Project Design Document

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Name of project:	Sonnenerde PyroDry
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Methodology:	Global Biochar C-Sink 3.1

Project location:	Oberwarter Strasse 100, 7422 Riedlingsdorf, Austria
Project start date:	30.11.2021
Project period:	The project has no end date, but it is verified on an annual basis
Project summary:	Sonnenerde is a true pioneer in the production of high-quality biochar. All the way back in 2012 it was one of the very first European companies to produce biochar from organic waste. The company has spent 6 years researching the use of biochar to produce a highly fertile terra preta like soil. Since then, the use of biochar as a soil additive has been continuously developed. Today, Sonnenerde and its subsidiary CharLine offer a wide range of ready-to-use biochar products, including a special substrate for the sustainable planting of urban trees. The two companies share the same premises, as well as the necessary infrastructure and machinery. Sonnenerde and CharLine continuously invest in research and development to open up new areas of climate-positive application for biochar. C-Sinks are generated exclusively by Sonnenerde, whereby all processing steps of the subsidiary ChraLine are also taken into account. The project increases carbon sequestration by working the produced biochar into different matrixes and in this way create a long-term carbon storage with a persistence of up to 1000 years as according to the Global Biochar C-Sink Standard. Without the project, no C-sink would be created since biogenic waste does not constitute a long-term carbon reservoir. In the initial 5 years of the project we expect carbon sequestration of approximately 6750 to CO2eq in total or 1350 to CO2eq / year.

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1. Purpose and general description of project

The project Sonnenerde PyroDry compromises one pyrolysis plant for biochar production from organic residues. Biochar is a versatile material with an increasing number of applications in agriculture, environmental engineering, and basic industry. Biochar applied a matrix permitted by the Global C-Sink Standard poses a stable carbon sink (C-sink). Without the project, no C-sink would be created since organic residues do not constitute a long-term carbon reservoir.

The raw materials for biochar production are organic residues from the processing of biomass and waste wood from landscape conservation. Without project activity this waste materials would release greenhouse gases due to disposal and decomposition.

Sonnenerde manufactures a range of biochar-based high-quality substrates and soil improvement products for various scopes. The subsidiary CharLine offers ready-to-use biochar products for agriculture. Biochar can improve soil quality significantly because of its impact on the soil pH, its water retention capacity, and its ability to store nutrients.

Sonnenerde and CharLIne continuously invest in research and development to find new climate-positive fields of application for biochar. There is a wide range of possible applications for biochar, for example as an additive in building materials or in the technical industry.

1.1. Project location

The company Sonnenerde and its subsidiary CharLine are located in Riedinglingsdorf in Eastern Austria.

GPS location of pyrolysis unit:

Latitude, longitude: 47.3300432692775,16.153561287932853

The geographical locations of the subsequently installed plants will be documented in the biochar tool.

Sonnenerde and its subsidiary CharLine process the biochar directly at the company site into ready-to-use products for clearly defined areas of application. These biochar products are sold to end customers and resellers primarily in Austria and Central Europe.

1.2. Description of baseline scenario

The raw materials for biochar production are organic residues from the processing of biomass and waste wood from landscape conservation. In a scenario without project activity greenhouse gases would be released due to disposal and decompostition or incineration.

The baseline scenario for carbon removal accounting is the "business as usual", in which no permanent biochar-based carbon sink is generated and is considered as zero. The fact that biomass could have been used differently in the baseline scenario, has no impact on the consideration of the baseline as zero. This is ensured by following the regulations of chapter 2 of the EBC C-sink Standard.

$$C - sink\ (Baseline) = \ 0\ tCO2e$$

1.3. Biochar carbon sinks

When plant biomass is burnt or decomposed, the assimilated carbon is released again in the form of CO2. However, if the plant biomass is pyrolyzed, about half of the plant carbon is transformed into a mixture of predominantly very persistent carbon compounds that form a solid material known as biochar. While in the environment, any carbon compound is subject to degradation; for most components of biochar, this process is extremely slow, and mostly even so slow, that it is hard to measure for thousands of years. Provided that the biochar is not burned, the biochar carbon remains as a C-sink in the terrestrial system.

If biochar with an H to Corg ratio < 0.40 is applied to soil, a major part of its carbon is considered Persistent Aromatic Carbon (PAC, the portion of biochar carbon bound in clusters of more than seven aromatic rings as analyzed by the hydro pyrolysis method) and will constitute a carbon sink for several millennia. A minor though relevant part of the biochar-carbon is less persistent (semi persistent carbon, SPC) and likely to be microbially degraded within decades to centuries, presenting a mean residence time of 50 years. The biochar carbon that may be decomposed within the first 1000 years after the application to soil is called Semi-Persistent Carbon (SPC) and constitutes a temporary C- sink. For biochars presenting an H to Corg ratio < 0.4, the PAC fraction is conservatively fixed by the standard at 75% and the SPC fraction at 25%.

1.4. Project Boundary

The emissions of fossil-carbon-derived CH_4, N_2O, and CO_2 caused by biochar production are recorded as follows:

a) Emissions from the provision of biomass
Only organic residues and waste wood from landscape conservation are used for biochar production. According to Global Biochar C-Sink Standard 3.1 Chapter 5.3.6 these raw materials are considered as C-neutral input materials.
However, emissions from the delivery of external biomass to the company site are taken into account

b) Emissions from the storage of the biomass
In order to avoid emissions from the storage of biomass, the recommendations of the Global Biochar C-Sink Standard 3.1 Chapter 6 are implemented.
If biomass has to be shredded, it is chipped only a few days and at a maximum of four weeks before pyrolysis.

c) Emissions from the pyrolysis process and other equipment at the production site
Emissions associated with the production and processing of biochar are recorded in accordance with the Global Biochar C-Sink Standard 3.1 Chapter 7.1.

The energy and fuel-related carbon expenditure for the entire process chain, from the provision of biomass to the packaging of the biochar, is calculated in CO_2eq and included in the emission portfolio of the batch and the respective production unit (i.e., the pyrolysis unitthat is used to produce the batch). This concerns in particular:

1) Onsite Transportation of the biomass to the pyrolysis plant.
2) Chipping, homogenization, and drying of the biomass.
3) GHG emissions of the pyrolysis plant (electricity and fuel consumption).
4) Post-pyrolysis treatment of the biochar (e.g. mixing, grinding, pelletizing, etc.).
5) Transport of the biochar to the collection depot (factory gate).

d) A safety margin in the amount of 20 kg CO_2eq per ton of biochar is added to account for all additional emissions not covered under the regular assessment.

The emissions are calculated by adding all the above-listed emissions as CO_2eq. For N_2O the GWP100 of 298 t CO_2eq t-1 is used as conversion factor, respectively (IPCC, 2022). The emission factor is given as mass proportion based on the dry weight of the biochar (t CO_2eq t-1). It is calculated by dividing the total amount of carbon expenditures per batch by the dry weight of the total amount of biochar produced per batch.

For Scope 3 emissions of involved organizations, only the emissions from biomass production transport of biomass or biochar and derived products are directly quantified. Other indirect emissions from Scope 3 are not recorded individually due to their comparatively low volume but are instead included in the calculation with a flat margin of safety to account for the whole value chain.
Organizations are required to include the emissions upstream to the next organization in their emissions portfolio. The last organization in the chain before the C-sink is established and registered is also responsible for reporting transport emissions downstream in their emission portfolio.

1.5. Eligibility

☒ Production of biochar according to EBC/WBC criteria in place.

☒ Producer is a legal entity and hold an operating license for the entire project region.

☒ Social Impact: The project complies with the requirements set by the methodology, see annex 17-0-2EN Self-Assessment Social Responsibility.

☒ The C-sinks issued in this project are not claimed in any other Carbon Crediting Scheme.

1.6. Ownership

By default the owner of a potential C-sink is the owner of the material that contains carbon in a stable form, thus the owner of the physical products as biomass or biochar or biochar containing products. With each sale of biochar or biochar-based products the ownership of the material that eventually forms a C-sink is transferred to the new owner. Every packaging unit containing more than 1 t CO_2eq of biochar must be labeled with a scannable identification code revealing the current owner of the C-sink material.

If the product is traded without its climate effect represented by the C-sink value it must be labeled informing the buyer that the C-sink of the product is already registered and cannot be claimed for other emission compensations. This reference must at least be made by printing the following Carbon Standards registered seal: "Registered C-Sink" and a QR-Code with the web link to more detailed information about the C-sink registration and use. This applies especially to diffuse C-sinks and biochar applied to soil.

