Biochar Carbon Code

A methodology for the quantification of biochar carbon sequestered to a carbon dioxide equivalent for the issuance of biochar carbon units (BCUs) from UK-based biochar projects

Executive Summary

We need more stakeholders to be able to produce and sequester biochar in the UK today in a safe and appropriate manner, but the barriers to entry are stopping this industry from taking off at the pace that is needed if biochar carbon removal is going to have any meaningful effect as part of the UK's Net Zero strategy. The UK Government has determined a Net Zero policy for 2050[1] with an interim goal of sequestering 20-30 Mt of carbon dioxide per year by 2030.

According to the (US) National Academies of Sciences, Engineering and Medicine, "the world must also remove around an additional 10 gigatons of carbon dioxide from the atmosphere each year by mid-century."[2]

This challenge, national and global, is enormous. Interrupting the decay of organic materials through pyrolysis can make a significant contribution to these targets on a Mt p.a. scale for the UK. Operations at a local level minimising transport mileage would ensure that communities can participate in this new industry.

Currently, if a stakeholder would like to produce/sequester biochar in the UK they have two options, purchase open burn/retort or continuous pyrolysis technology. Today, no codes/standards recognise simpler technology for use in the 'developed' world and continuous technology is priced out of reach for most stakeholders in the market. Our Biochar Carbon Code has been designed for use in the UK initially to bridge this gap, allowing for the use of more affordable batch pyrolysis technology with a code that holds participants to account for safe and appropriate operation. It does not replace UK regulatory requirements.

Biochar, produced by the pyrolysis of organic matter, is recognised by the Intergovernmental Panel on Climate Change (IPCC) as a vehicle for removing carbon dioxide from the atmosphere. Its permanent sequestration can be used as a carbon dioxide removal instrument for Carbon Capture and Storage (CCS) in exchange for payment via the issuance and sale of

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[1] Carbon capture usage and storage UK Government - Link

[2] (US) National Academies of Sciences, Engineering and Medicine 2019 - Link

biochar carbon units (BCUs). A biochar production operation uses pyrolysis technology to convert woody feedstock material into biochar carbon.

Any organisation that wishes to use the Biochar Carbon Code for the purpose of producing biochar, waste heat and BCUs, must operate a biochar production operation in the UK, use CapChar approved pyrolysis technology must collect and record data into the CapChar digital monitoring, reporting and verification (dMRV) software platform, which includes a Public BCU Registry.

The Biochar Carbon Code and its methodology provide assurance to organisations that any BCU purchase is backed by supply chain that includes provenance of feedstock, biochar production conditions, provenance of sequestration and processing/transport energy/carbon burdens. This provides a transparent digital chain of custody, where every one BCU issued represents one metric tonne of carbon dioxide equivalent sequestered permanently for 100+ years.

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Purpose

This quality assurance protocol - the Biochar Carbon Code - provides a robust approach to producing biochar together with a methodology and calculation to quantify the equivalent carbon dioxide removal when biochar is sequestered in permitted sequestration types with a permanence of 100+years. Fulfillment of these steps is necessary for the issuance of Biochar Carbon Units (BCUs). The code provides a framework for data collection covering the end to end process including feedstock provenance, biochar production, secure sequestration and the associated transport and process burdens. It is embedded into biochar production operations, ensuring operating parameters are captured in near real time via a digital Measuring, Recording and Verification tool (dMRV), creating a digital twin of the physical process. This data evidence is then independently audited for verification, providing assurance to BCUs purchasers.

It launches as a UK based code, which aims to:

- Support the scale up of Biochar Production and Carbon Removal in the UK
- Provide UK organisations and businesses with a “Made in the UK” carbon offset product
- Support the UK’s efforts to remove carbon dioxide from the atmosphere, using biochar production and sequestration as an engineered carbon removal tool
- Provide a framework, which allows biochar producers to use heterogeneous non-hazardous feedstock materials and recycle them back into carbon for added value

The Biochar Carbon Code coupled with affordable batch pyrolysis technology, creates an economically viable model that will allow more stakeholders to participate in the new biochar production and carbon removal industry.

Alignment with 3rd party carbon principals

The Oxford Offsetting Principles

A set of guidelines designed to enhance the integrity and effectiveness of carbon offsetting strategies. Developed by the University of Oxford, these principles aim to align offsetting practices with the global goal of achieving net zero emissions. The principles emphasise the importance of long-term sustainability, environmental integrity, and transparency. The Biochar Carbon Code is aligned with the following:

1. Shift to long-lived storage offsets

Biochar production/sequestration is a solution that results in long-term carbon storage, to prevent the re-release of carbon into the atmosphere.

2. Support carbon removal over avoidance

Biochar is a carbon removal solution rather than projects that merely avoid emissions (e.g., renewable energy projects). Removal is essential for achieving net zero goals.

3. Commit to Net Zero aligned offsetting

Biochar carbon removal is Net Zero aligned allowing organisations to adopt offsetting approaches consistent with the Paris Agreement and ensure that their offsets align with science-based pathways to achieving net zero by 2050.

4. Ensure environmental and social integrity

Biochar as a product has high environmental benefits in agriculture/water treatment reducing harm to biodiversity and the wider environment. Our decentralised model means many smaller stakeholders can participate bringing economic value to local communities, driving a new local/circular value added model into many parts of the UK.

5. Transparency and reporting

Our public registry provides a transparent view on any biochar carbon unit purchasers.

The Biochar Carbon Code sets out a clear chain of custody audit data trail, which provides confidence to purchasers.

The Integrity Council for the Voluntary Carbon Market (ICVCM) Core Carbon Principles

Recently established the Core Carbon Principles (CCPs) create a high-integrity standard for carbon credits in the voluntary carbon market (VCM). These principles aim to ensure that carbon credits deliver real, measurable, and verifiable climate benefits while upholding environmental and social integrity. Below is a summary of the CCPs:

1. Real, measurable and additional mitigation

Biochar carbon Units (BCUs) are real and represent actual emissions removals that have genuinely occurred.

The activities are all quantifiable, based on the Biochar Carbon Code with robust and consistent methodologies.

All emissions removals are additional and go beyond what would have occurred in a business-as-usual scenario.

2. Independently verified

All BCUs undergo rigorous verification via a third-party LCA provider to confirm compliance with the Biochar Carbon Code.

3. Permanent

Globally it is currently agreed that biochar is a permanent emissions removal solution over a 100 year time horizon, based on a set of agreed scientific criteria, which must be adhered to.

4. No double counting

The CapChar public registry will only contain BCUs that have been issued and retired from any stakeholders using our solution. They should not appear on any other registry. All BCUs are uniquely issued, tracked, and retired to ensure they are not counted more than once toward climate goals.

5. Transparent

The Biochar Carbon Code provides a level of transparency through its methodologies, issuance data, and social and environmental impacts.

