In a TLUD stove, biomass is loaded into a predominantly cylindrical container and ignited at the top. Only in this initial phase, the feedstock is heated by the reflective heat of the stove flame, which results from the interaction of pyrolysis gas and secondary air. As the process continues, the pyrolysis front gradually moves downward through the biomass feedstock. The exothermic pyrolysis and the reaction between pyrolysis gas and primary air, funneled through the feedstock cylinder, provide the necessary heat for the process. At this stage, the TLUD stove functions more like a gasifier than a pyrolizer.

An important commonality between TLUD and the Kon-Tiki method is that both require pyrolysis gases to pass through a fire front before being released into the atmosphere. This crucial feature significantly reduces non-CO2 emissions, as demonstrated by Adeniyi et al. (2023). One of the best and most comprehensive description of the TLUD principles and many aspects of its use can be found on the dedicated website of Paul Anderson: https://www.drtlud.com/.

The quality of biochar and the emissions from TLUD stoves are on par with those of the Kon-Tiki. As for the Kon-Tiki, the main risk for higher GHG emissions and lower biochar quality is associated with using too wet and/or too dense energy poor feedstock. Consequently, C-Sink Cook training must place its central emphasis on efficiently organizing and managing feedstock logistics to mitigate these risks.

Nonetheless, there are notable variations across different TLUD models. Consequently, each specific TLUD model must receive endorsement from Carbon Standards. An impartial entity is required to measure emissions across a minimum of three runs, using feedstock with varying moisture content. The biochar quality must be analyzed in an EBC/WBC-endorsed laboratory and meet at least the WBC-Agro certification class.

4.3. Requirements for other Pyrolysis Technologies

Other low-tech devices to produce biochar exist but are less well investigated regarding emission data, biochar characterization, and consistency of biochar quality using various feedstock. Often, pyrolysis gases are released in such devices without proper combustion into the atmosphere (Kajina et al., 2019), causing significant GHG emissions. When using such technologies, the total amount of greenhouse gases outweighs the C-sink potential of the resulting biochar.

The present standard does not exclude any particular (low) technology but requires that the pyrolysis gases pass a fire front or combustion chamber before being emitted into the atmosphere. Biochar from traditional charcoal piles and retorts where pyrolysis gases are released not passing a combustion zone cannot be certified under the present method. For giant TLUDs and retorts with gas combustion or other non-mentioned types of pyrolysis equipment, an application must be submitted to Carbon Standards, including biochar analysis from an EBC/WBC endorsed lab and accredited emission analysis including CH_4 emissions following national or international standards.

The Kon-Tiki type production of biochar is considered a bridge technology towards more carbon efficient and lower emission technologies. While High-Income industrial countries should have already today the financial means to invest in higher tech low emission pyrolysis plants of scale, farmers in lower-income countries do simply not have the means of investing in such large-scale pyrolysis plants and corresponding biomass collection and logistics. While Kon-Tiki and TLUD stove-type pyrolysis are less C-efficient, but has an overall positive short- and long-term climate effect when the pyrolysis is properly run (see next Chapter) and coupled with active methane compensation (c.f., Chapter 14. Methane emissions. It is a bridge towards higher efficiency devices but with a large positive effect already today, and is, therefore, acknowledged and certified as negative emission technology. However, the C-Sink certification for biochar made with Kon-Tiki and TLUD stove-type pyrolysis is limited to Low-Income, Lower Middle Income and Higher Middle Income countries as defined by the World Bank classification of countries (https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html) to incentivize High Income countries to invest into pyrolysis development and industrial production of pyrolysis plants.

5. Production of Biochar, Training of the Artisan Biochar Producers, and Exams

Flame curtain pyrolysis (Kon-Tiki) and TLUD stoves can cleanly burn the pyrolysis gases so that no or little smoke arises, particulate matter emissions remain low, and the emission of methane stays lower compared to other low-tech pyrolysis or combustion methods (Adeniyi et al., 2023; Gerard Cornelissen et al., 2016). Yet, the environmental impact of this method is highly dependent on the skills of the artisan and drying of the feedstock (Cornelissen et al., 2023). Proper training of the Artisan is crucial. It is, therefore, not the Kon-Tiki or TLUD technology as such that can be certified but only the combination of the technology and the executing artisan.

The Artisan C-Sink Manager must prove how the Artisan Biochar Producers were qualified to produce high-quality biochar with low emissions. The Artisan Biochar Producer must follow a biochar production training given by a qualified trainer and prove their proficiency in an exam. The training must include principles of feedstock selection and biomass drying (chapter 8), the biochar kiln operation principles, the volume measurement of the produced biochar, a biochar sampling procedure, and the proficient use of the Artisan smartphone app.

Producer training and verification of the producer's competence is an essential part of the Artisan C-Sink Manager's duties.

The training for C-Sink Networks must cover the post-pyrolytic treatment to refine the biochar for material and agronomic uses. The preparation and application of biochar-based fertilization should be taught and demonstrated in the training.

The training for C-Sink Cooks focuses mainly on feedstock preparation and storage, the handling of the stove, the quenching, and the storage of the biochar. A certified examen of the individual C-Sink Cooks is not required.

All C-Sink Cooks must equally be registered by their C-Sink Manager and C-Sink Cooks must participate in a TLUD training. However, there is no need for a formal examen.

5.1. Suitability of Artisan Biochar for Agriculture

Kon-Tiki and TLUD biochar was extensively analyzed following the EBC and WBC analytical requirements. All biochar that was produced from eligible feedstock with the Artisan endorsed technologies fulfilled all requirements of EBC and WBC certification (Bursztyn Fuentes et al., 2020; Cornelissen et al., 2023; G. Cornelissen et al., 2016; Pandit et al., 2017; Smebye et al., 2017). PAHs and other potential contaminants were found with generally low contents that allowed in all cases the certification as WBC-Agro. As PAH contents of biochar are mainly technology dependent (Bucheli et al., 2015) and generally low in Kon-Tiki and TLUD biochars, the Artisan standard does not require its regular analysis. Meeting the PAH thresholds is covered by the pyrolysis-type endorsement of the Kon-Tiki. Cornelissen et al. (2015) shows most exhaustively PAH EPA16 data of different Artisan biochars.

Therefore, biochar produced under the Artisan Standard are suitable for agricultural uses as they fulfill biochar quality requirements of WBC-Agro.

6. Biomass Feedstock

The present certification standard assumes that the biochar is made from biomass feedstock that originated from the artisan's farm or from biomass processing such as cocoa mills, coffee pealing, rice thrashing, sawmills, and comparable industries. Biomass may also come from disaster debris, maintenance of fallow fields, or dedicated biomass production like bamboo or switch grass plantations.

Under the present Global Artisan C-Sink guidelines, it is not permitted to use forest wood and to slash forest trees. The only exception is forest residue wood that may be used for cooking in TLUDs within the C-Sink Villages. Selected biomass from forest gardens, agroforestry, short rotation coppice, and fallow rotations are authorized. Woody residues from fallow fields are eligible when the fallow period does not exceed 10 years.

While invasive plants may threaten local ecosystems, they are removing and storing carbon from the atmosphere. If invasive plants are used as feedstock, the Artisan C-Sink Manager must be able to demonstrate how the biological carbon will be restored in the areas where the invasive species were harvested. The restoration plan must be submitted to and authorized by Carbon Standards.

It is not allowed to pyrolyze food or feed products except when expired. Hay may be pyrolyzed if the production exceeds the local demand for animal feed.

The restriction of eligible biomass for biochar production is explained by the intention to avoid by all means the overexploitation of ecosystems and the impairment of food security for the sake of C-sink maximation.

For Artisan C-Sink Farmers, the farm size and available biomass need to be reported. For residues from crop processing units, the annually available amount of biomass per processing unit should be estimated. Based on this data, the maximum amount of biochar that a given farmer, or a company may produce can be estimated. Overuse of biomass or fraud through misreporting can thus efficiently be avoided.

7. Application and Trade of Biochar

While C-Sink Farmers are expected to apply the biochar in their own farm to improve their soil and increase farm resilience to climate change, Artisan Pro producer will mainly sell the biochar, which needs to be tracked either by the producer, the Artisan C-Sink Manager, or a certified Biochar Trader. The production of individual C-Sink Cooks is too small for tracking to the C-sink and is generally collected by a Biochar Processor who must be endorsed by the Artisan C-Sink Manager.

The following exceptions to the above standard cases are possible:

- A farmer could pyrolyze residues from a neighboring farm or produce a biochar-based fertilizer to be sold in the respective region.
- A service provider comes with a mobile Kon-Tiki to farmers to pyrolyze residues and market the biochar on its own behalf.
- A farmer collects disaster debris or other occasionally available biomass and transforms it into biochar to be applied on his/her own land or to be sold on a not regular base to other farmers or processors.

The Artisan C-Sink Manager is obliged to document all those production scenarios and present them for acceptance to Carbon Standards.

In any case, the C-Sink Farmer, the Biochar Processor, and the Artisan Pro must document the biomass used, the production process and the final application of the biochar as described in Chapters 5, 6, and 9. The obligation to keep proper proofs and records of the application lies with the Artisan C-Sink Manager. The Artisan C-Sink Manager can transfer the obligation to the endorsed Biochar Processor or Biochar Trader.

8. Feedstock Preparation and Storage

To limit emissions and avoid smoke during biochar production, the feedstock needs to be pre-dried to a dry matter content of at least 75%. Usually, three days of sun drying is sufficient if the feedstock with diameters below 30 mm is not piled but thinly layered. Here are the requirement for feedstock preparation and storage:

1. The feedstock must not be used freshly cut or from a feedstock pile where it rained upon.
2. Feedstock needs to be stored airy and protected from rain.
3. To avoid methane emissions from feedstock storage, wet feedstock must not be piled higher than a meter. Otherwise, the humid feedstock will self-heat, consume the oxygen inside the pile and decompose anaerobically, which produces significant amounts of methane.
4. When feedstock got exposed again to rain, a new period of at least three days of thinly layered sun drying has to start.
5. Touching the feedstock must not feel humid.
6. The water content of feedstock should be below 25% when used in the Kon-Tiki or TLUD. Simple, low-cost digital devices (+/− 60 €) exist to measure feedstock humidity, which must be used at the biochar trainings so that artisans get the experience of how to test the feedstock for humidity even without digital devices. Producers of more than 100 m^3 biochar per year are required to measure the feedstock humidity for every load with an appropriate device and record it in the production protocols. Here, the average humidity is recorded using five measurements with the handhold device per m^3 of feedstock.