For temporary C-sinks the biochar-carbon is part of a material matrix that is owned by a legal entity, and the C-sink cannot be dissociated from the imbedding material such as thermoplastics, textiles, carbon fiber composites, asphalt, or concrete.

The C-sink value is therefore the property of the owner of the material, unless it is clearly stated on the receipts that the C-sink was not sold with it.

1.7. Additionality

The required additionality test consists of 3 steps. The project is deemed additional if it leads to additional carbon removal.

1.7.1. Assessment of regulatory requirements for biochar production and application as a removal technology

Sonnenerde was granted a license under Austrian trade law for the operation of its biochar plants. All legal requirements are defined in the decision. According to this decision there are no legally binding requirements for carbon-preserving application of biochar.

1.7.2. Additional Carbon Removal

The C-sink efficiency of a pyrolysis facility is a measure of the part of biomass-carbon that is preserved by a technical transformation process as a potential C-sink. According to chapter 4.2.5 of the PDD the producer commits to publish the C-sink efficiency of the production facility annually. This makes the clear objective of transforming a growing proportion of biomass carbon into carbon sinks transparent.

1.7.3. Biomass Feedstock Additionality

Sonnenerde uses organic residues from the processing of biomass and waste wood from landscape conservartion for biochar production. In a scenario without project activity greenhouse gases would be released due to disposal and decompostition or incineration. By using biochar as additive for the production of high-fertile soils, CO_2 is permanently stored. According to the Global Biochar C-sink Standard 3.1 chapter 5.3, there are no additional requirements for the use of organic residues from the processing of food and other biomass as feedstock for biochar production.

2. Ex-ante estimate of impact

The estimations are based on the dry matter amounts of biomass and the resulting biochar. The C-sink potential is calculated as the expected amounts of biochar multiplied by the expected carbon content.

The established temporary C-sinks are estimated on basis of the sum of the SPC fraction (25%) of the biochar used for soil application and the amount of biochar used materials (or the lifetime of the products where the biochar is applied to (e.g. cement/concrete in buildings or consumer products).

The established permanent C-sinks are estimated as based on the PAC fraction of the biochar (75%), when the biochar is applied to soils and has an H/C ratio below 0.4.

The ex-ante estimate is based on the following values:

Yield factor (feedstock to biochar): 0,4 t biochar (DM)/t feedstock (DM)

Ccontent of biochar: 59,9 (based on last analysis)

Year of operation	Amount of feedstock (t DM)	Amount of biochar (t DM)	C-sink potential (tCO_2eq)	Established temporary C-sinks (tCO_2eq)	Established permanent C-sinks (tCO_2eq)
1	1250	500	1000	250	750
2	2500	1000	2000	500	1500
3	2500	1000	2000	500	1500
4	2500	1000	2000	500	1500
5	2500	1000	2000	500	1500
sum	11250	4500	9000	2250	6750

3. Technology and business cases

3.1. Production unit

Biochar is produced via pyrolysis technology. Pyrolysis means the thermo-chemical decomposition of the feedstock under the exclusion of oxygen.

By converting sustainable biomass into biochar by pyrolysis, a long-term carbon reservoir is created. At the factory gate of the production unit the biochar poses a potential of C-sink (C-sink potential). It could still be burned. By safety measures, such as marketing and labeling the biochar with the aim of becoming a C-sink and monitoring all distribution channels in a digital Measurement, Reporting and Verification tool (dMRV), it is ensured in the best possible way, that the biochar is used to form a C-sink. C-sink certificates are only issued for those parts of the PC for which it can be proven that they have been put in a matrix. Without the project, no C-sink would be created, as non-pyrolytic biomass does not ensure persistent carbon storage.

The produced biochar is certified under the EBC standard, what guarantees that the biomass feedstock is sustainably procured and produced, biochar fulfils the analytical threshold values so no damage is caused to the environment, emissions limits of the pyrolysis unit are adhered to and storage procedures are environmentally sound.

The biochar production follows the EBC standard, which ensures:

- Compliance with laws regarding air pollution control
- Minimization of risks on human health, social and environmental impacts
- Energy and carbon efficiency
- Sustainable origin of the feedstock

Type of pyrolysis unit: NGE T-Cracker DH 5000 D
Planned operating hours per year: 8000 h
Planned feedstock consumption: 2500 to (DM)
Nominal biochar production: 1000 to (DM)
Concept for waste energy recovery: The waste heat is used to dry the raw materials for biochar production and to dry external sewage sludge.

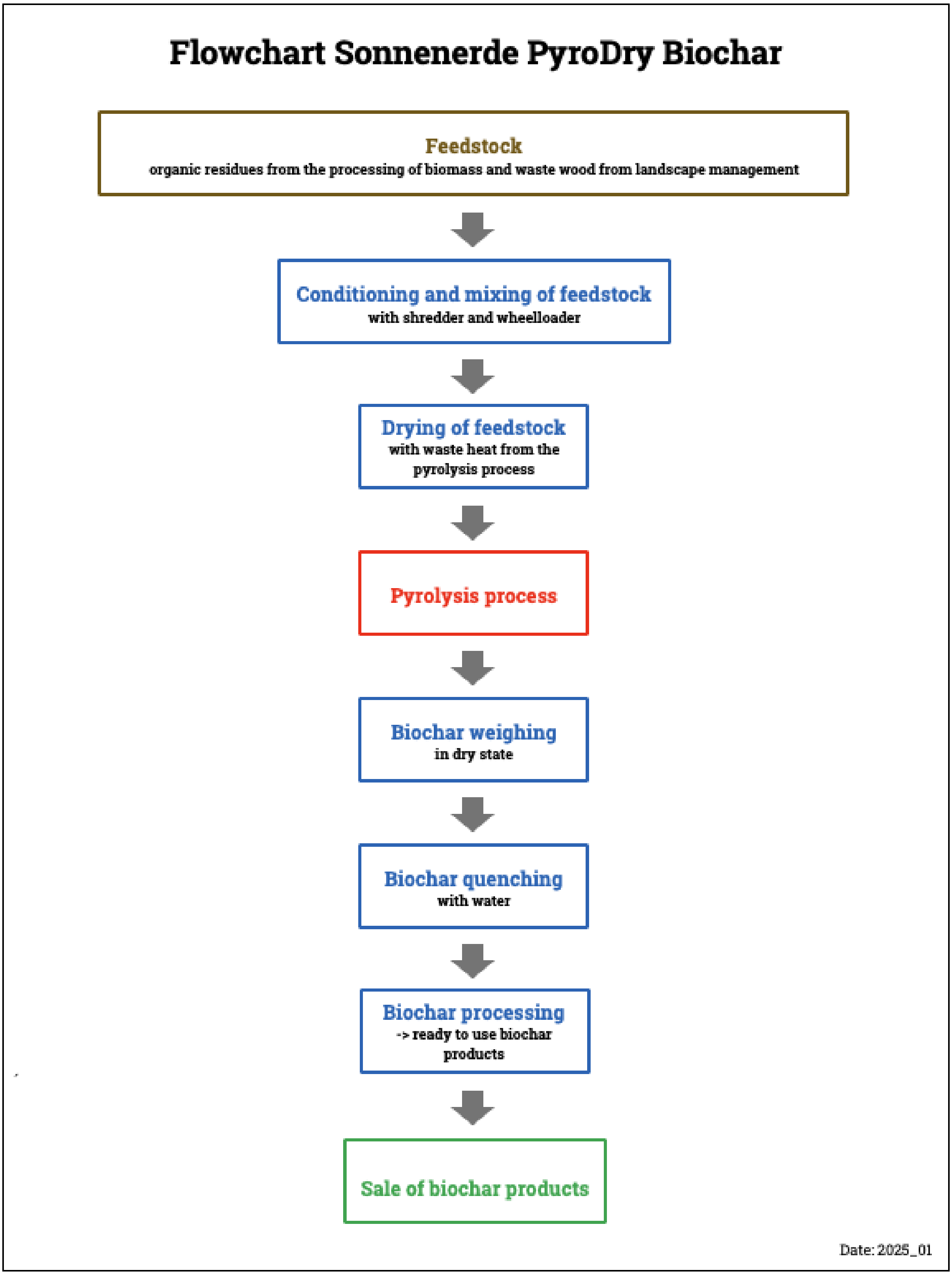

Figure 1: Flowchart PyroDry biochar production and processing at Sonnenerde

3.2. Feedstock

All used feedstock corresponds to the EBC positive list.