6. Additional environmental and social benefits

Biochar production/sequestration generate co-benefits, such as enhancing biodiversity, improving livelihoods, or supporting local communities, without causing harm.

7. Aligned with global climate goals

BCUs are aligned with the objectives of the Paris Agreement, contributing to global efforts to limit temperature increases to well below 2°C, with an ambition to limit warming to 1.5°C.

8. Regular updates

The Biochar Carbon Code will be reviewed initially every 6 months to reflect any latest scientific knowledge and policy developments.

The European Union - Carbon removals and soil emission reductions

In November 2024 the Council of Europe announced a regulation establishing the first EU-level certification framework for permanent carbon removals, carbon farming and carbon storage in products. This voluntary framework will facilitate and encourage high-quality carbon removal and soil emission reduction activities in the EU, as a complement to sustained emission reductions. The regulation will be the first step in introducing a comprehensive certification framework for carbon removals and soil emission reductions into EU legislation. It will help the EU to achieve its goal of climate neutrality by 2050.

1. Quantification

The Biochar Carbon Code provides a scientific calculation to quantify the carbon removed by producing and sequestering biochar resulting in measurable, robust, and scientifically valid outcomes.

Quantification accounts for baseline emissions, leakage, and the lifecycle of the carbon stored.

2. Additionality

Biochar carbon removal activities would not have occurred in a business-as-usual scenario.

A financial model is built to show support needed from the selling of BCUs.

3. Long-term storage

Globally it is currently agreed that biochar is a permanent emissions removal solution over a 100 year time horizon, based on a set of agreed scientific criteria, which must be adhered to.

4. Sustainability

Biochar production/sequestration generate co-benefits, such as enhancing biodiversity, improving livelihoods, or supporting local communities, without causing harm.

Summary of the Process

Feedstock must be virgin woody materials: the Biochar Carbon Code does not accept hazardous materials or chemically treated wood of any sort.

Whilst homogenous feedstock provides less variability in the biochar produced and therefore its reproducible characteristics, in many situations and operations feedstock material will be heterogeneous in nature.

Biochar production operators must use approved pyrolysis technology (Section 3.2) that:
- Recovers and uses 70%+ of the waste heat produced during process (Section 3.5)
- Produce biochar with >40% carbon
- Achieve an H/Corg ratio of <0.5 for permanence in the environment (Section 5.5.4)
- Produce biochar at pyrolysis temperatures between 480-600ºC (Section 3.3)
- Undertake a sampling and testing regime for carbon content, H/Corg and moisture measurement (see Appendix 1)

Biochar must be sequestered in soil, compost, growing media or products (Section 4.2) for Biochar Carbon Units (BCUs) to be issued.

The Biochar Carbon Code is designed to be used alongside the CapChar dMRV tool, which will provide a digital repository for all the supply chain data necessary for a Life Cycle Analysis (LCA) and Carbon Audit. An approved independent carbon auditor must conduct a LCA to establish the quantification of carbon dioxide equivalent removed based on the Biochar Carbon Code. When a verification document has been produced, a BCU can be issued and purchased by end customers.

Definition of biochar

Biochar is the carbon rich remains of organic material that has been heated to decompose and remove most of the hydrogen and oxygen containing molecules within the organic material - lost as tars and flammable gases. The thermochemical process is called pyrolysis and is carried out in the absence of air/oxygen to prevent the organic material burning. The resulting residue is black and contains the "skeletal" remains of the starting feedstock material e.g. wood[3]. The finer the starting material the more dust will be produced. Under higher temperature pyrolysis there is further condensation of the carbon into fused aromatic rings[4].

Biochar has uses as a material in agriculture, building and construction but in addition it has value for the carbon dioxide sequestration equivalence it holds. Sequestration via biochar has a value that is now widely recognised from the IPCC[5] through governments, enterprises and individuals. At the time of writing the value of biochar and other means of permanent sequestration of carbon dioxide are still being established in the marketplace.

1. Biochar production operation feasibility and compliance audits

1.1 Introduction

Prospective biochar production operators can apply to join the CapChar network. An initial assessment process will be undertaken by CapChar to check eligibility. CapChar will then visit the proposed biochar production operation site and carry out a compliance audit. A biochar production operation cannot be verified against the biochar carbon code for the issuance of BCUs, unless it can provide digital evidence (Section 5. Data and evidence collection)

1.2 Eligibility application process and criteria

New biochar production operators must apply to CapChar using the online application form. CapChar will review this information and respond with a pass or fail. Feedback will be given if an application fails and resubmissions can be made. A pass will lead to a phone call interview where the following set of criteria listed below (Sections 1.2.1-1.2.5) will be discussed and further evidence may be sought post phone call before a biochar production operation visit (Section 1.3) can be arranged.

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[3] Influence of Biochar Particle Size Fractions on Thermal and Mechanical Properties of Biochar-Amended Soil - Link
[4] Developing a molecular-level understanding of biochar materials using public characterization data - Link
[5] Intergovernmental Panel on Climate Change (IPCC) - Link

1.2.1 Feedstock plan

A plan of proposed feedstock including feedstock type, availability/quantity/frequency and proposed 3rd party feedstock stakeholder agreements. Distance of feedstock transport to the proposed site will be considered, ideally less than 30 miles.

1.2.2 Site location and services plan

Details of address, postcode and “What3words” exact site location. A plan for water supply, electricity supply, drainage, location of neighbours and site access. The site will be assessed for suitability of location including immediate neighbours, existing operations and potential use of heat recovery.

1.2.3 Biochar production operation size - regulatory requirements

1.2.3.1 Planning permission and Environmental impact assessment

Biochar production operators are required to check local planning permission requirements for the size of operation. Planning may also require an environmental impact assessment (EIA).

1.2.3.2 Emissions and environmental permits

Biochar production operators must check and if necessary adhere to the Waste Incineration Directive (WID)[6] and the Industrial Emissions Directive (IED) Chapter 4[7], paying special attention to the size of the biochar production operation and feedstock used.

Emissions reporting and operation permits are governed by either the Environment Agency or the Local Authority. Operating permits must be sought by local, national or regulatory bodies in the operation jurisdiction and evidence must be supplied.

1.2.4 Health, safety and environmental plan

Biochar production operators must provide a health/safety/environmental plan to demonstrate that appropriate measures are in place for a safe working environment including the safe materials handling and transport of both feedstock and biochar. Mitigation measures to reduce the risk of spontaneous combustion, fire, wood and biochar dust and health hazards should include biochar quenching, cooling and storage. When sampling biochar to send for laboratory analysis extra health and safety procedures are required (Appendix 1).

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[6] DEFRA - Waste incineration directive (WID) - Link
[7] DEFRA - Environmental permitting guidance: waste incineration - Link

1.2.5 Sequestration opportunities plan

Any proposed applications for the biochar at the site or surroundings or details of any proposed sequestration partner agreements.