The Kon-Tiki can consume lots of different feedstock and mixing of feedstock during one run is possible. However, most of the feedstock needs to be bulky to allow the continues release of pyrolysis gases and unrestricted passage through the flame curtain. Smaller portions of e.g., rice husks, saw dust, coffee parchment, empty corn cobs can be added slowly in thin layers if the pyrolysis zone is sufficiently hot.

Both, feedstock drying and correct bulkiness of the feedstock blend, is an essential part of the initial Artisan Biochar Producer and C-Sink Cook training.

9. Monitoring, Reporting, and Verification

Technically, the Global Artisan C-Sink certification procedure is based on a digital monitoring, reporting, and verification (dMRV) tool, which is usually a dedicated smartphone application. Carbon Standards provide the backbone for endorsed Artisan Apps to automatize data exchange to Global C-Sink Registry. Artisan C-Sink Managers may develop their own Artisan App to manage their Artisan biochar production and trade. During the first year after registration as Artisan C-Sink Manager, production documentation, including the necessary digital imagery and GPS data, may still be done manually before being transferred to a computer database.

The Artisan C-Sink Manager is required to submit a monitoring plan as part of the Project Design Document (PDD) to the Carbon Standards. This plan should specify the endorsed dMRV application being utilized. The monitoring plan should detail the methods and schedule for monitoring the biochar production within the C-Sink Network, the C-Sink Village, or at the Artisan Pro. Additionally, the plan needs to elucidate the process of transmitting data to the Global C-Sink Registry, describe the training procedures for dMRV application operators, and outline solutions to challenges like poor GPS signal or internet connectivity issues.

The designated dMRV must be enabled for transmitting all pertinent data to the project's primary database (e.g., amount and quality of biochar produced by individual farmers or cooks). This project-specific database shall feature an API connection to the Global C-Sink Registry. This ensures that the quantified C-sink, aggregated by the pre-defined C-Sink Units (i.e., C-Sink Network or C-Sink Village) within the project, is seamlessly transferred. Additionally, relevant supplementary data, such as C-sink type, geolocation, and timestamp of measurement, should accompany this transfer. Based on this API, the Global C-Sink Registry will automatically receive basic project information for each registered C-sink. The Artisan C-Sink Manager is mandated to retain the comprehensive, non-aggregated dataset for a minimum of 10 years. Carbon Standards and the third-party Certifier may request access to the complete dataset or specific sections of it as deemed necessary. Once the aforementioned data is transmitted to the Global C-Sink Registry, the Certifier will validate it. Only after this validation and certification will the respective C-sinks be officially registered.

The Artisan C-Sink Manager is also obliged to present the Certifier with a project description documentation (PDD) including a quality management system for an Internal Control System (ICS). A template for PDD is available from Carbon Standards. The ICS plays a pivotal role in ensuring and upholding the project's quality (e.g., measuring of production quantities) as well as the integrity of the data collected. This is achieved through systematic quality checks, conflict-of-interest resolutions, and imposing sanctions and corrective actions where needed. Guidelines for Artisan C-Sink Managers to establish ICS fit for purpose are provided by the Certifier.

The following data need to be recorded/uploaded using the dedicated smartphone application for, C-Sink Farmer, Artisan Pro, C-Sink Cooks, and Biochar Processors:

9.1. General Requirements

9.1.1 Registering each Artisan Biochar Producer and C-Sink Cook (name, address, phone number)

9.1.2 Upload of the proof for successful participation and proficiency test in an artisan biochar workshop (not necessary for C-Sink Cooks)

9.2. (a) Registration of Biomass for C-Sink Farmers (< 100 m^3 biochar per year)

9.2.1 GPS data of the cultivated land (creating a vector file for each field > 1 ha using the kml-filetype of Google maps, for all smaller fields, at least one GPS-point within the field and a list including the name of field and surface areas). Each field receives a unique identification number.

9.2.2 The crop rotation, harvest data, and harvest amount of biomass feedstock need to be recorded annually for each registered field (the Artisan C-Sink Manager correlates the biomass potential and the amount of biochar produced).

9.2. (b) Registration of Processed Biomass for Artisan Pro

9.2.3 Short description of what biomasses are processed (e.g., pealing of pineapples) – as predefined by the Artisan C-Sink Manager.

9.2.4 Upload of images documenting the biomass feedstock. A meter measure must be seen in the picture for controlling the feedstock sizes.

9.2. (c) Registration of Processed Biomass for C-Sink Cooks

9.2.5 Description of biomass used by the C-Sink Village.

9.2.6 If feedstock is not prepared and distributed centrally by the C-Sink Village, but individually by the C-Sink Cook, the Artisan C-Sink Manager must describe how the individual feedstock is prepared and controlled.

9.3. Biomass Preparation and Quantification

9.3.1. Description of biomass preparation (e.g., sun drying, chopping)

9.3.2. Quantification of biomass residues used for biochar making usually in m^3.

9.4. Registration of Biochar Production Device

9.4.1 Documentation of the technology used (Kon-Tiki type, TLUD) including a picture. For the Kon-Tiki devices the upper surface area and depth of the kiln must be registered.

9.4.2 Register the volume measuring device and respective volume (e.g., 10 l buckets, 60 l bags, 200 l barrels, etc.).

9.5. Registration of Each Biochar Production Load (Artisan Pro, C-Sink Network)

9.5.1 A biochar production load within Global Artisan C-Sink is defined as the amount of biochar produced with a single run of one Kon-Tiki. For deviating technologies, the production load must be defined appropriately.

9.5.2 Registering the biochar feedstock type (e.g., 40% rice straw, 60% cocoa pods)

9.5.3 Artisan Pro must register the humidity of each feedstock component and the average feedstock size.

9.5.4 Artisan Pro must register the location of the pyrolizer (address and GPS coordinates)

9.5.5 In the case of a new feedstock type or feedstock blend, the C- and H-content and the bulk density of the resulting biochar must be analyzed (see chapter 16). The dMRV guides the user how to take the sample, provides an ID for the sample, informs the user on how to proceed with the sample and communicates to the Artisan C-Sink Manager the necessity for analysis. The bulk density can be measured by the Artisan C-Sink Manager following the method described in Annex 2.

9.5.6 Documentation of the biochar making (registering a minimum of two photos from the middle and the end of production with georeferencing and date of picture). If the Artisan C-Sink Manager accompanies the respective process with approved auditors for the biochar making, this step is not necessary.

9.5.7 Accounting of the biochar produced (measured on a volume base)

9.6. Registration of Biochar Produced by Individual C-Sink Cooks

9.6.1 Usually, the individual C-Sink Cooks store their biochar production for several weeks or months. It is not necessary to measure the amount of biochar produced per TLUD run nor to register every run. The Artisan C-Sink Manager or the Biochar Processor shall measure and register the total amount under the name and ID of the C-Sink Cook once they pick up the biochar.

9.6.2 The C-Sink Cook signs the delivery slip and should get paid for the biochar and C-sink within five days after delivery.

9.6.3 If the C-Sink Cook uses the biochar in his own garden or field, which, in fact, would be the most meaningful, it would become practically impossible to monitor and verify the amount and quality of the small amounts of biochar. For that reason and to the regret of the standard owner, a biochar C-sink can only be registered when the biochar produced by individual C-Sink Cooks was first collected and measured by a certified Biochar Processor.

9.7. Tracking and Documentation of the Mixing and Application of Biochar

9.7.1 Documentation of the biochar mixing to compost, manure, fertilizer, etc. (in text and photo with georeferencing and date).

9.7.2 Registration of the volume applied to each respective matrix.

9.7.3 Registration of biochar amount, application date, and the reference to the registered field of the farm (for C-Sink Farmers).

9.8. Selling of the Biochar

9.8.1 If the biochar is sold to a Biochar Processor, Biochar Trader, or user, a transfer document about the carbon sink potential of the biochar may be issued. However, the carbon sink potential is not a registered C-sink and cannot be traded as such before the biochar is not verifiably applied to soil or another C-sink matrix.

9.8.2 The buyer of the biochar (i.e., a Biochar Trader, processor, or user), can become certified and deliver verified documentation and tracking of the biochar's end use so that C-sink certificates can be issued.

9.8.3 If the traded biochar is mixed to compost, manure, fertilizer, feed etc., the biochar cannot be burned or decompose anymore. Traded biochar-mixes containing > 1 t CO_2e from biochar per client and year must be tracked to the application field. When biochar-mixes are traded in smaller units and with total annual amounts per client and year that contain less than 1 t CO_2e from biochar, the GPS tracking to the field is not necessary, but the name and address of the buying farmer and the amount and type of sold biochar must be registered using invoice sheets or delivery bulletins.

10. C-Sink Units and Global C-Sink Registry

A C-Sink Unit is the registered amount of geo-localized or diffuse biochar C-sinks of the same controlled quality. The minimum size of a C-Sink Unit is 1 t CO_2e.

For C-Sink Networks, the C-Sink Unit may comprise all respective individual biochar production and application amounts for a maximum of one year. While the individual production and application amounts must be tracked and recorded in the database of the Artisan C-Sink Manager, the C-Sink Unit can be registered in the Global C-Sink Registry as one individual C-sink if the biochar or biochar-based fertilizer is applied on the fields of the farmers of the C-Sink Network.

Biochar or biochar-based fertilizers units of more than 1 t CO_2e that are sold outside of a C-Sink Network must be tracked to the application site and cannot be grouped under the C-Sink Unit of the C-Sink Network but must be registered as an individual C-sink. Smaller units than 1 t CO_2e from biochar may be sold and applied as diffuse C-sink without localization when mixed to a C-sink matrix and be registered under the C-Sink Unit of the C-Sink Network.

For C-Sink Villages, the biochar is usually collected by the Biochar Processor where the annual production of the C-Sink Village is considered as one production batch presenting the same biochar quality. The Biochar Processor creates the C-Sink Units by selling or delivering more biochar or biochar-based products containing more than 1 t CO2e from biochar to geo-localized sites where the C-sink is established and registered under controlled conditions.

Artisan Pro producers can group individual production loads (one Kon-Tiki production is considered one load) to batches as long as the feedstock stays the same. The Artisan Pro batches can become a C-Sink Unit if the entire batch is applied to the same tracked and registered field site. If a batch is distributed to several fields or processing sites, the separated sub-batches must receive their own C-sink ID, tracking record, and become, once applied to the field site or material, a C-Sink Unit to be registered in the Global C-Sink Registry.

Diffuse C-sinks: Biochar that is mixed to a C-Sink Matrix and marketed in package- and application-sizes containing less than 1 t CO_2e from biochar may be registered as diffuse C-sink without geo-localization. C-Sink Units may comprise up to the total annual production of a C-Sink Village or an Artisan Pro as diffuse C-sinks. However, bookkeeping must list the clients purchasing the biochar-products to be registered within the C-Sink Unit.