Only C-neutral biomass input materials are permitted for the production of biochar C-sinks. Biochar produced from biomass whose harvesting resulted in the destruction or depletion of a natural C-sink (e.g., clear-cutting of a forest) or has contributed to the disappearance of an existing sink (e.g., inappropriate agricultural practices on bog soil) does not render any positive climate service and must not be used for C-sink-potential certification.

However, it must be ensured that the removal of harvest residues does not decrease soil organic carbon stocks.

In the project the following feedstock is used which is eligible with the sustainability criteria:

- Woody residues from composting and landscape management
- Grain husks
- Paper fibre sludge
- Mushroom substrate

Origin of feedstock:

The raw materials for biochar production are organic residues from the processing of biomass and waste wood from landscape management. Without the project this waste materials would be composted or incinerated.
Sonnenerde continuously invests in research and development to further improve existing products and processes. In addition, new climate-positive fields of application for biochar are to be developed. The company therefore reserves the right to change the composition of the raw materials used for biochar production in accordance with the EBC positive list.

The feedstock mentioned above corresponds to the general feedstock classes:

☐ (1) Biomass from annual cropping

☐ (2) Biomass from pluriannual and perennial cropping including short rotation plantations

☐ (3) Forest biomass

☒ (4) Biomass from landscape conservation, agro-forestry, forest gardens, field margins, and urban areas

☐ (5) Wood processing waste and waste wood materials

☒ (6) Organic residues from the processing of food and other biomass

☐ (7) Municipal waste and municipal waste digestate

☐ (8) Manure and agricultural digestate

☐ (9) Biosolids and biosolid digestate

☐ (10) Other biogenic residues

To avoid methane emissions during storage of biomass the following principles should be followed:

- Wood and other biomass should be chipped only a few days and at a maximum of four weeks before pyrolysis. Log storage is considered unproblematic regarding methane emissions; coarse wood (thinner logs, branches, cuttings, etc.) should be stored as airy as possible and not mixed with green waste.
- If just-in-time chipping is not possible, the wood chips or biomass should be dried as soon as possible, e.g., with the excess heat from pyrolysis and stored dry with a maximum of 20% residual moisture. If the biomass is sufficiently dry, biodegradation does not take place or is slowed down considerably.
- Alternatively, the wood chips or the biomasses can be stored in small, well-ventilated containers such as lattice boxes (max. 2 m^3). Due to sufficient ventilation, anaerobic degradation and thus methane emissions can be prevented.

If compliance with these principles cannot be fulfilled, actual practice and parameters according to the monitoring plan will be documented.

3.3. Leakage by activity shifts outside the project boundaries

The Global C-Sink Standard prohibits non-sustainable biomass cultivation, land use change and soil organic carbon depletion - thus, leakage in sense of carbon expenditure outside of the project boundaries is avoided as much as possible. However, in specific constellations, e.g. if the amount of biomass pyrolyzed is significant there it can lead to activity shifts or market transformations. The emissions resulting from activity shifts and market transformations in the C-sink activity must be incorporated into the emission portfolio of the producer.

Only organic residues from the processing of biomass and waste wood from landscape management are used as raw materials for the production of biochar. Therefore, biochar production has no influence on the local markets and activities.

3.4. Distribution channels of biochar

The following applications are possible for this project. The produced biochar must be tracked until its final whereabouts by an endorsed dMRV system.

- Geological C-sink (biochar applied to soil)
- Temporary C-sink (biochar used in materials)
- Temporary storage of biochar

3.5. Planned business development

Sonnenerde's first biochar plant was put into operation in 2012. Since then, a wide range of biochar products have been developed for use in agriculture or home gardens. Due to the high demand for these high-quality, ready-to-use products, a new biochar plant with ten times the production capacity was put into operation in 2023. With this new system, woody residues from the company's own composting plant can be used to produce biochar. This closes another operational material cycle and creates more independence from external raw material suppliers. Sonnenerde and its subsidiary CharLine continuously invest in research and development to further improve existing products and processes. In addition, new climate-positive fields of application for biochar are to be developed.

4. Determination of C-sink potential

4.1. Monitoring plan

All data which are required to calculate the C-sink potential is entered into a dMRV System. The dMRV system is either provided by Carbon Standards or by an external MRV system provider. External MRV systems and tools must be endorsed by Carbon Standards annually. The data will be monitored as mentioned below. Each packaging unit containing more than 1 m^3 of biochar is labeled with a scannable identification code, via which the following information can be viewed:

- Batch ID
- Biochar analyses
- Date of production
- Year of CO_2 removal
- Owner of C-sink material
- Biochar C-content
- Link to the emission portfolio

4.1.1. General data

The following general data will be monitored:

Parameter	Monitoring frequency	Source of data
Batch Start Date	per batch	internal documentation
Batch End Date	per batch	internal documentation
H/Corg ratio	per batch	Laboratory report (by laboratories endorsed by Carbon Standards, see https://www.carbon-standards.com/en/standards/service-492~production-of-biochar.html?open=10796)
C-content of biochar	per batch	Laboratory report (by laboratories endorsed by Carbon Standards, see https://www.carbon-standards.com/en/standards/service-492~production-of-biochar.html?open=10796)
M_biochar (DM) (Total biochar production of batch (expected) in t dry matter)	continuous	operation recordings; continuous weighing of biochar in dry state; scale is integrated directly into the charcoal discharge (before spraying with water);

		Methode in the process of approval at CSI
Biochar Production (DM)	continous	operation recordings
Plan outlining how to reduce fossil GHG emissions of biochar production to less than 100 kg CO_2eq per ton of biochar until 2030 and to less 20 kg CO_2eq per ton of biochar until 2035	The fossil emission reduction plan must be updated annually and include a short progress report.	operation recordings

The following general conversion rates are fixed ex-ante:

Parameter	Ex-ante definition; value	Source of data
CO_2 emissions from diesel	2.7 kg CO_2eq / l diesel	Methodology, Juhrich, 2016
CO_2 emissions from heavy fuel	65 t CO_2eq / TJ	Methodology, Juhrich, 2016

4.1.2. Emissions from fossil fuels

4.1.2.1. Feedstock

For the feedstock the following parameters will be monitored:

Parameter	Monitoring frequency	Source of data
Type of feedstock (with ID of EBC positive list)	continuous	purchase receipts and EBC positive list
Average water content of feedstock at delivery	per batch	lab result or measurement
Amount of feedstock (DM) processed for the last batch	per batch	production protocols
Total amount of feedstock (dry matter) used for the batch	per batch	production protocols
Year of removal, determined as per the following table	per batch	year of cutting or year of pyrolysis; purchase receipts and production protocols;
Amount of fertilizers used as per the following table in kg N	not applicable	not applicable
Area on that pesticides were used as per the following table in ha	not applicable	not applicable
Amount of input of fuels for cultivation and harvest	not applicable	not applicable
Amount of diesel used for feedstock preparation	continuous	calculation based on internal documentation
Amount of electricity used for feedstock preparation	not applicable	not applicable

CO_2eq of electricity used for the pyrolysis plant in g CO_2eq/kWh	per batch	calculation based on the electricity labeling of the energy provider and the following literature: Umweltbundesamt, Dessau-Roßlau, 2022
How do you dry the feedstock?	continuous	waste heat from pyrolysis process; operation recordings;
Amount of fuel equivalent used for drying per ton (DM) of feedstock?	not applicable	not applicable
Amount of electric energy used for drying per ton (DM) of feedstock	not applicable	not applicable

For determination of year of CO_2 removal and of amount of fertilizers and pesticides the following requirements apply:

	Determination of year of CO_2 removal	Determination of amount of Fertilizers and Pesticides
(1) Biomass from annual cropping	The time of the CO_2-removal to be submitted to the Global C-Sink Registry is the year of harvest.	If biomass was deliberately grown to produce biochar, i.e., when it was the single or main product of this field, carbon expenditures for fertilization and pesticides need to be accounted for.
(2) Biomass from pluriannual and perennial cropping including short rotation plantations	If pluriannual or permanent crops are harvested annually to provide feedstock for biochar production, there is no difference compared to the accounting for biomass from annual crops (i.e., N-fertilizers are accounted annually, the time of CO_2 removal is the year of harvest). If the biomass harvest is only every second, fifth, or twentieth year, the time of CO_2 removal must be tracked for every single year of growth and entered accordingly into the Global C-Sink Registry.	If pluriannual or permanent crops are harvested annually to provide feedstock for biochar production, there is no difference compared to the accounting for biomass from annual crops (i.e., N-fertilizers are accounted annually, the time of CO_2 removal is the year of harvest). If the biomass harvest is only every second, fifth, or twentieth year, the carbon expenditures for fertilizers and fuels must be accounted for the entire growing period.
(3) Forest biomass	If the regrowth of last year is harvested and pyrolyzed, the time of removal is set to the year of harvest. If the regrowth of several years is harvested, the time of removal must be distributed proportionally to the growth years and entered	It is assumed that no fertilization occurs in the forest.