1.2.6 Additionality + simple economic model

Additionality is a concept used in the context of carbon projects, which refers to the notion that a biochar production operation must result in additional emission reductions or removals beyond what would have occurred in the absence of the project.

In other words, a carbon project can only be considered effective if it goes beyond business-as-usual and results in emissions reductions or removals that would not have otherwise occurred. This is essential to ensure that the offset credits generated by the project represent real and additional climate benefits.

To demonstrate additionality, a biochar production operator needs to prove that their biochar production operation would not have been implemented without the financial incentives provided by BCUs. This can be done through a variety of methods, such as demonstrating that it is not financially viable without carbon investment funding. A simple economic model will need to be provided.

1.3 Site visit - Compliance audit

If all eligibility criteria (Sections 1.2.1-1.2.6) and evidence has been provided, CapChar will arrange a time to visit the proposed biochar production operation location and meet the proposed biochar production operator and any team members. The biochar production operator must be able to validate any eligibility criteria in person to receive sign off.

1.4 Agreed equipment audit

The biochar production operator will provide a list of all the equipment expected to be used to operate successfully. This will form the basis for the energy use evidence (Section 5.6).

1.5 Agreed embodied carbon audit

The biochar production operator will provide a list of new/existing equipment on-site and civil infrastructure expected to be used to operate successfully. This will form the basis for the embodied carbon calculation (Section 7.6).

1.6 Training and manuals

CapChar will provide a training course on how to operate the pyrolysis technology safely and efficiently. This will be accompanied by an operational and a health/safety manual.

1.7 Legal agreement sign off

A biochar production operator must sign a legal agreement stating adherence to the Biochar Carbon Code, certifying that all data, information, and documentation evidence provided to the digital Monitoring, Reporting, and Verification (dMRV) system is, to the best of their knowledge and belief, true, accurate, complete, and not misleading.

1.8 Site sign off agreement

CapChar will review the audit data and any further evidence provided, as well as having provided a training course and handed over the manuals. A pass will lead to a notification provided to the proposed biochar operator within 7 business days of sign off. A failure will lead to a notification report detailing failure criteria, with the opportunity to rectify the failure criteria. CapChar will have the final say on whether a site can be signed off. An agreement will be signed clearly detailing the obligations in which the biochar production operator can operate.

2. Process Methodology - Feedstock requirements

2.1 Introduction

Feedstock must be derived from virgin woody materials and, if deemed a waste, must follow the Environment Agency (EA) Low Risk Waste Position (LRWP) 60[8] and must always be classed as non-hazardous waste.

Feedstock must be sustainability sourced and obtained from a variety of sources as local to the biochar production operation as possible. This can include arborists' arisings, brash from forest management, woodland and farming operations. In collaboration with feedstock suppliers, biochar producers will aim to enforce minimal introduction of extraneous material which could detract from the quality of the biochar.

[8] Environment Agency - Storing and treating waste to make biochar: LRWP 60 - Link

2.2 Permitted feedstock types

The biochar carbon code assumes that feedstock material will be heterogeneous in nature, meaning that there might be a significant variety of wood species/types being processed in any one batch.

The following feedstock types are permissible for biochar production under the biochar carbon code.

Note: Other non-virgin/chemically treated woody material should be rigorously excluded from any of the following feedstock types.

2.2.1 Whole tree

Whole tree is defined as trees where the entire mass of the tree, trunk, bark, branches and tops are all chipped. Whole trees are harvested for many reasons - good practice woodland thinnings to encourage greater overall growth, clearing for infrastructure projects, fire management, disease management or post storm clearance. In these cases the wood is unlikely to be suitable for use as a building or furniture material.

2.2.2 Forestry brash

Forestry brash is defined as the by-product of the trunk harvesting process, which includes all the tops, side branches and leaves. Much of this material is used as surface dressing for tracks and may pick up soil and stones. Biochar production operators must ask their feedstock partners to deliver a clean feedstock product that has been chipped or is suitable for chipping at the biochar production operation.

2.2.3 Sawmill by-product

Sawmill by-product is defined as the slab or flitch off-cuts and sawdust residue. These materials can be used for fuel for biomass boilers, compost or mulch and are suitable feedstock for biochar production.

2.2.4 Tree surgery arisings

Tree surgery arisings, arborist arisings are defined as materials created during normal arborists' operations, which may include woodland management. They include whole trees, shrubs, hedges, branches, clippings, tree stumps and associated leaves. Roots may also be included provided that as much soil as practical is discarded at the site of origin. This material is normally chipped at site to make transport practical. The resulting virgin wood chip is appropriate as a feedstock material for biochar production.

2.2.5 Green waste over-size (GWOS)

Green waste over-size is defined as material that is too large to be included in the compost produced from the green wastes collected by local authorities and others including garden and municipal materials.

For GWOS the incoming material must meet the UK's (Publicly Available Specification for Composted Materials) PAS 100[9] standard for composted material and be free from plastics, metal, soil and stones. Most trace plastic materials will pyrolyse to char, but material containing PVC should be rigorously excluded to avoid production of hydrogen chloride and its reaction products.

2.2.6 Orchard & Vine prunings

Orchard and vine prunings are defined as the branches, twigs, and other woody material that are trimmed or cut away from fruit trees (orchards) or grapevines (vineyards) during their routine maintenance and management. Pruning is typically carried out to enhance plant health, increase productivity, facilitate harvesting and prevent damage.

2.2.7 Other organic raw materials

There are other organic materials and agricultural wastes including but not limited to wheat straw, barley straw, oil seed rape stems, other cereal straw, reed canary grass, material from removal of invasive species and anaerobic digestate which may be included.
In the future, other materials such as animal manures, food waste and sewage that can be pyrolysed, will be considered on a case by case basis and agreement must be sought by CapChar to proceed using any of these materials.

2.3 Feedstock moisture (Advisory note)

Drying feedstock material is a time consuming process, so the wetter the material the longer it takes to dry. This will lead to longer operational days and higher fuel consumption. It is advised that all feedstock material is dried where possible before loading into the pyrolysis equipment. Ideally a moisture content of between 10-20% should be sought. Note: Freshly cut feedstock material can have 50+% moisture.

[9] REAL's certification scheme for quality composts PAS 100 - Link

2.4 Change in feedstock type

Written notice must be given to CapChar if feedstock is due to be changed. A new characterisation test must be carried out and passed before operations can continue with new feedstock. CapChar accommodates a variety of materials as feedstock, as described above, provided the final biochar meets the characterisation requirements (Section 5.5.2 & Appendix 2).

2.5 Feedstock transport

Feedstock should be sourced from less than 30 miles to the biochar production operation. In certain areas this may not be possible and must be agreed in the biomass audit (Section 1.2.1). The carbon burden of the transport of feedstock and biochar will be included in the LCA, (Section 5).

2.6 Feedstock storage

Feedstock should be stored in an appropriate and safe manner. If storing wood chips, special attention should be made to managing pile temperature to reduce any risk of spontaneous combustion from piles heating up. Fire safety must be considered: procedures and a plan must be in place.