The Artisan App (dMRV), the Artisan C-Sink Manager’s database, and its digital link to the Global C-Sink Registry are the backbone of monitoring, reporting, and verification in the Global Artisan C-Sink standard.

The Artisan C-Sink Manager must ensure that the following data are transmitted regularly to the Global C-Sink Registry. Verification of correct data transfer is part of the regular monitoring of the Artisan C-Sink Manager through the Certifier.

10.1. C-Sink Unit Information Requirements

1. Feedstock of biochar production
2. Technology of production
3. Date or period of production
4. C-content and H/C ratio of biochar (measured or taken from the Ithaka database)
5. Matrix into which the biochar was mixed (compost, manure, feed, cement etc.)
6. Location of the C-sink (vector file of field location; for fields < than 1000 m^2 one GPS point per field is sufficient, for C-Sink Networks and C-Sink Villages only the vector file of the network and village, respectively, is needed)
7. Amount of biochar applied in tons (dry matter tons)
8. Date of application
9. Owner of the C-sink site (name, address, birth date – not necessary for C-Sink Network and C-Sink Village)

The Artisan C-Sink Manager must safeguard the production records of all individual C-Sink Farmers containing the above information. The Artisan C-Sink Manager may then group the C-sinks of the C-Sink Farmers into C-Sink Units as described above and register these in the Global C-Sink Registry.

10.2. Mass and Volume Measurement

The amount of biochar produced is measured volumetrically by each Artisan Biochar Producer and controlled by the Artisan C-Sink Manager.

The Artisan C-Sink Manager is responsible for analyzing the carbon content and the bulk density of the biochar made from each feedstock type or feedstock mix. The bulk density must be measured by the Artisan C-Sink Manager or a local laboratory using the method described in Annex 2. The carbon content must be analyzed by a Carbon Standards endorsed laboratory. If the biochar is produced from the same feedstock in the same pyrolizer (e.g., Kon-Tiki, TLUD), the carbon content and the bulk density analyzed for an earlier load or batch can be used to calculate the mass of biochar and carbon production. However, bulk density must be measured at least once for every 500 m^3 biochar be it within an Artisan C-Sink Network, a C-Sink Village, or for an Artisan Pro producer.

The measured bulk density is then used to convert the biochar volume into mass (tons dry matter) with an accuracy of at least +/- 20% (Annex 2). The C-content of the respective biochar is used to calculate the amount of carbon contained in a given volume of biochar.

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Carbon for C-sink (kg C) = Biochar produced (l) x Bulk Density (g l^{-1}) x Carbon content (%)

Equation 1. Calculation of the amount of biochar carbon that is contained in a C-sink unit.

Example: 320 liter of biochar was produced from rice straw in a Kon-Tiki kiln. The bulk density of non-milled Kon-Tiki biochar made from rice straw is registered with 220 g per liter and a C-content of 62%. The amount of carbon that can be sequestered in a C-sink would then be calculated as below on Calculation example 1.

$$320 \text{ l} \times 0.22 \text{ kg l}^{-1} \times 62\ \% \text{ C} = 43.6 \text{ kg C}$$

Calculation example 1. Carbon sequestered (kg C)

10.3. Change of Land Title or Inactivity of Farmer

If a C-Sink Farmer stops his farming activity, or in case of the death of a farmer, or loss of the registered land lease, the Artisan C-Sink Manager must inactivate the participant from the system. In case of inheritance or modification of the land lease contract, the new owner or farmer must be re-registered, sign the respective declarations, and follow the required training.

If a C-Sink Cook changes its cooking method and does not produce biochar with a TLUD stove anymore, the Artisan C-Sink Manager must inactivate the participant from C-Sink Village database.

11. On-site and Remote Inspection

The present guidelines regulate the management, inspection, and certification. Carbon Standards is in the role of the endorsing agent of the Certifier. The list of endorsed "Artisan Certifiers" is published on the Carbon Standards webpage. The Certifier may conduct announced and unannounced inspections to verify compliance of the Artisan C-Sink Manager's duties, including visits to individual Artisan Biochar Producers (C-Sink Farmers, Artisan Pro, C-Sink Cooks, Villages), Biochar Processors, and Biochar Traders.

11.1. Internal Inspection and Payment of C-Sink Cooks and C-Sink Farmers

The Artisan C-Sink Manager is responsible for the monitoring of the individual C-Sink Cooks and C-Sink Farmers producing less than 100 m^3 biochar per year and participating in C-Sink Networks. The Artisan C-Sink Manager (e.g., via its employed field facilitators) is obliged to visit every individual C-Sink farmer of a C-Sink Network and every participating C-Sink Cook at least once a year. The visit must be documented and used to inform the participating farmers or cooks about new methods of biochar use, control payments, verify the drying, storing, and use of the biomass feedstock as well as the use of the pyrolysis technology.

The smartphone app used by the C-Sink Famer and/or Artisan C-Sink Manager is the key for dMRV. The Artisan C-Sink Manager takes the full responsibility for the correctness of the declared biochar productions and C-sinks. The Artisan C-Sink Manager must assure with measures that go beyond the declaration in the dMRV that the C-sinks declared by the participating C-Sink Farmers were set-up in the declared quality and quantity. Various control methods such as triad peer groups, farmer/village leaders, or independent inspections can be applied to improve the data quality. Which additional control method is best adapted to a given region and mentality can be decided by the Artisan C-Sink Manager.

Payments to C-Sink Farmers and C-Sink Cooks to produce biochar and the establishment and maintenance of carbon sinks within the C-Sink Network and C-Sink Villages must be transparent and publicly declared.

11.2. Control of Artisan Pro Biochar Production

Artisan Pro biochar producers with a production capacity of more than 100 m^3 per year must be controlled by an annual on-site inspection from the Certifier. In exceptional and justified cases, the on-site inspection can be replaced for a maximum of one year by a remote inspection. To prepare for the inspection visit, the Artisan C-Sink Manager must:

- Verify the data declaration in the dMRV (usually an Artisan C-Sink Manager smartphone app).

- Check the supply chain of the biomass feedstock, feedstock storage and preparation.
- Inspect on-site at least one Kon-Tiki production load per year.
- Control the sample taking and retention sample storage (Chapter 15).
- Measure the bulk density of the biochar for each feedstock or feedstock mix at least once for every 500 m^3 of biochar production.
- Send or control the sending of the analytical biochar sample for each feedstock or feedstock mix at least once per year to the Carbon Standards endorsed laboratory for C-content and H/C analysis.
- Check storage, packaging, and labeling of biochar.
- Check the tracking of the biochar from the production facility to soil, to the Biochar Processor or Biochar Trader, and/or to the incorporation into a matrix that cannot be burnt. This is a plausibility and process check using the dMRV; there is no physical check of each tracking step required.

12. Biochar-Carbon Persistence

Biochar-based carbon sinks differ from natural carbon sinks like afforestation and soil organic matter in presenting a very persistent carbon pool once the biochar is applied to soil or other such materials that prevent the biochar from burning. A total loss of a biochar-based C-sink in soil is practically impossible. Still, biochar will slowly degrade when applied to soil which can be calculated with a generally applicable degradation formula. Biochar consists of a Semi Persistent Carbon (SPC) pool that degrades within the first thousand years after soil application and a Persistent Aromatic Carbon (PAC) pool that will persist for more than 1000 years in soil or sediments and can be considered a geological carbon sink (Schmidt et al., 2022). Depending on the severity of the pyrolysis conditions (i.e., temperature, residence time, pressure) but also on the ash content of the feedstock and its particle size, the PAC fraction is smaller or larger (Bowring et al., 2020, 2022; Zimmerman and Gao, 2013). The size of the PAC fraction is related to the H/C ratio, the electric conductivity of the solid biochar, and can be measured using hydro pyrolysis (Schmidt et al., 2022).

Biochar made in a Kon-Tiki or TLUD reach highest treatment temperatures above 650°C and present an H/Corg ratio well below 0.4 (G. Cornelissen et al., 2016) indicating a PAC fraction of at least 75% (Howell et al., 2022; Schmidt et al., 2022). Certified artisan biochar is, therefore, registered in the Global C-Sink Registry with a PAC-fraction of 75% and SPC fraction of 25%. A more refined persistence grading based on new analytical methods will introduced in 2024/25. If the biochar carbon sink is geo-localized, the expected increase of the PAC fraction can be applied retroactively.

When C-sinks are sold to offset CO_2-emissions only the PAC fraction that is persistent for more than 1000 years (C_{1000} = 75%) must be used.

The semi-persistent carbon (SPC) fraction of biochar presenting an H to Corg ratio < 0.4 is defined as the part of soil applied biochar that decays within the first 1000 years after soil application. It has mean half-life of 50 years and constitutes a temporary carbon sink. The mean residence time of 50 years for the SPC fraction is based on the most conservative metanalytical estimate for biochar carbon degradation published to date (Schmidt et al., 2022). Other sources determined significantly lower degradation rates depending on the degree of pyrolysis and the experimental design (IPCC, 2019; Kuzyakov et al., 2014; J Lehmann et al., 2015; Zimmerman and Gao, 2013). However, without more reliable methods and long-term experiments, the present Global Artisan C-Sink standard uses conservative projections and calculates the climate-relevant effect of C-sinks with a sufficient safety margin.

The biochar persistence is calculated with the following conservative approximation:

$$C_{remain}\,(year) = \frac{M_{BC} * C\_cont}{1000}\,(750 + 45 * e^{-0.5232 * years\_of\_decay} + 205 * e^{-0.009966 * years\_of\_decay})$$

Equation 2. Decay function of biochar presenting an H to C_{org} ratio < 0.40. M_{BC} = mass of biochar; C_{cont} = carbon content of biochar; C_{remain} = Mass of biochar-carbon remaining in a C-sink after the years of decay since soil application. The equation is valid for 0 to 1000 years.

The formula is based on the assumption that 75% of the carbon is persistent for more than 1000 years (PAC fraction) and that the semi-persistent fraction (SPC) has a mean residence time (MRT) of 50 years. Those 50 years correspond to the MRT of bulk soil organic carbon (SOC) (Schmidt et al., 2011). As it is the common understanding that SOC is less persistent than biochar (Lehmann et al., 2015; Lehmann et al., 2020; Schmidt et al., 2011), the assumption of an MRT of 50 years for the SPC fraction is very conservative.

The SPC-fraction of biochar can be used for methane emission offsets (see next chapter) and global cooling services. The 100-years average of the SPC fraction can be expressed and used as C-Sink_100.