	accordingly into the Global C-Sink Registry as described in the Global Tree C-Sink Standard.	
(4) Wood from landscape conservation, agro-forestry, forest gardens, field margins, and urban areas	For pruning and landscaping material, the time of CO_2 removal is assumed to be the year of cutting.	If trees or hedges on agricultural land are pruned or trimmed but not felled and thus grow back from their roots, the biomass is considered C-neutral. Biomass from nature conservation, landscape management, including disaster debris removal and roadside greenery, and urban areas, is also considered C-neutral. Trees from forest gardens, orchard meadows, tree lines, and hedges for arable farming are often decades old. They have to be managed so that the amount of wood removed per unit area does not exceed the amount of the average annual regrowth.
(5) Wood processing waste and waste wood materials	The time of CO_2 removal is set to the year of pyrolysis.	considered C-neutral
(6) Organic residues from biomass processing	The time of CO_2 removal is set to the year of pyrolysis.	considered C-neutral
(7) Municipal waste and municipal waste digestate	The time of CO_2 removal is set to the year of pyrolysis.	Organic waste is considered C-neutral, for other waste radiocarbon analysis of a representative sample is required.
(8) Manure and agricultural digestate	The time of CO_2 removal is set to the year of pyrolysis.	considered C-neutral
(9) Biosolids and biosolid digestate	The time of CO_2 removal is set to the year of pyrolysis.	considered C-neutral
(10) Other biogenic residues	The time of removal would generally be the year of pyrolysis, though this is verified during the certification procedure.	considered C-neutral

In case of the usage of forest biomass the following criteria also applies:
If the climate neutrality of a forest is not ensured by the official LULUCF reports of the respective country or by regional legislation, proof can also be provided by *Program for the Endorsement of Forest Certification* (PEFC) or *Forest Stewardship Council* (FSC) certifications and the Global Tree C-Sink certification (cf. chap. 5.4). Alternatively, the carbon balance of the forest could be verified by ISO16064-accredited assessment of CO_2 fluxes for the last 20 years.
The following general conversion rates are fixed ex-ante:

Parameter	Ex-ante definition; value	Source of data
CO_2 emissions from Nitrogen fertilizer	1 t CO_2eq / 100 kg N	Methodology, Zhang et al., 2013
CO_2 emissions from pesticides	94 kg CO_2eq per hectare	Methodology, Audsley et al., 2009

4.1.2.2. Pyrolysis

For pyrolysis the following parameters will be monitored:

Parameter	Monitoring frequency	Source of data
Electricity consumption of pyrolyser for the entire batch (in kWh)	per batch	electricity meter
Source of electric energy for the pyrolysis plant	per batch	electricity labeling of the energy provider
CO_2eq footprint of electricity used for the pyrolysis plant in kg CO_2eq/kWh	per batch	calculation based on the electricity labeling of the energy provider and the following literature: Umweltbundesamt, Dessau-Roßlau, 2022
Energy source to preheat the pyrolysis reactor	per batch	purchase receipts for wood pellets
Amount of fuel which is used to preheat the pyrolysis reactor in t per batch	per batch	production protocols
CO_2eq of fuel used for the pyrolysis plant per t	not applicable	not applicable

If according to the project boundaries defined in 1.4 the pro-rata approach is applied, the following parameters will be monitored additionally:

Parameter	Monitoring frequency	Source of data
Lower heating values (LHV) of feedstock and products (biochar,_non-biochar_solid, liquid, gas)	not applicable	not applicable
Dry masses of feedstock and products (biochar,_non-biochar_solid, liquid, gas)	not applicable	not applicable
Produced quantity of electricity per batch	not applicable	not applicable

4.1.2.3. Post-treatment

For post-treatment of the biochar the following parameters will be monitored:

Parameter	Monitoring frequency	Source of data
Amount of diesel used for biochar post-treatment	continuous	calculation based on internal documentation
Amount of electricity used for biochar post-treatment	continuous	calculation based on internal documentation

4.1.2.4. Compensation of Fossil Emissions

All fossil CO_2 emissions, as well as N_2O emissions from biomass fertilization, must be offset by long-term carbon sinks before the registration of a biochar C-sink can be validated in the Global C-Sink Registry. CO_2 must only be offset with geological C-sinks, such as the persistent aromatic carbon (PAC) fraction of soil-applied biochar, that are registered in the Global C-Sink Registry.
The emission offsets can be realized with the registered permanent biochar C-sink whose production had caused the emission.

Parameter	Monitoring frequency	Source of data
Proof of compensation	not applicable	not applicable

4.1.3. Methane emissions

4.1.3.1. Storage of biomass

When biomass is stored, methane emissions can be produced, which need to be included in the C-sink potential calculation. This is why the storage period needs to be monitored. Not only the storage on the premises of the pyrolysis plant is considered, but the entire storage period of the biomass, be it at the harvest site or the site of any biomass processor or trader.

Parameter	Monitoring frequency	Source of data
months of storage	continuous	operation recordings
A) Is storage duration less than a month?	continuous	operation recordings
B) Is biomass stored well ventilated?	Whenever the answer to A) is no	operation recordings
C) Is moisture content below 20%?	Whenever the answer to A) and B) is no	operation recordings
core temperature of the biomass for all sites where biomass is stored for more than one month	annually	measurement during on-site inspection

Impact of the monitored parameters:

If at least one Point A) to C) is answered with yes: methane emissions are negligible.
If all points A) to C) are answered with no or temperatures of more than 5°C above ambient temperature is measured during on-site inspection: methane emissions are included in the C-sink potential calculation.

4.1.3.2. Pyrolysis

During pyrolysis, the pyrolysis gases are usually oxidized in a suitably designed combustion chamber. Usually, the gaseous combustion products pass a filtration step and are then emitted mostly as CO_2. If the pyrolysis process is well-adjusted and the combustion chamber correctly designed, non- CO_2 GHGs and other pollutants can be kept at very low levels in the exhaust. However, CH_4, NO_x, CO, and particulate matter (PM) are, as in all combustion processes, never completely absent and must be controlled. Concerning the net climate impact, methane emission is particularly important to measure. CO, NO_x, SO_x, and PM are also harmful to the environment, but according to the IPCC, they do not have a clear greenhouse gas effect (IPCC, 2013) and are therefore not accounted for the emission portfolio, while CH_4 is included.

Measuring methane emissions below 5 ppm is technically complex. Continuous measurement over an entire production year is not possible with currently available technology. Therefore, either at least two CH_4-emission tests per pyrolysis unit with the same feedstock representing the typical operation of the unit are required, or the pyrolysis unit must have a system certification according to EBC or WBC.

The average methane emission of a type of system is then set to be the mean value plus one standard deviation. If an emission measurement for methane or CXHx is below the measuring accuracy of the instruments, the limit of quantification (LOQ) is used. The assessed methane emissions are thus higher than the calculated average and provide a sufficiently high safety margin to cover any potential emission peaks, e.g., during start-up and shutdown of operation.

☐	Default: Pyrolysis unit used in the project has a system certification, see system certification.

Accordingly, ex-ante definition of the following parameter:

Parameter	**Ex-ante definition; value**	**Source of data**
[CH$_4$_emissions_pyrolysis]	0.1 kg CH_4/t DM feedstock	system certification

☒	Pyrolysis unit used in the project has no system certification. A detailed measurement strategy with precise details of the measurement technology, measurement intervals, and measurement for CH_4 emission tests will be provided to Carbon Standards and approved.

Accordingly, following parameter will be monitored once during first monitoring period:

Parameter	**Monitoring frequency**	**Source of data**
[CH$_4$_emissions_pyrolysis] in kg CH_4/t DM feedstock	first monitoring period	measurement

4.1.3.3. Compensation of CH_4 Emissions

Methane compensation 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.