2.7 Feedstock regulatory requirements

2.7.1 Interpretation of waste

Biochar production operators are responsible for the feedstock material that is pyrolysed to produce biochar. The EA have published details of waste codes that apply to their LRWP 60[3] and 61[10], as well as an evidence report[11] detailing what is deemed a non-waste or a waste feedstock material.

Biochar production operators will need to record what type of feedstock material they are using as part of the digital data collection evidence.

[10] Environment Agency - Storing and spreading biochar to benefit land: LRWP 61 - Link
[11] Environment Agency - Evidence report | Product comparators for materials applied to land: non-waste biochar - Link

2.7.2 End of waste status

Today there is no quality protocol (QP) for end of waste status that applies to feedstock materials that are classified as wastes that are pyrolysed resulting in biochar. Like PAS100 for composting operations, an equivalent could be developed for biochar. CapChar aims to partner with organisations that would like to develop a QP for biochar in the UK.

2.7.3 Low risk waste position (LRWP) 60

If the input feedstock material is deemed a 'waste' then LRWP 60[3] applies and must be complied with.

2.7.4 Low risk waste position (LRWP) 61

If the input feedstock material is deemed a 'waste' then LRWP 61[5] applies and must be complied with.

2.7.5 Wildlife and Countryside Act 1981 - (Advisory note)

In the UK, it is an offence under Section 1 of the Wildlife and Countryside Act of 1981[12] to intentionally take, damage or destroy the nest of any wild bird while it is in use or being built, or to intentionally kill, injure or take chicks or adults, or intentionally take or destroy any eggs (with some exceptions). Nesting season is considered from March to August.

Biochar production operators must check if their feedstock partners are providing feedstock material that would be felled during these months and if so that they have appropriate paperwork licences.

3. Process Methodology - Production requirements

3.1 Introduction

A biochar production operation can vary in size with an output from 50 kg/day to >1 tonne/day. A variety of pyrolysis technologies can be used to produce biochar, these broadly fall into batch and continuous process technologies. Both approaches heat the feedstock in the absence of oxygen or in low oxygen conditions. This is necessary to avoid the material combusting and releasing all the carbon dioxide. The highest pyrolysis temperature feedstock is processed,

[12] Wildlife and Countryside Act 1981 - Link

determines some of the key properties of the resulting biochar. The literature[13][14] suggests that temperatures above 500ºC drive greater aromatisation within the char - more graphitic phase. In turn this is associated with lower rates of decomposition in the soil and hence longer sequestration. Pyrolysis temperatures below 500ºC result in chars with more amorphous carbon with greater fraction of environmentally shorter-lived carbon. However, this type of biochar has properties that can be more suitable for growing plants e.g. better cation exchange properties[15][16].

3.2 Approved pyrolysis technology (batch)

Currently CapChar provides a batch pyrolysis technology solution. 'Batch' is defined as an integrated process where a batch of feedstock is processed as a whole through loading, drying, pyrolysis, unloading, cooling, quenching and storage.

The batch pyrolysis technology solution includes cloud connected continuous temperature monitoring and weighing scales for collecting data (Section 6), quenching and crushing equipment.

Any other pyrolysis technology is not permitted for use with this Biochar Carbon Code.

3.3 Permissible fuel/energy

Woody biomass is the only permissible fuel for startup and operation of the pyrolysis technology. Fossil fuels cannot be used as a fuel under any circumstance. A butane/propane blow torch is permissible for the lighting of fuel biomass to start the process.

Advisory note: For all electricity used for the safe and efficient running of a biochar production operation, the biochar production operator will ideally contract a renewable energy green tariff electricity plan.

This can be used for, but is not limited to:

- Pyrolysis technology heating

[13] How biochar works, and when it doesn't: A review of mechanisms controlling soil and plant responses to biochar - Link
[14] Insight into Multiple and Multilevel Structures of Biochars and Their Potential Environmental Applications: A Critical Review - Link
[15] Biochar – synergies and trade-offs between soil enhancing properties and C sequestration potential - Link
[16] Nitrogen enrichment potential of biochar in relation to pyrolysis temperature and feedstock quality - Link

- Computer and process control equipment
- Internet connection
- Tools and machinery
- Augers and conveyors

3.3 Pyrolysis conditions

CapChar will provide an operational manual for the pyrolysis technology, which will detail the processes and optimisation for an efficient pyrolysis process.

Pyrolysis gases must be efficiently burnt or condensed as a liquid into wood vinegar/bio-oil, not emitted to the atmosphere.

The upper pyrolysis temperature must be sufficient to ensure all the material is converted into biochar leaving no un-pyrolysed material in the batch of production stream. Typically that temperature should be between 450 - 600ºC+.

3.4 Waste heat recovery and use

The current pyrolysis technology has simple waste heat recovery options. CapChar will aim to provide a number of heat recovery options in 2025, to drive greater efficiency towards 70% heat recovery. The heat can be used for, but is not limited to:

Drying duties - including feedstock, fuel, grains, compost, manures
Heating duties - including hot water and hot air
Electrical generation - organic Rankine cycle generator[17], thermoelectric generator[18]

3.5 Emissions

Efficient combustion is paramount for the carbon audit. In 2025 CapChar will use a 3rd party organisation to test the approved pyrolysis technology for its emissions profile under various conditions/feedstocks. Flue gases and other emissions need to meet local environmental emissions standards. (Section 1.2.3.2)

[17] Wikipedia - Organic Rankine cycle - Link
[18] Wikipedia - Thermoelectric generator - Link

4. Process Methodology - Sequestration requirements

4.1 Introduction

To determine that biochar has been deployed as a vehicle for sequestration a documented understanding of its final use is needed. In agriculture where and how much has been applied to a field, likewise in forestry settings must be established and documented. In horticulture the material may be combined with compost or other materials prior to use in growing. In all these cases the biochar must end up in a situation where it can not be burnt or otherwise rapidly degraded to carbon dioxide.

In all situations where biochar is used for sequestration and related biochar carbon units are issued then the final use must be documented and recorded on the CapChar dMRV tool.

4.2 Permitted sequestration types

4.2.1 Soil

Biochar will be considered sequestered once it is in/on soil having been applied to land. This includes farming, tree planting and construction/infrastructure groundworks.

4.2.2 Manure/compost for agriculture

Biochar can be mixed with an animal manure product, mixed with compost or incorporated into animal bedding.

4.2.3 Growing media compost

Biochar will be considered sequestered once mixed with a growing media substrate. Growing media that includes peat will NOT be accepted.

4.2.4 Considerations but currently excluded

CapChar is aware of other ways that biochar can be sequestered, but due to permanence uncertainty, these will need new permanence methodologies to be created in the future. If a biochar production operator would like to sell into these markets, CapChar will aim to develop new methodologies to enable BCU issuance in a reasonable time frame. BCUs cannot be issued if the biochar is sequestered in the following, but are not limited to:

4.2.4.1 Biochar products

A wide range of products that can be fully or partially composed of biochar including superconductors, packaging and insulation boards.