If biochar is used in construction materials as a sand substitute or as an additive in asphalt and plastics, it can be assumed that the entire carbon content of the biochar persists and remains a C-sink for as long as the material itself persists. Only when the biochar-containing material is disposed of, destroyed, or decomposed may the sequestered carbon be released back into the atmosphere, causing the C-sink to lose its value. It must be removed then from the C-sink register which is regularly monitored according to the controlling period stipulated for each C-sink matrix.

The Artisan C-Sink Manager is responsible for informing the registry and the Certifier of the changes.

13. Emission Portfolio, Carbon Leakage, and Margin of Security

To provide for an accurate depiction of the climate impact of a biochar-based C-sink, all direct and indirect greenhouse gas (GHG) emissions caused by biomass cultivation, harvesting, transportation, crushing, pyrolysis, pyro-gas combustion, milling, blending, and soil or material incorporation must be assessed and registered by the Artisan C-Sink Manager. All emissions caused by the C-sink production must be offset with carbon sinks of corresponding persistence before the C-sink can be validated in the Global C-Sink Registry and used for compensating or offsetting other GHG emissions. Here, the carbon sink of the applied artisan carbon sink can be used for direct offsetting.

As the biochar production in Kon-Tiki kilns does not consume any electricity or fuel, the carbon footprint of the biochar production with this technology is very low. However, the occurrence of some minor emissions is possible. This could be the fuel for transportation of the biomass feedstock to the kiln or of the biochar to the field, the displacement of the kiln, a pump for quenching water, fuel for a chain saw for pruning, milling, and blending of the biochar, and/or application to the soil. In some cases, none of those operations cause GHG emissions because everything is executed manually; in most cases, however, some of those emissions occur. To keep the certification procedures reasonably lean, Artisan Biochar Producers are not required to provide a detailed account of these potential emissions, but a margin of security of 20 kg CO_2e per ton of biochar (DM) is levied. This corresponds to roughly 0.7% of the biochar carbon. It is an industry-standard margin for the inherent uncertainty of the overall process that allows Carbon Standards to keep the certification process lean and efficient without misappropriating emissions.

The potential emissions for transporting of biochar to the field site, milling, blending with other substrates, and application are included in the margin. However, when the transport distance from the production site to the final field site exceeds 100 km, the transport emissions have to be accounted and offset in addition to the margin. The emission factors to be applied for longer distance transportation depend on the type and size of the vehicles and must be calculated by the C-sink manager and presented to the Certifier.

If a biochar producing company or network prefers to calculate exactly the carbon footprint of the production and if this calculation is verified and approved by Carbon Standards, the more exact carbon footprint can be provided on the certificate, though it does not replace the 20 kg CO_2e per ton of biochar margin that covers all sorts of further uncertainties.

$$\text{Margin of Security} = \text{Biochar produced}\ (\mathrm{m}^3) * \text{Bulk density}\ (\mathrm{t\ m}^{-3}) * 0.02\ (\mathrm{t\ CO2e\ per\ t\ BC})$$

Equation 3. Margin of Security. Biochar produced is measured by using buckets of at least 10 liter and then converted into m^3. Bulk density is applied as of Annex 2. 0.02 ton CO_2e per ton of biochar is the margin of security to be applied for Artisan Biochar Production.

If an Artisan Pro produces for example 1000 m3 of biochar with a bulk density of 0.26 t/m3, the margin of security would be (1000 m3 biochar * 0.26 t/m3 * 0.02 t CO_2e t biochar^{-1}=) 5.2 t CO_2e.

This margin equals the consumption of (5200 kg CO_2e / 2.7 kg CO_2eq per l diesel / 260 t biochar =) 7.4 l diesel per ton of biochar which is largely sufficient to account for the handling, transport, and diminution of the biomass and packaging and transport of the biochar.

The C-sink of the 1000 m^3 biochar of the example above would have to be registered in the Global C-Sink Registry as (1000 m^3 biochar * 0.26 t/m^3 bulk density * Carbon Content (%) * 44/12 =) 953 t CO_2e. The PAC fraction that can be used for CO_2 offsetting would be (953 t CO_2e * 75% PAC =) 715 t CO_2e. The SPC fraction to be used for methane offsetting or annual global cooling services would be (953 t CO_2e * 25% SPC =) 238 t CO_2e. The 5.2 t CO_2e for the margin of security must be retired from the PAC fraction of 715 t CO_2e resulting in a total marketable PAC fraction of (715 t CO_2e – 5.2 t CO_2e =) 710 t CO_2e. If the biochar was transported more than 100 km, the transport emissions exceeding the distance of 100 km would have to be retired equally from the PAC fraction to offset the CO_2 emission at 2.7 kg CO_2e per liter of diesel.

The margin of security as well as the exceeding transport emissions can be offset with the PAC fraction of the biochar production of the same batch or of another biochar C-sink registered in the Global C-Sink Registry.

The additional offsetting of the methane emissions occurring during the artisanal biochar production is explained in the next chapter.

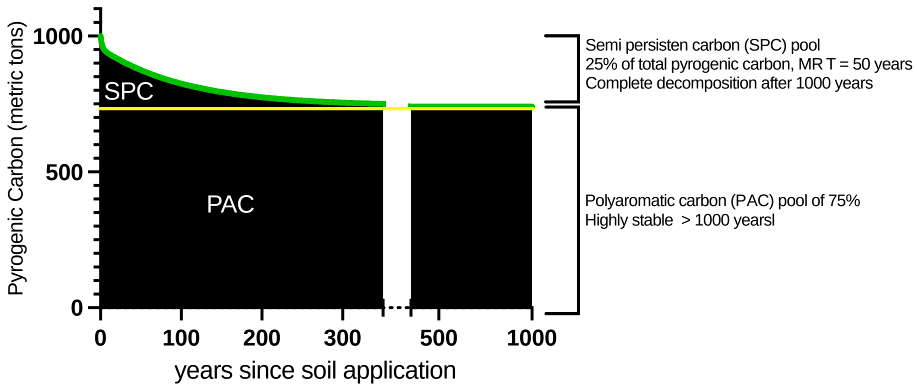

Figure 3. Sequestration curve of a 1000 tons carbon sink made from soil-applied biochar with an H:Corg ratio well below 0.4.

14. Methane emissions

In both industrial and artisanal biochar production, small but relevant methane emissions occur. Based on emission data gained with various types of Kon-Tiki and various fresh biomass feedstock containing up to 50% humidity, Cornelissen et al. (2016) calculated an average of 30 kg CH_4 emissions occurring during the production of one ton of biochar in a Kon-Tiki type kiln, which equals an emission factor of 4.2±1.2 kg CH_4 t^{-1} biomass considering a 14±3% conversion factor of biomass to biochar (Karananidi et al., 2020). The methane emissions in Kon-Tiki type kilns depend mainly on the craft to fire the kiln and on the humidity of the feedstock. The dryer the feedstock, the hotter and more homogenous the flame curtain that oxidizes the combustible gases rising from the kiln (Cornelissen et al., 2023). If the feedstock is not layered with care and the flame curtain is disrupted, smoke may arise from the kiln and within the smoke CH_4. For that reason, the training and proof of expertise of the Artisan Biochar Producers are of utter importance.

Today, the 30 kg CH_4 per ton of biochar (on a dry matter base) is considered the average for different feedstock and Kon-Tiki kiln geometries. However, many common feedstocks like rice straw, cocoa pods, husks, and leaves have not yet been investigated regarding potential CH_4 emissions. Also, if the feedstock is dry (< 15% water content), CH_4 emissions could be very low and even below the detection limit of field scale CH_4-analyzers (Cornelissen et al., 2023). In the next years, more precise data and production guidelines can be expected and will be used to update the standard. In the meantime, we are confident that using the robust mean of 30 kg CH_4 emissions per ton of Kon-Tiki biochar accounts reliably for the climate forcing that has to be compensated for as long as the use of wet feedstock is efficiently prevented by the Artisan C-Sink Manager and its MRV.

14.1. Methane emission of TLUD stoves – The pro-rata approach

CH_4 emissions of TLUD stoves are comparable to the Kon-Tiki type pyrolysis (Jetter et al., 2012). However, all TLUD types must be endorsed by Carbon Standards which includes CH_4 measurements of at least three runs with at least one type of standard feedstock with three significant different dry matter contents of the feedstock. The mean CH_4 emissions of the test runs plus a 20% security margin will then be used as standard CH_4 emission of the respective TLUD stove type.

As the main purpose of TLUD stoves is cooking and not biochar production, the methane emissions caused by cooking and by the biochar production are separated on a pro rata base. Only those CH_4 emissions that were caused by the pyrolysis of the feedstock carbon that is eventually contained in the biochar must be compensated before registering the biochar as carbon sink.

To calculate the emission pro rata, the biochar mass is multiplied with the lower caloric value (LLV) and divided by the multiplication of the corresponding feedstock mass and the LLV of the feedstock.

$$TLUD\ Pro\ rata\ = \frac{biochar\ mass * LLV_{biochar}}{feedstock\ mass * LLV_{feedstock}}$$

Equation 4. Calculation of the part of total emissions that must be accounted for the production of the biochar C-sink. It reduces the amount of CH_4 emissions that must be compensated.

If a TLUD uses, for example, 1.40 kg wood (DM) with an LLV of 17.5 kJ/kg to produce 0.32 kg biochar with a LLV of 28.5 kJ/kg, the part of feedstock energy contained in the biochar is (0.32 kg * 28.5 kJ/kg / (1.4 kg * 17.5 kJ/kg =) 37%. If the given TLUD produces a total of 25 g CH_4 emission per kg of biochar, the CH_4 emission to be compensated for the biochar C-Sink would only be 37% of it, (25 g CH_4 / kg BC * 37% =) 9.25 g CH_4 / kg BC.

The methane pro rata must be assessed by Carbon Standards for each TLUD stove type during the endorsement of the TLUD stove type in combination with the registered feedstock type. The LLV of the feedstock and of the biochar must be analyzed by an EBC or WBC endorsed laboratory.

14.2. Climate forcing of atmospheric methane

Although the methane concentration in the atmosphere is around 200 times lower than that of CO_2, methane currently contributes between 16 and 30% to global warming, with no consensus between the scientific references. However, the average residence time of methane in the atmosphere is only nine to twelve years as it is oxidized to CO_2 and H_2O in the atmosphere (Prather et al., 2012). During this short period, methane has a climate impact that is over 200 times greater than that of CO_2. To compare these different effects of greenhouse gases and the varying duration of their effectiveness, the global warming potential (GWP) of the gases is calculated for a specified period of time. In recent decades, a period of 100 years has been predominantly used for this purpose (GWP100) (Fuglestvedt et al., 2003). However, in the case of methane emissions, any reference time above 12 years underestimates the global warming effect during the first 12 years and overestimates the climate effect after those 12 years. The longer the reference period exceeds the 12 years during which methane causes a global warming effect, the more the climate forcing is diluted and climate action through compensation with negative emissions delayed (Myrhe et al., 2013).