Parameter	Monitoring frequency	Source of data
Proof of compensation	per batch	emission portfolio

4.1.4. Energy flows

In order to determine the energy efficiency of the pyrolysis unit the following parameters have to be monitored:

Parameter	Monitoring frequency	Source of data
LHV_feedstock	per batch	Laboratory report (by laboratories endorsed by Carbon Standards, see https://www.carbon-standards.com/en/standards/service-492~production-of-biochar.html?open=10796)
M_feedstock (DM) (Total amount of feedstock (dry matter) used for the batch)	per batch	Is equivalent to "Total amount of feedstock (dry matter) used for the batch" monitored in 4.1.2.1.
LHV_biochar	per batch	The LHV of the biochar and charcoal is analyzed from the EBC certification sample.
M_biochar (DM)	per batch	Is equivalent to "M_biochar (DM)" in 4.1.1.
Supply of $E_{electric}$ (Produced quantity of electricity per batch)	not applicable	not applicable
E_expenditure (energy used for the production)	Is equivalent to "Total amount of feedstock (dry matter) used for the batch" monitored in 4.1.2.1	sum of all sources of energy used for the production
Supply of E_thermal (Produced quantity of heat per batch)	not applicable	not applicable
If thermal energy from reactor is used for feedstock drying:		
Water content of biomass at delivery	per batch	measurement
Mass of biomass at delivery	per batch	delivery bills / weigh ticket
Water content of biomass after drying	per batch	measurement
Mass of biomass after drying	per batch	production protocols

If relevant:		
LHV_pyrooil	not applicable	not applicable
M_pyrooil (Mass of pyrooil)	not applicable	not applicable
E_fuelproducts (energy contained in all fuel products)	not applicable	not applicable
Mass of CO_2 seperated	not applicable	not applicable

Ex-ante definition of following parameters:

Parameter	**Ex-ante definition; value**	**Source of data**
Energy to evaporate water	810 kWh per ton of evaporated water (2.44 kJ per gram of water + 20% margin)	methodology
Energy per captured CO_2	1000 kWh t^{-1} CO_2	methodology

4.2. Calculation of C-sink potential at factory gate

The C-sink potential at factory gate reflects the remaining C-content of the biochar at factory gate, for which all fossil emissions have been offset against a permanent sink. Preferably the permanent portion of the biochar itself. The emissions are reported to the emissions portfolio of the producer.

4.2.1. Emissions from fossil fuels

Emissions from fossil fuels are calculated based on the following formulas

$$[Total\ GHG\ emissions\ in\ CO_2eq\ per\ batch] = [Total\ biomass\ related\ GHG\ emissions\ without\ CH_4\ per\ batch] + [Total\ pyrolysis\ related\ GHG\ emissions\ without\ CH_4\ per\ batch] + [Emissions\ for\ post\ treatment\ of\ feedstock\ per\ batch] + [safety\ margin\ for\ leakage] + [leakage\ emissions]$$

$$[Total\ GHG\ emissions\ in\ C\ per\ ton\ of\ biochar\ (dry\ matter)] = [Total\ GHG\ emissions\ in\ CO_2eq\ per\ batch] * \frac{12}{44} * [Amount\ of\ biochar\ (dry\ matter) produced\ per\ batch]$$

4.2.1.1. Feedstock

The production of biomass usually causes emissions that need to be accounted for as carbon expenditures of the C-sink. Emissions are calculated in t CO_2eq.

- If mineral nitrogen fertilization was used to produce the biomass, its carbon footprint, including soil borne N_2O emissions, must be accounted for according to the formula 100 kg N = 1 t CO_2eq (Zhang et al., 2013). This represents a consideration of the GWP100 for N_2O and the production emissions for nitrogen fertilizer.

$$[Emissions\ due\ to\ fertilization\ per\ batch] = \frac{[Amount\ of\ fertilizers\ used]}{100kgN}$$

- If pesticides were used, a flat value of 94 kg CO_2eq per hectare (Audsley et al., 2009) is applied for their production-related emissions.

$$[Emissions\ due\ to\ pesticides\ per\ batch] = [Area\ on\ that\ pesticides\ were\ used] * 0{,}094\ t\ CO_2e$$

- The input of fuels for cultivation and harvest or preparation of feedstock must also be added to the emission portfolio with a conversion factor of 2.7 kg CO_2eq per liter diesel (Juhrich, 2016).

$$[Emissions\ for\ Preparation\ of\ feedstock\ per\ batch] = [diesel\ used\ for\ feedstock\ preparation]l * 2.7\ \frac{kg\ CO_2eq}{l} + [electricity\ for\ prepartion]kWh * [CO_2eq\ of\ electricity]\frac{kg\ CO_2eq_{elec}}{kWh}$$

- The fuel for trucks for transporting the biomass from the source to the biochar production facility must be calculated with the conversion factor of 2.7 kg CO_2eq per liter diesel and the road distance according to google maps. If the truck returns back empty, the distance will be multiplied by 2.

$$[Emissions\ due\ to\ transportation\ of\ biomass\ to\ pyrolysis\ site\ per\ batch] = \frac{[amount\ of\ feedstock]}{[loading\ capacity]}\frac{t(DM)}{t(DM)} * [distance]\ km * [diesel\ demand]0.2\ \frac{l}{km} * 2.7\ \frac{kg\ CO_2eq}{l}$$

- Emissions for drying feedstock are calculated, fuel and electricity are considered. The fuel for drying feedstock is calculated with a conversion factor of 2.7 kg CO_2eq per liter diesel.

$$[Emissions\ for\ drying\ of\ feedstock\ per\ batch] = [diesel\ used\ for\ drying]l * 2.7\frac{kg\ CO_2eq}{l} + [electricity\ used\ for\ drying]kWh * [CO_2eq\ of\ electricity]\frac{kg\ CO_2eq_{elec}}{kWh}$$

The total biomass related GHG emissions without Methane per batch is calculated according to the following formula:

$$[Total\ biomass\ related\ GHG\ emissions\ without\ CH4\ per\ batch] = [Emissions\ due\ to\ fertilization\ per\ batch] + [Emissions\ due\ to\ pesticides\ per\ batch] + [Emissions\ due\ to\ transportation\ of\ biomass\ to\ pyrolysis\ site\ per\ batch] + [Emissions\ for\ Preparation\ of\ feedstock\ per\ batch] + [Emissions\ for\ drying\ of\ feedstock\ per\ batch]$$

4.2.1.2. Pyrolysis

Emissions which are produced during the pyrolysis process contain electricity consumption and fuel for preheating the pyrolysis reactor. The emissions are calculated in **tCO_2eq**.

$$[Emissions\ due\ to\ electricity\ consumption] = [electricity\ for\ biochar\ production]kWh * [CO_2eq\ of\ electricity]\frac{kg\ CO_2eq_{elec}}{kWh}$$

Note: If renewable energy is used, a CO_2eq footprint of zero is assumed. If the pyrolysis plant itself generates at least as much electricity on an annual average as is consumed in the production facility, a CO_2eq of zero is assumed for electricity consumption.

$$[Emissions\ due\ to\ fuel\ for\ preheating] = [Fuel\ consumption]kg * [CO_2eq\ of\ fuel]\frac{kg\ CO_2eq}{kg}$$

The total production emissions are calculated with the formula:

$$[Production\ emissions] = [Emissions\ due\ to\ electricity\ consumption] + [Emissions\ due\ to\ fuel\ for\ preheating]$$

According to the project boundaries defined in 1.4 the pro-rata approach is applied:

☒	No
	$[Total\ pyrolysis\ related\ GHG\ emissions\ without\ CH4\ per\ batch] = [Production\ emissions]$

☐	Yes
	(1) $E_{input} = LHV_{feedstock} * m_{feedstock}(DM)$ (2) $E_{nonBCoutput} = LHV_{nonBCsolid} * m_{nonBCsolid}(DM) + LHV_{liquid} * m_{liquid} + LHV_{gas} * m_{gas} + E_{electric} + E_{thermic}$ (3) $E_{biochar} = LHV_{biochar} * m_{biochar}\ (DM)$

	To calculate the GHG attribution of the biochar product, the total emissions assessed for the entire process from biomass production to biochar output are multiplied by the ratio of $E_{biochar}$ to the total E_{output} (= $E_{nonBCoutput}$ + $E_{biochar}$). (4) $[Total\ pyrolysis\ related\ GHG\ emissions\ without\ CH4\ per\ batch]$ = *[production emission]* * $E_{biochar}/(E_{nonBCoutput} + E_{biochar})$