4.2.4.2 Concrete and asphalt

Any concrete products including bricks, panels, beams and asphalt used in roads, cycle lanes, pavements and driveways.

4.3 Change in sequestration type

A biochar production operator may choose to change the sequestration type as new sequestration partners are established. Biochar production operators must inform CapChar when their sequestration type is going to change and provide a digital record via a digital data collection tool.

4.4 Distance travelled

CapChar has the vision that all biochar produced must be delivered and sequestered within 30 miles of the biochar production operation, however the nascent market means not enough operations exist and end users are located across the UK. As such this section will be waived, but constantly reviewed every 6 months.

4.5 Regulatory requirements

4.5.1 Low Risk Waste Position (LRWP) 61

If the input feedstock material is deemed a ‘waste’ then LRWP 61[19] applies and must be complied with.

5. Data and evidence collection

5.1 Introduction

The biochar production operator must collect and input digital data to report on many aspects of the biochar production process and operation.

[19] Environment Agency - Storing and spreading biochar to benefit land: LRWP 61 - Link

Careful record keeping is key to ensuring a transparent chain of custody audit trail that facilitates verification that the biochar has suitable quality for end applications and that a value for carbon sequestration can be accurately ascribed.

All data including paper based evidence needs to be uploaded and stored digitally via the dMRV platform to be provided to a 3rd party LCA provider.

5.2 Digital Monitoring, Reporting and Verification (dMV) platform

CapChar has developed a digital Monitoring, Reporting and Verification (dMRV) platform, which is designed to provide a digital chain of custody audit to collect all supply chain data, which forms the basis for the verification of biochar produced/sequestered into a carbon dioxide equivalent.

A schematic diagram for the overall process and the Digital Monitoring, Recording and Verification (dMRV) Platform is shown below in Figure 1.

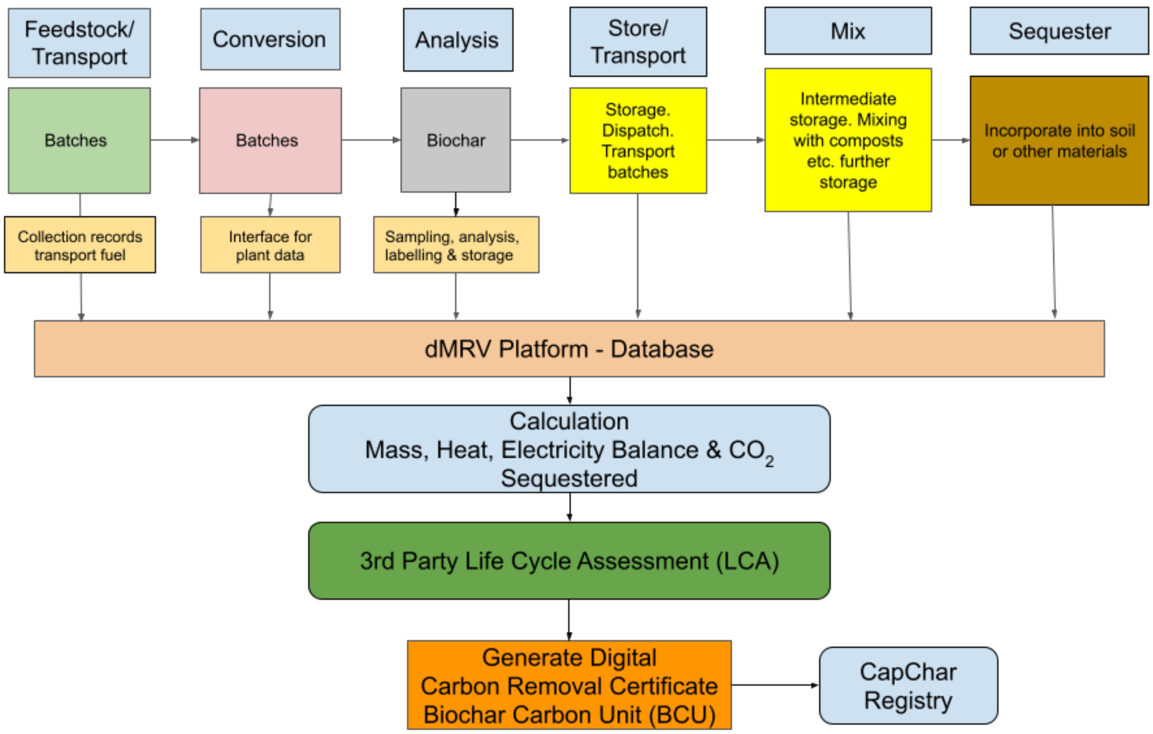

Figure 1 - Schematic for the CapChar Digital Monitoring, Reporting and Verification (dMRV) Platform

5.3 Data input evidence

The following feedstock evidence must be inputted into the dMRV platform.

5.3.1 Overall agreement

A signed agreement from the biochar production operator stating adherence to the Biochar Carbon Code, certifying that all data, information, and documentation evidence provided to the digital Monitoring, Reporting, and Verification (dMRV) system is, to the best of their knowledge and belief, true, accurate, complete, and not misleading. The following inputs are needed for the life cycle assessment (Section 6):

5.3.2 Feedstock evidence

- Delivery date
- Delivery vehicle make/model
- Distance travelled
- Approx weight/volume of feedstock
- Feedstock type
- Feedstock delivery notes or video evidence
- Proof of sustainability (e.g. FSC certification) where material is sourced from forestry operations or felling licenses where appropriate
- Waste operator/transport licenses where appropriate

5.3.3 Biochar production evidence

- Production date
- Feedstock input batch photo/video evidence
- Weight of the feedstock in and biochar out photo/video evidence
- Temperature profile data from pyrolysis technology
- Associated feedstock delivery if applicable

5.3.4 Sequestration evidence

- Associated batch numbers
- Delivery date
- Delivery vehicle make/model
- Delivery postcode
- Sequestration type
- Delivery note or invoice evidence
- Waste operator/transport licenses where appropriate
- (Advisory) Photo evidence of sequestration from end user

5.3.5 Electrical energy use evidence

The equipment list from Section 1.4 will be used and the following will be needed:

- Type and energy rating of equipment
- Hours of use/batch

5.3.6 Fuel energy use evidence

Receipts of fuel used will be needed as evidence for all equipment that runs on the following:

- Petrol
- Diesel
- LPG

5.3.7 3rd party external electrical or fuel energy use evidence

- Feedstock pre-processing information including the number of hours of processing for a specific feedstock delivery batch and what equipment was used to undertake the process

5.4 Sampling

Representative sampling of biochar is key to obtain valid measurements and ensure quality, safety and veracity of the subsequent carbon dioxide sequestration. Appendix 1 describes CapChar's approach for sampling biochar related to batch (and continuous) process systems.