The decades up to 2050 are the decisive period for limiting anthropogenic global warming. Since methane emissions occurring today and in the upcoming decade have a particularly severe climate impact until 2050, the calculation of methane's climate impact should not be diluted over 100 years. Therefore, the Global Artisan C-Sink standard requires that the compensation of methane emissions must occur during the first 20 years following the emission. This reflects the comparatively short but intense impact of methane and is in line with recommendations from various organizations and scientists (Balcombe et al., 2018).

To compensate methane emissions, the GWP100 of the emitted amount of methane is calculated using the factor 25 kg CO_2e per kg CH_4. We then calculate the absolute global warming potential (AGWP) over 100 years using Jeltsch-Thömmes & Joos (2019). The AGWP must then be compensated by a same-sized absolute global cooling potential (AGCP) over a maximum of 20 years.

The comparatively short lifetime of methane in the atmosphere allow to compensate its climate impact with temporary C-sinks. The Global C-Sink standards developed the option to compensate methane emissions with temporary C-sinks such as the SPC fraction of biochar, tree plantations, and biomass materials in buildings (see detailed examples in the following sub-chapters).

Box1: Methane calculation example

To produce 10 tons of Kon-Tiki biochar (dry matter), an average (30 kg CH4 / tBC * 10 tBC =) 300 kg of CH_4 is emitted. The GWP100 of this emission is (0.3 t CH_4 * 25 t CO_2e / t CH_4 =) 7.5 t CO_2e. The absolute global warming potential (AGWP) over 100 years results in 381.0 tons aCO_2e (equivalent to a radiative forcing of 3.3×10^{-8} W m^{-2} yr). Those 381.0 t aCO_2e of global warming must be compensated by 381.0 t aCO_2e of global cooling within 20 years which corresponds for example to maintaining a carbon sink of 26.1 t CO_2e without decay for 20 years considering the impulse response function (IRF) to calculate the respective C-sinks global cooling effect. The SPC fraction of a biochar C-sink could equally be used (see chapter 14.5). To encourage afforestation, the global warming effect of the methane emission could also be compensated by an exponential growth curve of a newly planted forest over 20 years (exponential increase of tree-based carbon removal over 20 years). The compensating global cooling must start in the first year, provide annual global cooling in every following year, and finalize the compensation latest 20 years after the methane emission.

14.3. The principle of methane compensation by negative emissions

Unfortunately, there is no technology ready to directly remove methane from the atmosphere (Jackson et al., 2019). Equally, no method is available to accelerate methane elimination in the atmosphere. Thus, to balance the global warming effect of a given methane emission, another greenhouse gas such as CO_2 could be removed from the atmosphere (i.e., carbon dioxide removal – CDR). The principal of methane compensation is to create a climate cooling effect equal to the climate warming effect of the emission during a defined period of time.

As the climate warming effect of methane over a period of 20 years is 86 times higher than the effect of the same amount of CO_2, 86 times more CO_2 must be removed from the atmosphere for those 20 years. Due to the limited lifetime of methane in the atmosphere (< 20 y), there is no need for a long-term carbon sink such as the persistent fraction of biochar that sequesters carbon for more than 1000 years. Instead, carbon sinks such as the semi-persistent fraction of biochar or 20 years of a growing tree can be accounted for as a temporary CO_2 removal to compensate for the equally temporary climate warming effect of methane emissions.

Considering the urgency of limiting radiative forcing and climate warming until 2050, the compensation of methane emissions that occur once as a single pulse (running a Kon-Tiki for 2-3 hours) needs to be performed within a short time frame. Therefore, **methane emissions occurring during biochar production must be fully compensated within 20 years after emission**.

Trees grow over an extended period and slowly build up a natural C-sink. The C-sink is thus accumulative, i.e., the climate effect of a tree in the first, second, third…, twenties year sums up to the accumulative cooling effect. In the first year, the very small tree extracts only a tiny amount of CO_2 from the atmosphere, in the fifth year the extraction amount is already substantial, in the 20^{th} year it is a multiple of the fifth year's amount. The annual climate cooling effect is thus the highest towards the end of the 20-years period, while in the case of a methane emission, the global warming effect is highest in the first years after the emission because the atmospheric decomposition of methane is fastest in the beginning and slows down towards the end of the fifteenth year when eventually all CH_4-molecules of the emission decayed to CO_2 and H_2O.

To compensate the one-time methane emission with the accumulative C-sink of a growing tree or any other temporary C-sink, the effect of the methane emission and the C-sink are both converted into an amount of annual CO_2e that enables the calculation of the equivalent climate forcing (warming or cooling) during the 20-years' time horizon. To calculate the climate cooling effect of a nature-based solution like a growing tree, we do not base it on the carbon removal at the end of the selected period, but on the average annual C-sink in t CO_2e over the entire 20 years.

Calculating the climate warming effect of a CH_4-emission as done by the IPCC with the GWP100, and then calculating a corresponding climate cooling effect of an incremental CO_2 removal from the atmosphere over only 20 years, allows to establish a balance of the two effects at the end of the 20 years. Using this method, it can be determined how many tons of what type of C-sink are necessary to offset the climate warming effect of a given methane emission.

Methane compensation within Global Artisan C-Sink is defined as creating a carbon sink for 20 years that has a climate cooling effect equal to the climate warming effect of a methane emission over 100 years after the emission occurred. Thus, the total climate forcing of a methane emission must be compensated within 20 years after the initial emission.

The global warming that will be caused by the one-time methane emission is considered as compensated by an equivalent 20-year C-sink given that only a minor global warming effect of the methane-borne H_2O persists after the accounted 100 years.

14.4. Compensation of methane emissions by growing additional biomass

To compensate methane emissions, the Global Artisan C-Sink accepts the plantation of trees to create forest gardens on fallow land, silvo-pastures on pastures, agroforestry on annual and perennial crop land, re- and afforestation. Replacing existing older trees in a tree-crop or forest garden cultivation cannot be accounted for methane compensation. However, the active management of natural regeneration of eroded, deforested steppe land where natural regrowth of trees is promoted through measures such as scrub removal, weeding, irrigation, pruning, etc. can equally be accepted for methane compensation.

Young natural sprouting or newly planted trees grow slowly in the first five or so years and continuously increase the annual growth rate for the next twenty to thirty years, depending on the tree species, the soil, and climate. For most tropical trees, the growth rate follows an exponential function over the first >20 years. The tree's extraction of CO_2 from the atmosphere follows the growth rate and underlies the same exponential function. If methane emissions are compensated by newly planted trees over 20 years, as suggested above, the amount of compensated CO_2e is not the amount of carbon accumulated at the end of the 20th year (the yellow square in Figure 5) but the incremental global cooling effect of each years CO_2 removal. To compensate for the effect that the methane emission has on global warming, we need to calculate the tree's impact on global cooling, which means estimating the effect of the removed CO_2 for every year and summing up every year's effect over the 20 years. Here, we need to include the impulse response function (IRF) of the annual CO_2 removals because part of the removed CO_2 returns from oceanic and terrestrial carbon pools back to the atmosphere (i.e. reflux).

In the first five years of the tree growth, the climate effect is minimal, and then it increases rapidly every year.

To demonstrate the calculation, we choose a *Michelia champaca* tree planted in the tropics with sufficient precipitation and average soil quality. The tree grows quickly and will reach after twenty years the capacity to remove annually more than 1.3 t CO_2 from the atmosphere. The average growth curve of *Michelia champaca* is:

$$f(t) = 0.04664 \times e^{0.1676 * t} \text{ (for } t < 25)$$

Equation 5. The growth of Michelia champaca by an exponential function with t being the time in years since plantation.

Equation 5 allows to calculate the annual CO_2 removals over the first 20 years and thus the absolute global cooling effect of the tree over these 20 years using the IRF function provided by Jeltsch-Thömmes and Joos (2019). The IRF calculator for annual tree growth is provided on the Carbon Standards webpage.

A *Michelia Champaca* tree accumulates during the first 20 years of its growth on average 1.3 t CO_2e which represent an absolute global cooling of 6.4 t ACO_2e over these 20 years.

In Box 1 above we used the example of 10 tons biochar that cause an absolute global warming potential of 381.0 tons ACO_2e over 100 years related to the methane emission of its Kon-Tiki production. To compensate this global warming entirely with tree based global cooling over 20 years, (381.0 t ACO_2 / 6.4 t ACO_2e =) 60 *Michelia champaca* trees would have to be planted and grown over 20 years.

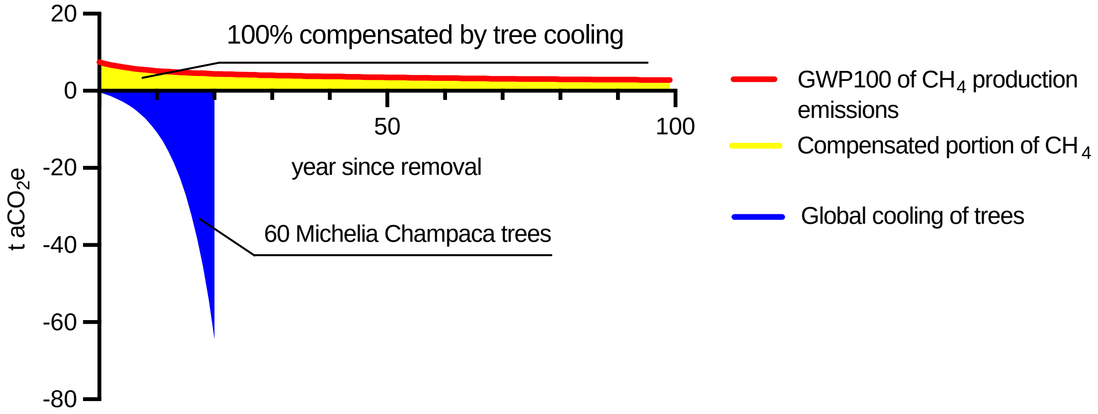

Figure 5. *The production of 10 t biochar in a Kon-Tiki causing 300 kg CH_4 with a GWP100 of 7.5 t CO_2e presenting a global warming effect over 100 years of 381.0 t aCO_2e (area below the red curve). The plantation of 60 Michelia Champaca trees removes a total of 77.5 t CO_2e over 20 years, presenting an absolute global cooling effect over 20 years of 381.1 t a CO_2e (blue area). The yellow area presents the part of the global warming caused by the methane emission that is compensated by the global cooling caused by the tree growth. The blue and the yellow area are of the same size. As the global cooling effect of the 60 trees over 20 years is equal to the global warming effect of the methane emission over 100 years, the methane emission can be considered compensated after 20 years.*

If part of the methane emissions are compensated with the SPC fraction of biochar (see next chapter), the number of necessary trees will be reduced. This can equally be computed in the online calculator on the Carbon Standards webpage. It should be noted that further climate-relevant effects of the tree such as change in albedo, evapotranspiration, and increase in soil organic carbon are not considered here.