4.2.1.3. Post-treatment

If the biochar will be post-treated, the emissions are calculated according to the following formula:

$$[Emissions\ for\ post\ treatment\ of\ feedstock\ per\ batch] = [diesel\ used\ for\ biochar\ post\ treatment]l * 2.7\frac{kg\ CO_2eq}{l} + [electricity\ for\ biochar\ post\ treatment]kWh * [CO_2eq\ of\ electricity]\frac{kg\ CO_2eq_{elec}}{kWh}$$

4.2.1.4. Safety margin

For the determination of the emission portfolios relevant for the C-sink generation according to Global Biochar C-Sink standard, the emissions from Scope 1 and 2 of each involved and registered organization (producers and processors) are recorded.
For Scope 3 emissions of involved organizations, only the emissions from biomass production transport of biomass or biochar and derived products are directly quantified. Other indirect emissions from Scope 3 are not recorded individually due to their comparatively low volume but are instead included in the calculation with a flat margin of safety to account for the whole value chain

This includes, for example, the emissions caused by:
- Production and disposal of polypropylene bags,
- Electricity for the operation and cooling of the company's external computer servers,
- Potential methane emissions during the first month of storage of the biomass,
- Fuel consumption by employees for commuting to work and for business trips,
- Marketing and management activities including trade shows and conference attendance,
- Operation of chainsaws or harvesters for felling and peeling trees and for digging up roots,
- Emissions from machine fuels during cultivation of agricultural land and plant protection measures,
- Production, maintenance, repair, and disposal of pyrolysis equipment, transport vehicles, warehouses, and other machinery.
- The margin further contains unavoidable imprecisions of the C-sink accounting such as sampling, packaging, volume and dry mater analysis, etc.
- Unlikely loss of c-sink material e.g. by burning small portions of diffuse C-sinks in waste incineration plants

The margin of safety generally amounts to 20 kg CO_2eq per ton of biochar which corresponds to roughly 0.7 % of the biochar carbon. The margin of safety is applied per ton of biochar at factory gate of the producer and thus not affected by pro-rata accounting.

$$[safety\ margin] = 0.020 \frac{tCO_2}{t} * [m_{biochar}] t(DM)$$

4.2.1.5. Leakage emissions

The leakage emissions are calculated based on the results of the assessment in chapter 3.3.

$$[Leakage\ emissions] = 0\ tCO_2eq * [amount\ of\ biomass\ dry\ matter\ (batch)]$$

4.2.2. Methane emissions

During biomass storage and pyrolysis process methane emissions are produced. They are calculated according to the following formula:

$$[Total\ methane\ emissions] = [Feedstock\ storage\ emissions\ per\ batch] + [CH_4\ emissions\ from\ pyrolysis\ of\ entire\ batch]$$

4.2.2.1. Emissions from the storage of the biomass

If methane emissions are negligible according to section 4.1.3.1.: 0 tCH_4

If methane emissions are included in the C-sink potential calculation: Emissions are calculated in **tCH_4**:

$$[Feedstock\ storage\ emissions\ per\ batch] = ([\#months\ of\ storage] - 1) * [amount\ of\ biomass\ dry\ matter\ (batch)] * [Ccontent\ of\ biomass] * [methane\ emissions\ per\ month] * \frac{16}{12}$$

Default values given in the methodology are used:

$[methane\ emissions\ per\ month]$	0,13% of C-content for woody biomass 0,25% of C-content for non-woody biomass
$[Ccontent\ of\ biomass]$	48% for woody biomass 50% for non-woody biomass

4.2.2.2. CH4 Emissions from Pyrolysis reactor

Emissions are calculated in **tCH_4.**

$$[CH_4\ emissions\ from\ pyrolysis\ of\ entire\ batch] = \frac{\left[CH_{4\,emissions_{pyrolysis}}\right] kg}{1000} * [m_{biochar}] t(DM)$$

4.2.2.3. Compensation of CH_4 Emissions

The Absolute Global Warming Potential of the methane must be compensated by a same-sized absolute global cooling potential (AGCP) over a maximum of 20 years. The compensating global cooling starts in the same year as the CH_4 emission occurred, provide annual global cooling in every following year, and finalize the compensation latest 20 years after the methane emission.

In order to claim that methane emissions where compensated it must be proven that

$AGCP(20) \geq AGWP_{CH4(100)}$.

Absolut Global Warming Potential of methane emissions
The Absolute Global Warming Potential of the methane emissions are calculated based on:

$$AGWP_{CH4(100)} = \sum_{y=0}^{100} \left(IRF\big(CO2, a(y)\big) * \ [CO_2e \ of \ CH_4 \ emissions \ per \ load] \right)$$

To calculate the *Absolute Global Warming Potential (AGWP)* over 100 years we are using Jeltsch-Thömmes & Joos (2019)[1] to account for the decay of the CO_2. Greenhouse gases decay in the atmosphere. The quantities of CO_2 still present in the atmosphere each year are added up over the 100 years, resulting in the absolute global warming potential (AGWP) over 100 years.

The decay is described by the equation:

$$\left[IRF\left(CO_{2,a}(t)\right)\right] = a_0 + \sum_{i=1}^{5} a_i * \exp\left(\frac{-t}{\tau_i}\right) for \ t \geq 0$$

With the values

i	ai	ti
0	0.008	
1	0.044	68521
2	0.112	5312
3	0.224	362
4	0.31	47
5	0.297	6

The resulting methane emissions of the produced biochar are calculated as below, with the GWP100 (CH_4) value of 25 CO_2eq.

$$[CO_2eq \ of \ CH_4 \ emissions \ per \ load] = [Total \ methane \ emissions] * \left[GWP100_{CH_4}\right]$$

[1] Jeltsch-Thömmes, A., Joos, F., 2019. The response to pulse-like perturbations in atmospheric carbon and carbon isotopes 1–36.

Absolut Global Cooling Potential of soil applied SPC fraction

The Absolut Global Cooling Potential (AGCP) of the SPC fraction of soil applied biochar for the first 20 years is calculated as follow:

$$[AGCP(20)] = \sum_{t=0}^{20}(C_{remain}(t,SPC) * \ IRF(CO_{2,a}(t) * M_{biochar} * C_{content})$$

With:

C_{remain} (t, SPC) as the adjusted equation 2 of Global Artisan C-Sink Standard for the SPC fraction of the biochar (25%)

$$[C_{remain}(t,SPC)] = (\frac{M_{BC} * C_{Content}}{1000} - 0.75) * (750 + 45 * \ e^{-0.5232*t} + 205 * \ e^{-\ 0.009966*t})$$

4.2.3. Value of C-sink potential

The C-sink potential at factory gate reflects the remaining C-content of the biochar at factory gate, for which all fossil emissions have been offset against a permanent sink. Preferably the permanent portion (PAC) of the biochar itself. For biochars with H/Corg ratio ≥ 0,4 no maximum value for the SPC fraction can be given. Therefore, the respective biochar cannot be used for creation of a permanent C-sink and is treated as if it consists out of 100% SPC and can only serve as a temporary C-sink. This in turn leads to the fact that GHG emissions cannot be set off against the potential permanent C-sink value of the biochar.

$$[CSink\ Potential] = [CContent]$$

$$[CSink\ Potential\ per\ batch] = \ [CSink\ Potential] * [m_{biochar}]t(DM)$$

Note: It is mandatory to label biochar with its H/Corg ratio.

4.2.4. Energy efficiency

The energy use efficiency provides the rate of how much of the energy contained in the biomass feedstock was transformed into usable energy and other beneficial products with a market value. If the non-biochar fraction of the pyrolysis products is used for energy production or as raw material for chemical or other industries, the biomass-carbon is considered as having been used meaningfully.

For every batch of a certified pyrolysis unit, at least 60 % of the sum of the energy contained in the biomass and all energy expenditures of the process must be used.