The sampling protocol in Appendix 1 must be followed. This provides a representative sample of all the biochar batches produced within each monthly period for routine analysis.

A 10l biochar sample for the characterisation test must be collected in the first month of operation and sent to an approved laboratory before the end of the second month of operation.

A 2.5l biochar sample for elemental analysis and moisture content must be collected and sent to an approved laboratory every month.

5.5 Laboratory testing

To remain economically viable for smaller biochar production operators there is a balance to be struck between the amount of sampling and testing and its associated cost and verification. An initial biochar characterisation test suite provides confidence in the validity of the process and the produced biochar.

5.5.1 3rd party laboratory testing

CapChar will provide biochar production operators a list of 3rd party laboratories that can conduct the biochar tests necessary for compliance with the Biochar Carbon Code. Any approved laboratory will need to adhere to the Laboratory Testing Protocol (Appendix 3).

5.5.2 Biochar characterisation test (*one off)

Where local or national rules apply biochar must be produced in accordance with those rules and regulations for the proposed application.

Biochar production operators must undertake an initial biochar characterisation test, which will provide values for heavy metals, polycyclic aromatic hydrocarbons (PAH), dioxins/furans and PCBs benchmarked against European Biochar Certificate (EBC) Guidelines[20].

- Dry matter
- Water content
- Elemental analysis (CHNOS)
- H/Corg
- Bulk density
- Water holding capacity
- Electrical conductivity
- Major & minor elements
- pH
- Polycyclic Aromatic Hydrocarbons (PAH)
- Surface area & pore size distribution
- Particle size distribution
- Dioxins
- Furans
- Polychlorinated biphenyls (PCB)

*Any change or new feedstock types being processed will trigger the need for a new biochar characterisation test.

This test must be uploaded as evidence into the dMRV.

5.5.3 Elemental analysis test (monthly)

Using batch pyrolysis technology means a greater likelihood of nuanced pyrolysis conditions and therefore final biochar outcomes. As the percentages of carbon and hydrogen in the resulting biochar are significant factors in the value of the resulting biochar and associated BCUs, a once monthly test is needed to reduce the risk of variance.

Each monthly test must be uploaded as evidence into the dMRV.

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[20] European Biochar Certificate (EBC) Guidelines - Link

These elemental analysis tests constitute the Biochar sales specifications for selling biochar and the associated BCUs. The test methods are all publicly available (at cost) and internationally accepted (Appendix 2).

5.5.4 H/Corg ratio <0.5

The molar H/Corg ratio is the ratio of hydrogen (H) to organic carbon (Corg) in the biochar material, expressed on a molar basis.

H/Corg = Moles of Hydrogen (H) / Moles of Organic Carbon (Corg)

This ratio serves as an indicator of the chemical structure and stability of biochar. A lower H/Corg ratio indicates a biochar with a more aromatic (condensed ring structures) and less aliphatic (straight-chain hydrocarbons) structure. Biochars with low H/Corg ratios are more thermally altered, indicating they have undergone significant carbonisation during pyrolysis. A low H/Corg ratio (typically <0.4) is associated with high stability and resistance to microbial decomposition, meaning the carbon in the biochar is more likely to remain sequestered in soil for centuries. Higher H/Corg ratios (e.g., >0.7) indicate a less stable biochar with a higher proportion of labile (easily degradable) carbon compounds[21][22]. The H/Corg ratio decreases as pyrolysis temperature increases. Biochars produced at higher temperatures (e.g., >500°C) generally exhibit lower H/Corg ratios and greater stability compared to those produced at lower temperatures.

Biochar production operators will need to show an H/Corg ratio of less than 0.5 from each monthly batch sampled.

This section will be reviewed every 6 months or whenever new academic evidence is published in the public domain, whichever comes first.

5.5.5 Biochar characterisation sign off

If all results are within the limits described in Sections 5.5.2 - 5.5.3 then a biochar production operator can contract the services of a 3rd party LCA provider.

If any results are not within the limits described in Sections 5.5.2 - 5.5.3 the remediation will be necessary, which may involve changing the feedstock or the pyrolysis process conditions. Further tests will be needed to produce results that are within the limits.

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[21] One Step Forward toward Characterization: Some Important Material Properties to Distinguish Biochars - Link
[22] Biochar Carbon Stability Test Method: An assessment of methods to determine biochar carbon stability - Link

6. 3rd party life cycle assessment (LCA)

6.1 Introduction

To determine the final carbon dioxide equivalent value that can be truly ascribed to a given load/quantity of sequestered biochar, a Life Cycle Assessment (LCA) must be performed. This must be executed by a 3rd party organisation not affiliated to CapChar or any biochar production operator.

CapChar has considered the boundary conditions for a biochar production operation and has clearly defined these.

All 3rd party LCA providers will adhere to Sections 6.3 - 6.5 and Section 7 to provide a final quantification value in their report and work using ISO standards 140404/44 for the methodology of completing an LCA.

6.2 3rd party LCA provider selection process

CapChar will provide a list of organisations that have been approved to carry out an LCA against the Biochar Carbon Code. A biochar production operator must choose an LCA provider and engage with them independently to have the LCA carried out.

Once selected the biochar production operator must inform CapChar of their choice and contact will be made, so that CapChar can provide dMRV platform access to all the relevant data that has been collected.

6.3 Boundary conditions

The 3rd party LCA provider must adhere to the following boundary conditions in which the LCA should be carried out. The boundary conditions encompass emissions produced during the entire production lifecycle, see Figure 2 below. This includes feedstock processing and transport, biochar production and processing, transport and sequestration of biochar. For the Life Cycle Assessment (LCA) to be considered comprehensive, it should contain a breakdown of emissions data at various stages of the lifecycle and from various greenhouse gases.