Fast-growing tropical Giant Bamboo (*Dendrocalamus Asper*) plants grow exponentially over the first eight years and can maintain thereafter its atmospheric carbon accumulation at a stable rate when the annual regrowth is continuously harvested. Such a bamboo plant accumulates during the first 20 years of its growth and partial harvest on average 23.3 t CO_2e which represent an absolute global cooling of 30.9 t

ACO_2e over these 20 years. Using again the example from Box 1 above and compensating the absolute global warming potential of the methane emissions caused by the production of 10 t Kon-Tiki biochar with a bamboo plantation, only (381.0 t ACO2 / 30.9 t ACO2e =) 13 such fast growing bamboo plants would be necessary even when harvesting the annual regrowth from the ninth growing year onwards.

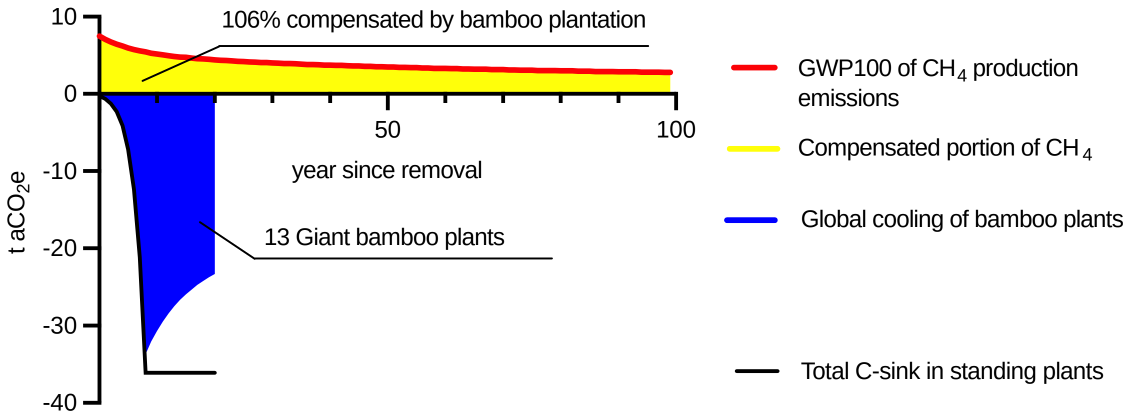

Figure 6. *The production of 10 t biochar in a Kon-Tiki causing 300 kg CH_4 with a GWP100 of 7.5 t CO_2e, presenting a global warming effect over 100 years of 381.0 t aCO_2e (area below the red curve). The plantation of 13 Giant Bamboo* (*Dendrocalamus Asper*) *removes a total of 23.3 t CO_2e over 20 years, presenting an absolute global cooling effect over 20 years of 401.7 t a CO_2e (blue area). The yellow area presents the part of the global warming caused by the methane emission that is compensated by the global cooling caused by the tree growth. The blue and the yellow area are of the same size. As the global cooling effect of the 13 bamboo plants over 20 years is equal to the global warming effect of the methane emission over 100 years, the methane emission can be considered compensated after 20 years.*

As part of the Global Tree C-Sink standard, the Ithaka Institute develops an open-access database collecting the growth curves and corresponding sequestration functions of the most frequently used trees in the countries of the Global Artisan C-Sink standard. Based on this database, the expected growth curves of the trees can be calculated and used to compensate methane emissions of artisan biochar production. However, **all tree plantations considered for methane offsetting must be certified under the Global Tree C-Sink standard and registered in the Global C-Sink Registry.**

After the compensation period of 20 years, the trees can be used without any further restrictions, i.e., the carbon contained in the tree can be assessed as carbon removal from the 21st year onwards. If, for example, the tree is cut after 20 years and the trunk is used as a beam in a building, the beam-carbon could be considered a C-sink for as long as the beam stays in place.

14.5. Offsetting methane emissions with the SPC-fraction of biochar

The global warming effect of methane emissions caused by a Kon-Tiki or TLUD can at least partly be offset by the global cooling effect of the first 20 years of the SPC fraction. To calculate it correctly, the annual global cooling of the SPC for each of the first 20 years must be summed-up and match the AGWP100 of the CH_4 emission to be compensated.

Let's use the example from Box 1 above where 10 tons Kon-Tiki biochar caused 300 kg CH_4 with a AGWP over 100 years of 381.0 tons aCO_2e. The SPC fraction of the 10 tons biochar with a C-content of 80% represents 7.3 t CO_2e. Due to the reflux function as shown with the blue line in figure 8, the absolute global cooling of the decaying SPC fraction over 20 years is 83.7 t aCO_2e. The SPC fraction of the produced biochar can thus compensate (83.7 / 381.0 =) 22% of the methane emissions caused by the Kon-Tiki biochar production. The remaining (381 t aCO_2e – 83.7 t aCO_2e =) 297.3 t aCO_2e of global warming caused by the methane emission must be compensated by other means during the 20 years following the emission.

Carbon Standards provides a Global Cooling Calculator for the SPC fractions on its website.

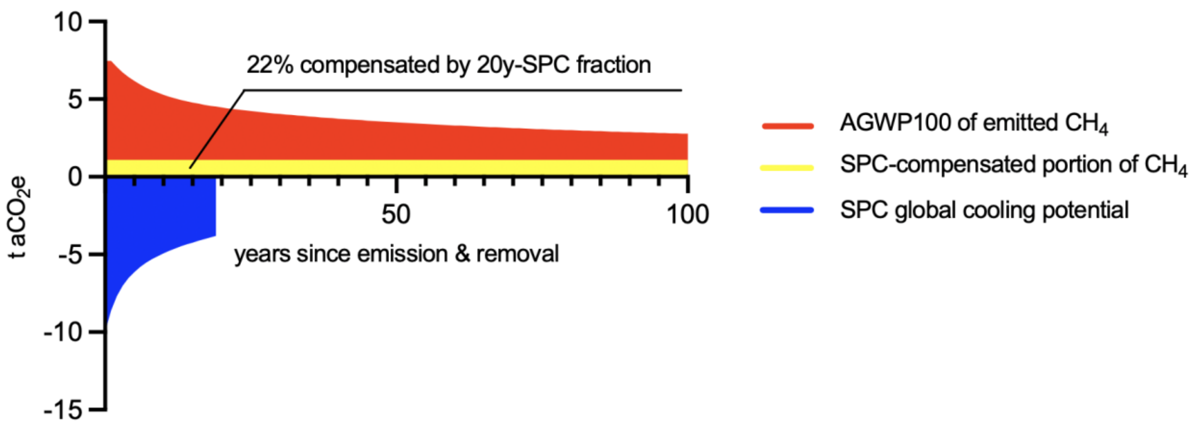

Figure 7: ***Compensating CH_4 emissions with the temporary C-sink of the SPC fraction.*** *The production of 10 t biochar in a Kon-Tiki caused 300 kg CH_4 with an absolute global warming potential (AGWP) over 100 years of 381.0 t aCO_2e (area below the red curve). The semi-persistent carbon (SPC) fraction of the 10-ton soil-applied biochar with a C-content of 80% represents a 7.3 t CO_2e removal from the atmosphere. Considering the slow decay of the SPC fraction and the reflux function of the CO_2e removal, the SPC fraction causes a global cooling effect of 83.7 t aCO_2e during the first 20 years since the methane emission (blue area above the blue curve). The yellow area presents the part of the global warming caused by the methane emission that is compensated by the global cooling caused by the SPC fraction. The compensated part of the total CH_4 emissions is 22.0 %.*

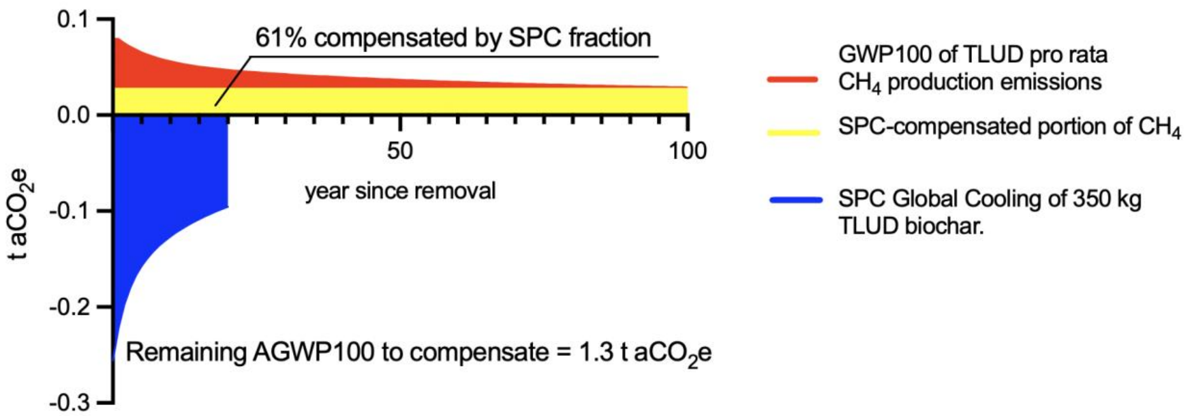

Figure 8: ***Compensating TLUD emissions****. If a TLUD stove is used three times per day 365 days a year, it produces roughly 350 kg biochar (DM). At 25 g CH_4 per kg biochar, the annual CH_4 emissions would be 8.75 kg, corresponding to the global warming potential over 100 years of an emission of 218.75 kg CO_2. Considering a pro-rata between cooking and biochar-containing energy of 37%, the CH_4 emissions to be accounted for the biochar are only 80.9 kg CO_2e and present an absolute global warming potential over 100 years of 4.1 t CO_2e (red curve). The semi-persistent carbon (SPC) fraction of the 350 kg soil-applied biochar with a C-content of 80% represents a 257 kg CO_2e removal from the atmosphere with an absolute global cooling potential of 2.85 t aCO_2e over 20 years. Thus, (2.85 t aCO_2e /4.1 t aCO_2e =) 69% of the pro rata emissions of the biochar can be compensated with the SPC fraction. The remaining 1.27 t aCO_2e (over 20y) for one year of family cooking could be compensated with planting, e.g., a giant bamboo (i.e., AGCP of 1.3 t aCO_2 over 20 years) which would deliver a good part of the yearly cooking wood.*

14.6. Avoiding GHG-emissions from burning crop residues

In many tropical countries, crop residues are burnt directly in the fields. While it has some positive effects on farming (ash fertilization, some pyrogenic carbon, elimination of pests), emissions of such practices are massive. Besides significant emissions of particulate matter that cause smog (the main reason for air pollution, e.g., in Delhi (Shyamsundar et al., 2019), methane and carbon monoxide emissions are very high due to the uncontrolled combustion of mostly wet or humid residues (Lin and Begho, 2022).