The total amount of used electrical and thermic energy, and the heating value of the marketed pyrolysis products is divided by the sum of the energy content of the biomass feedstock and the external energy used to produce the entire batch. The value is given as a percentage.

$$E_{eff} = \frac{E_{solid} + E_{pyrooil} + E_{fuelproducts} + E_{thermal} + E_{drying} + E_{electric} + E_{co2pur}}{E_{feedstock} + E_{expenditures}}$$

In most cases of today's pyrolysis facilities, some summands are zero, the formula then simplifies to:

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

With:

Energy contained in the feedstock:

$$E_{feedstock} = LHV_{feedstock} * M_{feedstock}\,(DM)$$

Energy expenditures for the entire pyrolysis facility:

$$E_{expenditures}$$

Energy content of the biochar:

$$E_{solid} = LHV_{biochar} * M_{biochar}\,(DM)$$

Energy used for feedstock drying:

$$E_{drying} = 810\frac{\text{kWh}}{\text{t}} * M_{water}$$

$$M_{water} = [Water\ content\ of\ biomass\ at\ delivery] * [Mass\ of\ biomass\ at\ delivery] - [Water\ content\ of\ biomass\ after\ drying] * [Mass\ of\ biomass\ after\ drying]$$

Produced thermal energy:

$$E_{thermal}$$

Produced electric energy:

$$E_{electric}$$

And, if applicable:

Energy content of the pyrolysis oil:

$$E_{pyrooil} = LHV_{pyrooil} * M_{pyrooil}$$

Energy content of separated CO2 from the flue gas:

$$E_{CO_2pur} = 1000\frac{\text{kWh}}{t_{CO_2}} * M_{CO_2}$$

Energy content of the fuels produced by the pyrolysis process:

$$E_{fuelproducts}$$

4.2.5. Carbon efficiency

Carbon efficiency refers to the ratio of carbon transformed into a storable form (i.e., amount of carbon in a batch of biochar) to the input of carbon (i.e., amount of carbon in the biomass used to produce the biochar).

The carbon efficiency is assessed at the factory gate and does not assess the use of the carbon products or the durability of storage. As long as the carbon is stored for a minimum of one year, this can be included in the carbon efficiency calculation.

Benchmarking current carbon efficiency of a biochar production facility is calculated according to the following formula:

$$[Carbon\ efficiency] = \frac{\sum([amount\ of\ product\ dry\ matter\ (batch)]*[Ccontent\ of\ product])}{[\text{Total amount of feedstock (dry matter)used for the batch}]*[Ccontent\ of\ biomass]}$$

With product being any outcome of the process that's intended to be stored for a minimum of one year, e.g. biochar, bio-oil, CO_2.

The producer publishes the Carbon efficiency of the production facility annually.

Default values given in the methodology are used:

$[Ccontent\ of\ biomass]$	48% for woody biomass 50% for non-woody biomass

5. Determination of C-sink

Once the C-sink potential of the biochar has been determined and the label has been applied to the packaging units in accordance with the requirements in chapter 4.1, the further fate of the biochar is only indirectly influenced by the producer. In the further chain up to the final C-sink, there are processors and users. It is incumbent on all of them to play their part in quality assurance and monitoring as well as reporting on their emissions. The final C-sink is registered by the first C-sink owner.

5.1. Biochar processing

If the biochar is delivered to a processing company who makes new biochar-based products from the biochar, the receiving company must be EBC or WBC certified as a processing company and/or trader. If production and processing are done by the same company the company must be certified as producer and processor. This allows the verification of the climate relevant processes as part of annual on-site inspection. All processing steps must be recorded with their CO_2eq emission factor. The emissions are reported in the processor's emission portfolio and all fossil GHG emissions from processing have to be offset against long-term carbon sinks.

Once the products are repackaged, they must be registered in the dMRV system as new product and C-sink unit providing the following information:
- Product processor
- Biochar production batch ID and/or QR code to access EBC/WBC biochar analysis.
- Date of biochar production
- Year of CO_2 removal
- Owner of C-sink material
- Point of new departure (GPS)
- Biochar C-content of product
- C-sink matrix, if mixed to one
- Emission that occurred during processing
- Link to the emission portfolio of the C-sink unit and/or company

Processing of the biochar is done by Sonnenerde and its subsidiary CharLine. Due to the shared use of infrastructure and machinery that CharLine leases from Sonnenerde, all emissions in the course of processing by both companies (Sonnenerde and CharLine) are taken into account as emissions from Sonnenerde.

At Sonnenerde, biochar is primarily used as a component for the production of highly fertile soils and for the production of soil conditioners. In this case, the biochar is mixed with compost and other additives. (Figure 2)

Figure 2: Processing for biochar-based soil products

For the use of biochar as a compost additive, the biochar is screened. (Figure 3)

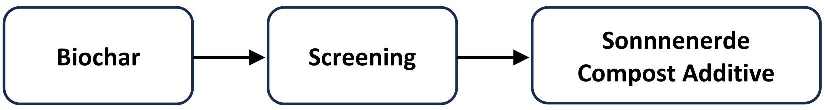

Figure 3: Processing for biochar-based compost additive

CharLine produces biochar products for use in agriculture.

For the use of biochar as a manure additive, the biochar is finely ground. (Figure 4)

Figure 4: Processing for biochar-based manure additive

For the use of biochar as a feed additive, biochar is ground and pelletized. (Figure 5)

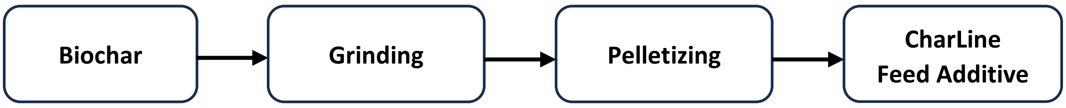

Figure 5: Processing for biochar-based feed additive

Sonnenerde monitors the emissions caused by the processing of biochar at Sonnenerde and CharLine. For each processing step an emission factor is calculated based on the consumption data of the respective machines used. All emission factors are then added together and applied to the total quantity of biochar produced at Sonnenerde, regardless of whether and to what extent the biochar is further processed.

This approach enables an efficient calculation even with the large product diversity of the two companies. At the same time, a safety buffer is included, as the maximum possible emissions that can arise during processing are also taken into account for biochar products that do not include all processing steps.

Parameters monitored to determine processing emissions:

Parameter	Monitoring frequency	Source of data
Diesel used for processing	per batch	Calculation
Electricity used for processing	per batch	Calculation
Input biochar and output biochar based-product documentation	Per batch	Operation recordings and extract from accounting software
Any other GHG emitting process	not relevant	Not relevant

The following general conversion rates are fixed ex-ante:

Parameter	Ex-ante definition; value	Source of data
CO_2 emissions from diesel	2.7 kg CO_2eq / l diesel	Methodology, Juhrich, 2016
CO_2 emissions from electricity	kg CO_2eq_{elec} /kWh	calculation based on the electricity labeling of the energy provider and the following literature: Umweltbundesamt, Dessau-Roßlau, 2022

5.1.2. Calculation of processing emissions

A wheel loader is used to transport and mix the biochar on site. The diesel consumption for the on-site transport and mixing of one tonne of biochar (DM) is calculated based on the diesel requirement and the processing capacity of the wheel loader per hour. The resulting value is multiplied by the conversion factor of 2.7 kg CO_2eq per litre of diesel to determine the emission factor.

$$[Emissions\ due\ to\ onsite\ transportation\ and\ mixing\ of\ biochar] = \frac{[diesel\ used\ for\ onsite\ transportation\ and\ mixing]}{[processing\ capacity]} \frac{\frac{l}{h}}{\frac{t(DM)}{h}} * 2.7\ \frac{kgCO_2eq}{l}$$

Onsite screening of biochar is carried out using a drum screening machine. The diesel consumption is calculated based on diesel requirement and the screening capacity of the screening machine. The resulting value is multiplied by the conversion factor of 2.7 kg CO_2eq per litre of diesel to determine the emission factor.

$$[Emissions\ due\ to\ screening\ of\ biochar] = \frac{[diesel\ used\ for\ biochar\ screening]}{[screening\ capacity]} \frac{\frac{l}{h}}{\frac{t(DM)}{h}} * 2.7\ \frac{kgCO_2eq}{l}$$

The total emission due to diesel use for biochar processing per batch are calculated with the formula:

$$[Total\ biochar\ processing\ related\ GHG\ emissions\ per\ batch] = [Emissions\ due\ to\ onsite\ transportation\ and\ mixing\ of\ biochar\ per\ batch] + [Emissions\ due\ to\ onsite\ screening\ of\ biochar\ per\ batch]$$

Grinding of biochar is carried out using a hammer mill. The electrical energy demand is calculated based on the device power and the period of use. The resulting value is multiplied by a conversion factor derived from the energy service provider's electricity sources. Only renewable sources are used.