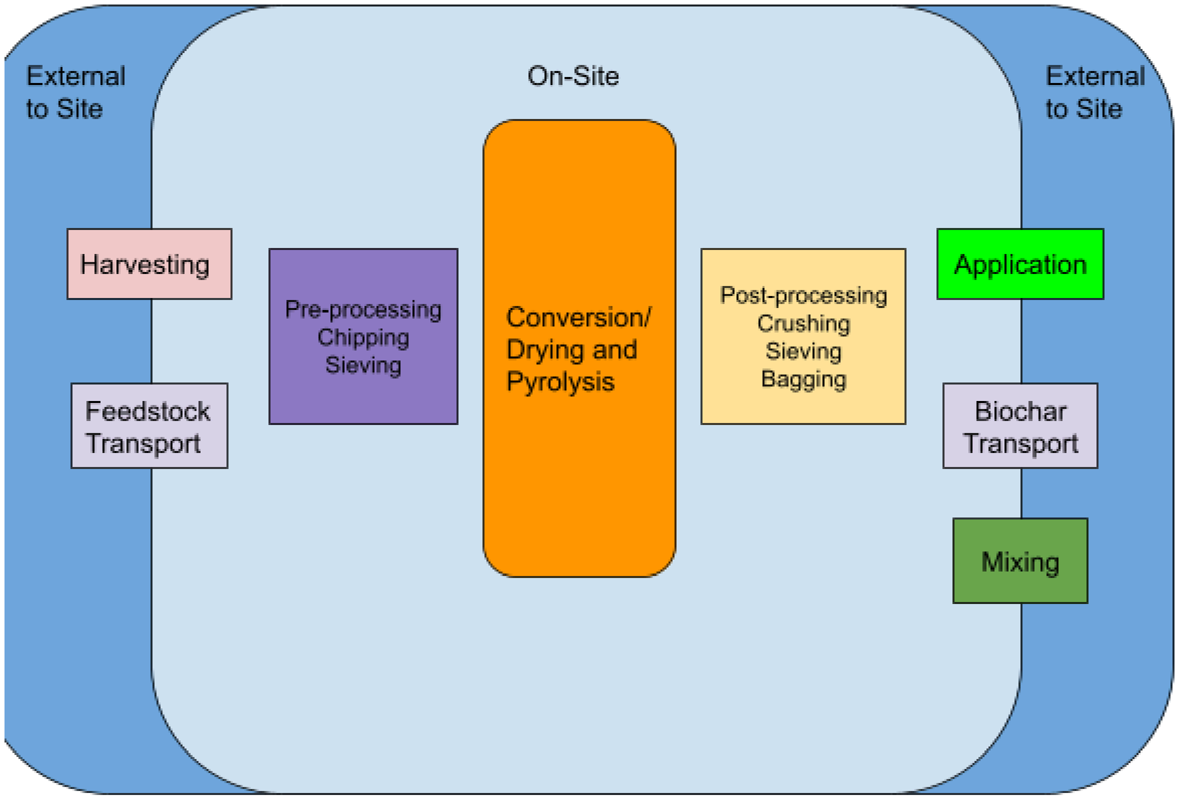

Figure 2 - Boundary conditions for any biochar production operation

6.3 Sequestration batch dates

The biochar production operator must define the date period to which they would like the LCA to be performed.

6.4 Data provision

The biochar production operator will input all the data required for a submission and ask CapChar to provide all the data contained in the dMRV to be made available to the 3rd party LCA provider. This will include all the data as seen in (Section 5).

6.5 Data used for calculation

The 3rd party LCA provider will use published data sets and where appropriate UK Government published stats where relevant (e.g. geographically).

6.6 LCA delivery

The 3rd party LCA provider will complete and deliver a report, which will detail the quantification and calculation of how much carbon dioxide has been sequestered based on the specifics of the production.

7. Quantification methodology

7.1 Introduction

The 3rd party LCA provider will collate all the data provided and quantify each batch according to the quantification methodology. This will result in a tonnes of carbon dioxide equivalent (tCO_2e) result for the amount of biochar produced and sequestered by the biochar production operator

7.2 Defined time period

A biochar production operator must define the time period in which an LCA should be conducted. Typically this will be every 6 months or when all feedstock has been used on a site, but a biochar production operator can choose any time period. This defines the data set needed from CapChar for the 3rd party LCA provider.

7.3 Complex material journeys

Due to the complex nature of following the journey of specific material through this process, all carbon emissions will be summed to provide the total emissions burden over the defined time period. This could lead to some feedstock material still being on site unprocessed or some biochar not sequestered, which would then feature in the next defined time period. This will mean over time all material will be accounted for.

7.4 Units of measurement

Energy rating of equipment will be provided in kW and fuel consumption in kg/hr, these will be converted into kWh and kg/CO2e respectively.

7.5 Full end to end carbon emissions burden

All of the following processes will need quantification and the total carbon emissions burden will be calculated for the defined time period as follows:

Total carbon emissions burden = (Fpe + Ft + Fp) + Pe + Bp + Bt + Bs

7.5.1 Feedstock pre-processing external to the biochar production operation (Fpe)

Feedstock pre-preparation is defined as any of the following: harvesting, shredding, grinding, chipping, sieving, drying or bagging.

In many scenarios feedstock material will arrive at the biochar production operation in a way that is BAU. e.g. Tree surgeon arisings are chipped at harvest site, which is normal practice and will therefore NOT be included in the emissions burden. If however pre-preparation is undertaken where it isn’t BAU, it must be included.

The calculation is based on the number of hours of processing for a specific feedstock batch delivery, what equipment was used to undertake the process and the fuel and energy burden associated with that equipment use.

7.5.2 Feedstock transport to the biochar production operation (Ft)

Feedstock transport is defined as the journey that the feedstock takes from feedstock harvesting or site starting point to the biochar production operation and back.

The calculation is based on the type of vehicle used to transport the material, its emissions burden fully laden in kg/CO_2e multiplied by the round trip distance travelled, assuming it is empty on its return journey.

7.5.3 Feedstock pre-processing biochar production operation (Fp)

Feedstock pre-processing is defined as any of the following: shredding, chipping and sieving.

The calculation is based on the number of hours of processing for a specific feedstock batch delivery, what equipment was used to undertake the process and the fuel and energy burden associated with that equipment use.

All feedstock deliveries will be continually summed and averaged to provide the transport burden associated with every biochar batch produced.

7.5.4 Pyrolysis production operation energy (Pe)

Pyrolysis production operation energy is defined as the energy needed to run the pyrolysis technology which may include but is not limited to fans, control systems, motors, actuators, sensors and any other auxiliary equipment including telehandlers and transportation.

The calculation is based on the number of hours of processing over a defined period of time divided by the number of biochar batches produced in that period of time, what equipment was used to undertake the process and the fuel and energy burden associated with that equipment use.

7.5.5 Biochar post-processing biochar production operation (Bp)

Biochar post-processing is defined as any of the following: quenching/inoculating, sieving/grading, grinding/crushing/hammer milling, drying or bagging.

The calculation is based on the number of hours of processing per biochar batch cycle, what equipment was used to undertake the process and the fuel and energy burden associated with that equipment use.

7.5.6 Biochar transport to sequestration location (Bt)

Biochar transport is defined as the journey that the biochar takes from the biochar production operation to the sequestration location and back.

The calculation is based on the type of vehicle used to transport the material, its emissions burden fully laden in kg/CO2e multiplied by the round trip distance travelled, assuming it is empty on its return journey.

7.5.7 Biochar sequestration (Bs)

Biochar sequestration is defined as the final process of applying biochar into its final substrate which includes spreading of the material on land (which can include further processing - inoculation with liquids, mixing with composts/manures), mixing with compost and inclusion in growing media, which are not BAU processes.