Based on the published data summarized below, it is assumed that the overall climate impact of pyrolysis within Global Artisan C-sink is in any case not worse than direct burning of crop residues in the field. Therefore, abandoning crop residue burning can be accounted as an offset for emissions of Kon-Tiki-pyrolysis within the limits specified below.

Today, there are only few scientific publications about emissions from the Kon-Tiki and from crop burning in open fields. Both, crop residue burning and the Kon-Tiki release particulate matter, carbon monoxide, nitrogen oxides (NO_x), methane, and some other gases to the atmosphere. While the effect of methane on climate warming can be stated with certainty, the climate effect of those other gases is less clear, and the IPCC does not provide a global warming potential for their conversion into CO_2e.

It is technically challenging to measure methane emissions from crop waste burning in open fields. The few available data include data from airplane sampling, remote sensing, and small-scale lab trials, which do not allow precisely relating the emissions to the amount of burnt crop waste. Based on a review of 20 emission studies, the burning of agricultural residues causes 5.7±6.0 kg of methane emissions per ton of feedstock (Andreae, 2019), which is similar compared to the data measured for the biochar production in a Kon-Tiki (Gerard Cornelissen et al., 2016). 30 kg methane per ton of biochar corresponds to 4.2±1.2 kg methane per ton feedstock considering typical Kon-Tiki biochar yields of 14±3% of feedstock dry matter (Karananidi et al., 2020).

However, the pyrolysis of agricultural residues in a Kon-Tiki system emits seven times less CO, four times less particulate matter, and 33 times less NO_x (Andreae, 2019; Gerard Cornelissen et al., 2016). Treating agricultural residues with a Kon-Tiki significantly reduces the environmental burden of crop residue burning and does not increase total GHG emissions. Carbon monoxide is not a greenhouse gas, but its emission contributes to ozone changes in the troposphere and slows down atmospheric methane degradation (Prather, 1996; Prather et al., 2012). Carbon monoxide, NO_x, and particulate matter, reduce air quality and contribute to respiratory diseases.

Thus, despite complex atmospheric physics and chemistry and very limited data, replacing crop residue burning with pyrolysis in a Kon-Tiki is a sound approach to contribute to climate change mitigation and improvement of air quality that should be promoted by accounting this measure as an offset for greenhouse gas emissions occurring during Kon-Tiki pyrolysis. Changing agricultural habits is always tricky and switching from burning the fields to pyrolyzing the residues is not a slight change of tradition. To perpetuate the abandonment of field burning (including crop residue burning, gras and stubble burning), farmers must sign a declaration of honor not to burn harvest residues anymore. The Artisan C-Sink Manager must define the exact wording of this declaration of honor depending on the prevailing tradition of crop waste treatment in the region. The Artisan C-Sink Manager must define separate control mechanisms for compliance with the declaration of honor. Only when the farmer, farming company, or farming organization signed the declaration, the compensation of Kon-Tiki emissions by avoiding field burning emissions can be accepted for a limited time horizon of 10 years. If a farmer or farming company or organization burns one of its fields, they lose the entitlement to generate C-sink certificates with Kon-Tiki pyrolysis on their land for at least five years.

During a transition phase of a maximal of three years, farmers may stop crop residue burning in some of their fields and continue the traditional practice in other clearly separated fields. We allow such a transition phase to facilitate the decision-making process, as it is always challenging to change a traditional practice. The transition phase needs to be clearly documented by the Artisan C-Sink Manager. The certifier is entitled to verify it.

14.7. Avoiding GHG-emission from biomass decomposition

When biomass is pyrolyzed that otherwise would decompose uncontrolled, the avoided emissions from biomass decomposition can equally be used to compensate for CH_4 emissions of the Kon-Tiki. Examples are cocoa pods, sawdust from sawmills, pulp from coffee, oil palm residues, and sugar cane filter cake. Uncontrolled decomposition, especially in the humid tropics, can cause significant methane emissions in the same or higher range than CH_4 emissions during Kon-Tiki pyrolysis. However, data allowing the calculation of emission factors is scarce and not all crop residues left in the fields or at production sites cause methane emissions, and there are plenty of other methods to avoid methane emissions from uncontrolled decomposition. Spreading the biomass on the soil exposed to sunlight for drying and aeration to prevent anoxic conditions is equally efficient. However, in many cases, the tradition of leaving crop residuals or processing waste carelessly behind is so strong that it needs strong incentives to change the habits. In such situations, the compensation of methane emission from the Kon-Tiki with the avoidance of uncontrolled biomass decomposition can be accepted.

If avoided emissions from biomass decomposition can be accepted for methane compensation, has to be decided case by case by Carbon Standards. A flowchart of the current practice has to be submitted by the Artisan C-Sink Manager for evaluation. A well-founded estimate of current methane emissions can be submitted to support the proposal. If accepted by Carbon Standards, the contracted farmer must sign a declaration of honor to stop the uncontrolled decomposition of crop residues in the fields cultivated by him. The exact wording of this declaration of honor must be defined by the Artisan C-Sink Manager. A written form with original signature is mandatory. The Artisan C-Sink Manager must define separate control mechanisms for compliance with the declaration of honor. If a farmer recommences to leave crop residues in his fields decomposing uncontrolled, he loses the entitlement to generate C-sink certificates with Kon-Tiki pyrolysis compensated by emission avoidance for five years. Mulching with crop residues is not considered as uncontrolled decomposition nor is composting or anaerobic digestion.

14.8. Time horizon for methane compensation by emission avoidance

Compensation of methane emissions with avoided emissions from crop residue burning or from decomposition requires a “reference scenario” in which crop residues are burned and/or biomass is subject to uncontrolled decomposition. As avoided emissions cannot be measured physically, their benefit to the climate solely depends on socio-economic assumptions. Still, they are a useful tool to stop unsustainable practices.

In this context, Global Artisan C-sink defines a time horizon of 10 years after the first issuance of a Biochar Artisan C-sink certificate. After these 10 years, the new practice is considered common practice and cannot be used to compensate the climate warming of any emissions anymore. By then, methane emissions can only be compensated through the removal of CO_2, e.g., via the plantation of trees or SPC fractions of biochar. The time horizon must be included in the contract between the Artisan C-Sink Manager and the farmer, farming company, or organization. It must also be part of the declaration of honor.

15. How to prepare the analytical and retention samples

15.1. Analytical samples for C-Sink Farmers

If the biochar feedstock is already listed in the Artisan biochar database and if the annual production does not exceed 100 m^3, no retention and analytical samples are required. The technology of flame curtain pyrolysis allows the production of biochar with rather constant properties when the same type of feedstock is used. The main parameters influencing the biochar properties in Kon-Tiki type kilns when using the same feedstock are the water content of the feedstock and the craft of the Artisan Biochar Producer. For this reason, particular attention is paid to the education of the Artisan Biochar Producers and the pre-drying of the feedstock, especially during the rainy seasons.

If the feedstock or feedstock mixture is not listed in the Artisan biochar database, a biochar sample must be sent to an endorsed laboratory (Chapter 15.3) to analyze at least the carbon content and include it in the Artisan biochar database according to the following protocol:

1. After biochar production, the entire Kon-Tiki needs to be emptied on a clean floor to take a sample.
2. To obtain a biochar sample sufficiently representative for the production load, the biochar needs to be shoveled two times from one pile to another pile.
3. Take then 12 samples of about three liters at twelve different pile spots. Put all 12 subsamples in a bucket or vat or pile them again on a clean floor.
4. Mix the biochar of the 12 subsamples thoroughly and take then three liter and seal it in a clean airtight bag to be sent to the laboratory.

Ideally, the sampling would be done by a Carbon Standards endorsed sample taker. Carbon Standards offers online sample taking courses with examen for the endorsement. The C-Sink Manager must submit a detailed sampling plan to Carbon Standard.

15.2. Analytical samples for Artisan Biochar Processors from C-Sink Villages

- The biochar of each C-Sink Village must be sampled separately.
- The sampling procedures depend on the daily, weekly, and monthly amounts of collected biochar and the procedures of processing the biochar. Therefore, a detailed sampling plan for the biochar produced by every C-Sink Village must be submitted to Carbon Standards.

15.3. Retention sample for Artisan Pro producers

Artisan Pro certified producers with a production capacity of more than 100 m^3 biochar per year must take retention samples according to the following protocol:

1. Biochar samples are taken from each production load made with a Kon-Tiki type kiln.
2. Take four samples at four different spots of each Kon-Tiki load (middle, lower third, upper third, top of the kiln) using a sample cup of at least 100 ml.
3. If the feedstock does not vary by more than 20%, the retention samples from different loads and different kilns of the same production site can be united in the same closable container or vat for a maximum of six months. After six months the sample container or vat must be sealed and a new sample container or vat for the next series of retention samples started.
4. The sealed six-month sample container must be stored for at least 24 months.
5. At least once a year, an endorsed sampler from the Artisan C-Sink Manager will take a representative sample from the six-month sample container and send it to an endorsed laboratory for analysis.
6. The samples are analyzed according to the specifications of the European Biochar Certificate (EBC, 2012) for the following parameters: C, H, ash, pH, water holding capacity.

The data generated by the endorsed analysis are used to certify the biochar quality and to calculate the C-sink.

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

The endorsed sampler must seal the representative samples for analysis. The producer sends the sealed sample to the endorsed laboratory selected by the producing company.

15.3.1. The endorsed laboratory shall send the analysis results to the biochar-producing company and a copy to the endorsed Certifier, Carbon Standard, and the Ithaka Institute.

15.3.2. The Ithaka Institute has the right to use the results of the analysis in anonymized form for statistical and scientific purposes.