$$[Emissions\ due\ to\ grinding\ of\ biochar] = [electricity\ for\ grinding]\frac{kWh}{t(DM)} * [CO_2eq\ of\ electricity]\frac{kgCO_2eq_{elec}}{kWh}$$

Pelletizing of biochar is carried out using a feed mixer for homogenization and a pelletizer. The electrical energy demand is calculated based on the device power and the utilization period of the machines. The resulting value is multiplied by a conversion factor derived from the energy service provider's electricity sources. Only renewable sources are used.

$$[Emissions\ due\ to\ pelletizing\ of\ biochar] = \left\{[electricity\ for\ homogenization]\frac{kWh}{t(DM)} + [electricity\ for\ pelletizing]\frac{kWh}{t(DM)}\right\} * [CO_2eq\ of\ electricity]\frac{kgCO_2eq_{elec}}{kWh}$$

The total emission due to electricity consumption for biochar processing per batch are calculated with the formula:

$$[Total\ biochar\ processing\ related\ emissions\ for\ electricity\ consumption\ per\ batch] = [Emissions\ due\ to\ grinding\ of\ biochar\ per\ batch] + [Emissions\ due\ to\ homogenization\ and\ pelletizing\ of\ biochar\ per\ batch]$$

The total processing emissions per batch are calculated with the formula:

$$[Emissions\ for\ processing\ of\ biochar\ per\ batch] = [diesel\ used\ for\ biochar\ processing\ per\ batch] + [electricity\ used\ for\ biochar\ processing\ per\ batch]$$

5.2. Registration of C-sink

As Sonnenerde's biochar is used for the production of high-quality substrates and soil improvement products, it is incorporated into a stable matrix directly at the company site, creating a long-term C-sink.

In addition Sonnenerde and its subsidiary CharLine produce a range of ready-to-use biochar products, which are intended for clearly defined applications in agriculture. By purchasing these products, the customer accepts the general terms and conditions of the companies. In doing so, the customer guarantees that he will use the products exclusively for their intended purpose, which includes incorporation into a stable matrix. These biochar quantities are claimed as diffuse C-sinks. The customer is expressly informed in the general terms and conditions that the carbon contained in the products has already been offset in the form of CO_2 certificates. In order to avoid double counting, the CO_2 sink potential of the product may therefore not be claimed again.

The following information are registered for biochar carbon sink:
1. C-sink owner (owner of the material that contains the biochar, or producer of biochar containing products).
2. A GPS point of the land or area where the C-sink was established. (in case of a diffuse C-sink, the company location is specified as the sink location)
3. For soil application: Consent of the landowner or tenant to accept the biochar application to his soil (usually part of the purchase contract).
4. Date of C-sink establishment.
5. Year of CO_2-removal (date of carbon uptake of biomass that was pyrolyzed).
6. EBC/WBC batch number.
7. Biochar analysis - can be linked with the Carbon Standard Biochar Tool
8. Type of C-sink (geo-localized or diffuse).
9. C-sink matrix.
10. Amount of biochar in dry tons.
11. Amount of carbon in CO_2eq.
12. Persistence curve of C-sink (depending on C-sink matrix).
13. Controlling period (depending on C-sink matrix).
14. C-sink project documentation
15. Report of the verification and validation body
16. Confirmation of the compensation of the emission portfolio of the biochar

5.2.1. Monitoring of transport parameters until final location

First C-sink owners are obliged to monitor the following data. They are obliged to define appropriate monitoring frequencies and data sources in annexes to this PDD.

Parameter
Amount of diesel used for transportation from last processor to application site
Amount of diesel used for application
Any other GHG emitting process
Emission reports from Producer and Processors

For the part of the production that is brought into the producer's sphere of influence, we record:

Parameter	Monitoring frequency	Source of data
Amount of diesel used for transportation from last processor to application site	continuous	distance and amount of trucks; in case of diffuse C-sink: statistically determined mean distance

Amount of diesel used for application	continuous	calculation
Any other GHG emitting process	continuous	operation recordings
Emission reports from Producer and Processors	per C-sink	Producer and Processors

5.2.2. Calculation of C -sink

The C-sink is registered in the Global C-sink Registry.

Under the condition that the GHG emissions from processing and application are offset against permanent carbon sinks, the C-sink potential can be calculated as:

$$[C - sink(year = 0)] = [CSink\ Potential] * [dry\ mass\ of\ biochar\ applied]$$

Note: It is mandatory to label biochar with its H/C_{org} ratio.

However, every biochar C-sink underlies a time-dependent evolution, and the C-sink is a measure of the mass of carbon that is physically present in the C-sink matrix at any given moment in time since the establishment of the C-sink. The size of a biochar C-sink is, thus, a function of the type of biochar determining its specific persistence in a specific C-sink matrix and the time since the application to the C-sink matrix.

$$C - sink(year) = C - sink(year = 0) * specific\ persistence\ (year)$$

5.2.3. Geological C-sink

Biochar which is applied to soil can be registered as geological C-sink. EBC and WBC certified biochar with an H/C_{org} ratio < 0.4 that was applied to soil is therefore registered with a PAC fraction of 75% and SPC fraction of 25% in the Global C-Sink Registry. Soil-applied biochars with an H/C_{org} ratio ≥ 0.4 that was applied to soil, are registered with an SPC fraction of 100%, and no PAC fraction can be registered.

The remaining carbon for soil-applied biochar with an H/Corg ratio < 0.4 is calculated with the following conservative approximation:

$[remaining\ C\ (year)]=[\ dry\ mass\ of\ biochar\ applied\ ]/1000 * Ccontent * (750 + 45 * e^{-0.5232 * year} + 205 * e^{-0.009966 * year})$

Biochars with an H/C_{org} ratio ≥ 0.4 that was applied to soil, are registered with an SPC fraction of 100%, and no PAC fraction can be registered.

When C-sinks are sold to offset CO_2 emissions only the PAC fraction must be used.

The SPC-fraction of biochar can be used for methane emission offsets (see section **0**).

5.2.4. Temporary C-sink

Biochar which is used in materials can be registered as temporary C-sink. They require a specific monitoring plan.

5.2.4.1. Monitoring plan for materials

For consumer products:

Parameter	Monitoring frequency	Source of data
lifetime	one-time	Average lifetime from statistics for specific products can determine an average lifetime

For stationary infrastructure:

Parameter	Monitoring frequency	Source of data
lifetime	frequency to be proposed by first C-sink Owner and accepted by CS	Proof of existence of the permanent infrastructure, e.g. by satellite imagery

5.2.4.2. Calculation of temporary C-Sink for materials

$C - sink(year) = C - sink(year = 0)$ if year < [lifetime]; $= 0 \; if \; year > [lifetime]$

Temporary material C-sinks are registered with their statistically validated lifetime or their controlling period. If the control at the end of the defined controlling period confirms the continued presence of the C-sink, the registry entry of the temporary C-sink is prolonged until the end of the next controlling period. The duration of the new controlling period is updated at the end of each controlling period.

5.2.5. Temporary Storage of Biochar

Biochar can be stored to preserve it for later years when, e.g., demand and prices increase. For as long as the biochar is stored under controlled conditions and with regular verification, such as in containers, below ground protected from water and biologically active matrices, and in ancient salt or coal mines, it can be considered a temporary C-sink during the controlled storage time.

5.2.5.1. Monitoring plan for temporary storage:

Parameter	Monitoring frequency	Source of data
C loss	continuous	remote control of temperature and/or CO_2 concentration
amount of carbon in temporary storage	annually	calculated

5.2.5.2. Calculation of temporary C-sink for temporary storage

$$C - sink(year) = C - sink(year = 0) - \sum C \; loss \; (year)$$

6. Public consultation

During public consultation the following comments were raised:

(This section must be filled earliest after the first feedback round with the VVB. The public consultation starts with handing in the PDD for validation. Carbon Standards International will upload it to its website for 30 days and informs the project proponent about the comments raised during this consultation. If there are comments raised the project proponent has to document in the table below if a comment was taken into account with a justification and an indication which sections of this document where affected.)

Comment	Was comment taken into account (Yes/ No)? Where?	Explanation/ justification (Why? How?)
xx	xx	xx
xx	xx	xx

7. Annexes

- BE Vertrieb GmbH & Co KG, Eisenstadt, 2024, Sekundäre (vollumfassende) Stromkennzeichnung
- Social responsibility declaration 25_01
- Umweltbundesamt, Dessau-Roßlau, 2022, Emissionsbilanz erneuerbarer Energien