15.5. Analyses and endorsement of local laboratories

To endorse a local laboratory for the analysis of the carbon content of biochar, Ithaka will send two fully EBC analyzed standard biochar samples to the new laboratory for the analysis of C-content. The difference between the results of the new laboratory and the endorsed laboratory must not exceed 6% for each respective biochar.

To endorse laboratories that analyze biochar for Artisan Pro, the above procedure must be followed for the parameters: C, H/C, ash, pH, and water holding capacity.

Laboratories are invited to participate in the official EBC interlaboratory ring trial organized every year. Passing the EBC proficiency test allows Carbon Standards to endorse the laboratory for the corresponding parameter of biochar analysis. Information and procedures for laboratory endorsement can be found on the website of Carbon Standards.

15.6. Analyses to be provided by the Artisan C-Sink Manager

As it is practically unfeasible to measure the dry weight of each biochar run produced by every C-Sink Farmer or C-Sink Cook, a decision was made to establish the standard measurement parameter for artisanal biochar as the volume of biochar relative to the type of feedstock used. To convert this biochar volume into its corresponding dry weight, it becomes essential to determine the bulk density of the biochar based on the specific feedstock utilized. However, sending raw biochar samples to laboratories, especially those located abroad, not only consumes a significant amount of time but also risks altering the biochar particles, potentially leading to inaccurate bulk density measurements. Therefore, Artisan C-Sink Managers are encouraged to acquire the necessary equipment, such as ovens and devices, for analyzing the bulk density of biochar near the production facilities, following the methods outlined in Annex 2. Alternatively, they can commission a local laboratory to measure the bulk density following the Global Artisan C-Sink method.

Artisan C-Sink Manger must successfully complete the online course for sample takers provided by Carbon Standards.

16. Trading and labeling of biochar

A Biochar Trader buys biochar from C-Sink Farmers, C-Sink Villages, C-Sink Networks, and/or Artisan Pro producers. He may process the biochar into biochar-based products and sell those or the pure biochar to farmers or industries (e.g., for construction materials). The Biochar Traders must be certified under Global Artisan C-Sink and are not allowed to trade biochar that is not certified under Global Artisan C-Sink.

If a farmer or company produces biochar and sells it to other farmers or users, the buyer must also use the Artisan App to document and track the application to soil, compost, anaerobic digestor, or its use in animal farming systems or in any other way that preserves predictably the biochar carbon. Otherwise, the biochar cannot be certified as a carbon sink. With that level of security, it is the same as if the Artisan Biochar Producer would have applied the biochar him/herself.

If the biochar is sold to a Biochar Trader, the trader must be registered and monitored by the Artisan C-Sink Manager to ensure the complete tracking of the traded biochar to the eventual carbon sink. Otherwise, the biochar cannot be certified as a carbon sink.

International trade is not allowed within Global Artisan C-sink. For biochar that shall be traded across borders, the guidelines for industrial biochar production apply (EBC 2012-2023, WBC 2023). An exception may be granted in border regions with cross-border exchange of agricultural goods.

Traded biochar must be labeled containing the name and address of the Biochar Trader, the feedstock the biochar was made from, the C-content, and the year of production.

17. Endorsement of the Artisan C-Sink Manager

The endorsement process contains a full application review by Carbon Standards (in general, this implies several review rounds and may include consulting by external partners.

Companies, non-governmental organizations, farmer unions, or regional authorities may become Artisan C-Sink Managers for the Global Artisan C-sink certificate. The purpose of the pre-audit interview (an online video meeting) is to clarify expectations and discuss the upcoming certification process.

The Artisan C-Sink Manager must submit a Project Design Document (PDD) that includes at least the following chapters (the template for the PDD is provided by Carbon Standards (https://www.carbon-standards.com/en/standards/service-505~global-artisan-c-sink.html)).

a. Description of the applicant (type of organization, existing local structures, etc.)

b. Scope of the activities (definition of the region, type of farming, if the activities are restricted or at least focused on farming, especially when focused on special crops or industries, e.g., coffee, cocoa, oil palm, sugar cane, etc.)

c. C-sink registry (written documentation of the local registries' architecture including back-up and IT security, protocol for data transfer to the Global C-sink Registry)

d. Biochar artisan payment scheme (when, how, and at what rate the c-sink money is paid to whom)

e. Procedures for the on-site control and monitoring strategy (i.e., type and frequency of monitoring, how to measure its effectiveness, etc.)

f. Infrastructure and procedures to assure that biochar samples are taken correctly and reach the endorsed laboratory in proper condition.

The Artisan C-Sink Manager can delegate defined tasks of the managing and monitoring process to other organizations or persons, such as training in making biochar, C-sink tracking, and on-site controls. However, the Artisan C-Sink Manager is entirely responsible for all activities related to the production, monitoring, and declaration of Global Artisan C-Sinks as described in the present guidelines.

The detailed procedures for Artisan C-Sink Manager endorsement and certification can be found on the dedicated web page at Carbon Standards (https://www.carbon-standards.com/en/standards/service-505~global-artisan-c-sink.html).

18. Additionality

Despite being a century-old tradition in some parts of the world (Wiedner and Glaser, 2015), the production and application of artisanal biochar are not widespread in most tropical countries. Artisanal biochar producers do not generate income yet with biochar in most regions, there is no market for biochar-based fertilizers, and the production costs are higher than the expected agronomic benefit, or tropical smallholder farmers do not have the financial resources to pay biochar-based fertilizers. Farmers could produce their biochar from their feedstock to improve their yields, but without the training provided by the Artisan C-Sink Manager, they would hardly acquire the craft to do so.

The Global Artisan C-sink will, thus, be the decisive monetary incentive and knowledge transfer to produce climate positive biochar and thus carbon sinks. The Artisan C-Sink Manager will provide not only training on biochar production but also on the preparation and application of biochar-based fertilizers, which (a) will enable most farmers to establish this practice and (b) will avoid the adoption of unsustainable biochar production practices which could result in pollution and GHG-emissions. Moreover, methane compensation, as introduced by the Global Artisan C-sink is a key element to achieving net negative emissions with Kon-Tiki based PyCCS.

Artisan Pro will mainly sell their biochar, and one might argue that selling the biochar could fund this practice alone. However, without the income from C-sink certificates, the price for biochar would be too high to establish local markets. Moreover, Global Artisan C-sink assures the adoption of low-emission technology, methane compensation, and the use of sustainably sourced biomass. Without those boundary conditions, biochar production in countries with low purchasing power and limited financial and technical possibilities would hardly result in net negative emissions. Hence, additionality of any C-sink certificates issued under this standard is guaranteed.

19. Exclusivity

The demand for negative emissions and the generally high potential to generate negative emissions in the tropics with nature-based solutions will create numerous methodologies for certification, e.g., biomass carbon capture and use (BCCU) and soil organic carbon. Moreover, there are existing schemes for afforestation and reforestation. All approaches differ in permanence and risks of a partial or total loss of the carbon sink.

In general, farmers and biochar producers benefitting from Global Artisan C-Sink shall not be certified under any other methodology for nature-based climate services (i.e., biomass production and soil organic carbon). This needs to be assessed and controlled by the Artisan C-Sink Manager.

Biochar application will increase soil organic carbon as a co-benefit. However, a routine soil analysis cannot distinguish soil organic matter and biochar-derived carbon. It is, thus, not possible to measure soil organic carbon increases without an accurate assessment of the applied biochar, and it is, therefore, not permitted to create a C-sink certificate for soil organic carbon on the fields registered for Global Artisan C-Sink. Within Global Artisan C-Sink, increases in soil organic carbon are looked at as a co-benefit, and additionality is thus not given. The time horizon must be included in the contract between the Artisan C-Sink Manager and the farmer, farming company, or organization. It must also be part of the declaration of honor.

Planting trees to compensate for methane emissions could interfere with additional afforestation or reforestation programs. It might result in double accounting, which must be prevented through explicit registration of all cultivated land. Exceptions to the exclusivity rule are, therefore, possible if the Artisan C-Sink Manager can explain why an additional C-sink certification for a nature-based solution is meaningful and how double accounting is efficiently prevented. An example is a certification of a newly planted bamboo forest that is not used for methane compensation.

Carbon Standards must explicitly permit all exceptions.

20. Closing remark

Several finicking points and exceptions that cannot be addressed in the general guidelines with sufficient detail remain and will be solved in annexes and updates according to practical needs.

The Kon-Tiki and TLUDs are seen as bridge technologies and should as soon as possible be replaced by cooking and pyrolysis technology with better control of gas combustion and uses of biomass energy. (Schmidt et al., 2019).

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Annex 1. Bulk Density Analysis for Biochar Produced in a Kon-Tiki under the Global Artisan Standard.

Version 2 (9/18/23)

The bulk density of the unground sample as delivered must be analyzed following the procedures of DIN EN ISO 17828 or ASTM D291/D291M-20. Two photographs with a resolution of at least 300 dpi from the bulk biochar sample must be taken and recorded with the analytical results.

The sample has to be analyzed as produced and delivered. The sample is neither dried nor milled.

NOTE:

Bulk density of biochar may be altered by transport, storage, or handling. Therefore, factors, such as vibrations, shocks, pressure, drying, and humidification, must be avoided when transporting the biochar from the production site to the laboratory.

A) For biochar with a maximum particle size of 50 mm

The minimum sample volume is 30 liters.

1. 90% of the sample material must present a particle size below 50 mm, and no particle must be larger than 100 mm.
2. Use a measuring box of 300 mm x 300 mm x 350 mm. The measuring box is ideally made from steel or aluminum but can also be made from wood or plastic.
3. Add an indelible marker (e.g., by paint, adhesive tape) at the insight of the measuring box at the height of 300 mm.
4. Measure the weight of the measuring box.
5. Fill the measuring box up to the 300 mm height marker. Be exact!
6. Weight the measuring box with the biochar.
7. Dry the open measuring box for 24 h at 80 to 110 °C in a ventilated drying oven.
8. Measure the weight of the measuring box immediately when removing it from the drying oven.
9. Calculate the bulk density and water content using the following formula.

$$\text{Bulk density} = \frac{\text{Dry weight}^{a)}}{\text{Biochar Volume}}$$

Equation 2. Biochar bulk density calculation. Dry weight = Weight after drying – Weight of the measuring box.

$$\text{Water content} = \text{Weight before drying} - \text{Weight after drying}$$

Equation 3. Biochar water content calculation

B) For biochar with a particle size > 50 mm

For samples, where more than 10% of the particles present a particle size larger than 50 mm and/or present particles with a particle size > 100 mm, the necessary sampling volume becomes impracticable large (>120 l). Please contact in those cases the Ithaka Institute for further instructions and a practicable solution.