The calculation is based on equipment used to mix the biochar and substrate and the type of vehicle used to spread the biochar, its emissions burden fully laden in kg/CO2e multiplied by the round trip distance travelled, assuming it is empty on its return journey.

7.5.9 Excluded emissions

7.5.9.1 Pyrolysis operation fuel (Pf)

Pyrolysis operation fuel is defined as virgin wood, wood chip or old untreated pallets used as the fuel to start up the warming, drying or heating process. These emissions are excluded as BAU practice would mean that the feedstock material will decompose over a number of years[23] or be incinerated back to carbon dioxide.

7.5.9.2 Feedstock storage at biochar production operation (Fs)

Feedstock storage is defined as the way in which feedstock material is stored at the biochar production operation before it is processed into biochar. These emissions are excluded as BAU practice would mean that the feedstock material will decompose over a number of years[24] or be incinerated back to carbon dioxide.

Specifically for biochar production operations that are using wood chip as their feedstock material, the biochar plant operator should ideally aim to employ a just in time system for feedstock delivery to minimise storage of feedstock material. This isn't always practical, but no more than one month's worth of feedstock material should be held on a site at any one time.

There is limited academic work on the decomposition of wood chips in the environment, but compost practitioners indicate a decomposition via composting takes 1-4 years depending on conditions and wood material.

7.6 Embodied carbon emissions from biochar production operation setup

7.6.1 Calculation

Pyrolysis technology transport delivery is defined as the journey that the pyrolysis technology takes from the pyrolysis technology production facility to the biochar production operation site and the return journey assuming an empty load.
All of the following processes will need quantification and the total embodied carbon emissions burden will be calculated as follows:

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[23] From wood pellets to wood chips, risks of degradation and emissions from the storage of woody biomass – A short review - Link
[24] From wood pellets to wood chips, risks of degradation and emissions from the storage of woody biomass – A short review - Link

Total embodied carbon emissions burden = ECp + ECc + ECe

7.6.1.1 Pyrolysis technology transport delivery (ECp)

Pyrolysis technology transport delivery is defined as the journey that the pyrolysis technology takes from the pyrolysis technology production facility to the biochar production operation site and the return journey assuming an empty load.

7.6.1.2 Civils (ECc)

Civils are defined as any civil engineering works that need to be executed to successfully run a biochar production operation and may include, but are not limited to a concrete pad, construction of buildings/structures, material bays, drainage, services (water/electricity) and storage/containerisation.

7.6.1.3 Equipment transport delivery (ECe)

Equipment transport delivery is defined as the journey any equipment takes from its purchase to the biochar production operation site and the return journey assuming an empty load, that is needed to successfully run a biochar production operation and may include, but is not limited to a telehandler/skid steer, trommels and conveyors.

7.6.2 Depreciation period

Biochar production operations are a new industry, but are likely to be deployed/situated at an existing site, which may have existing equipment and civil infrastructure. For any new equipment and civil infrastructure that needs to be purchased/built this will need to be summed and depreciated over a seven (7) year time horizon.

The depreciation period shall be calculated on a day-based basis, explicitly accounting for the actual number of calendar days within the seven-year period, including any leap years that occur. For avoidance of doubt, the depreciation period shall therefore comprise either 2,556 or 2,557 days, depending on the presence of leap years within the defined horizon.

Depreciation shall be applied sequentially across biochar production batches. Each batch shall be allocated a proportion of the remaining depreciable emissions corresponding to the number of days that batch occupies within the seven-year depreciation window.

The seven-year depreciation window shall commence from the processing date of the earliest batch included in the assessment and shall continue uninterrupted across subsequent batches, such that:

- Each batch inherits the remaining depreciation balance from the immediately preceding batch;
- The number of days attributed to each batch reflects the actual production period of that batch; and
- No batch may extend the depreciation period beyond the fixed seven-year horizon.

Once the full seven-year depreciation period has elapsed, no further emissions may be allocated to subsequent batches, and any remaining biochar production shall be assessed independently under a new depreciation window.

7.7 Calculation of Biochar to Carbon Dioxide equivalent (CO_2e) sequestered

7.7.1 The molar ratio - carbon dioxide vs carbon

Pure carbon represents 3.67 times the mass of carbon dioxide (44/12, the molar ratio). Biochar has a carbon content ranging from 40% and upwards. Residual ash components and hetero atom molecules within the biochar (from wood and most organic materials) ensure that it normally contains less than 90% carbon[25]. Measuring the carbon content chemically provides the basis for determining how much sequestration is possible.

7.7.2 Permanence of Sequestration

The longevity of biochar in the proposed environment of incorporation (e.g. soil or substrates) is a critical factor and widely discussed in the biochar community including published academic work[26]. Currently there are two percentage permanence positions that have been published, creating a range from 74 -98+% permanence.

The first published[27] uses a degradation rate of 0.3% p.a. as an average rate. This translates into a remaining concentration from originally applied as 74% after 100 years.

The second published[28] explains inertinite content can be assessed by 'Ro reflectance testing' where inertinites have Ro > 2%. The fraction of a biochar identified as derived from inertinites could be treated as having a zero effective decay rate.

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[25] Properties of biochar derived from wood and high-nutrient biomasses with the aim of agronomic and environmental benefits - Link
[26] Modelling biochar long-term carbon storage in soil with harmonized analysis of decomposition data - Link
[27] Greenhouse Gas Inventory Model for Biochar Additions to Soil - Link
[28] Assessing biochar's permanence: An inertinite benchmark - Link

The industry has held the view that maximum pyrolysis temperature, pyrolysis residence time and H/Corg ratio are measurable factors to determine biochar permanence over a 100 year time horizon, but this is now being questioned. In an academic publication by Sanei et al.[29], released in early January 2025, the authors highlighted several key observations. They identified significant shortcomings in current biochar permanence models, which inaccurately assume that biochar is predominantly composed of the labile fraction. This assumption leads to the application of an incorrect, higher decay constant to nearly the entire biochar mass, resulting in a substantial overestimation of the decay rate for the largely inert recalcitrant fraction.

Moreover, the assignment of the recalcitrant fraction in biochar samples within previous models shows no correlation with production temperature or the H/C ratio. This finding challenges the well-established principle that higher production temperatures and increased carbonisation typically yield a greater proportion of the recalcitrant fraction. The inconsistency between the metadata and the expected chemical behaviour of biochar's labile and recalcitrant fractions reveals a critical limitation of current models, emphasising their inability to accurately represent biochar's long-term carbon sequestration potential.

80% PERMANENCE: The biochar carbon code will take a new position on the % permanence based on published work. All samples used in these meta-studies suggest a range of labile carbon from 15-1%. If we assume all 15% would decay over a 100 year lifetime that would leave 85% recalcitrant carbon left. As the science is still nascent allowing for another 5% of that remaining 85% would decay over the 100 year lifetime that would provide a final 80% permanence.

If in the future the % permanence increases due to new published evidence, retrospective BCUs will be issued on behalf of biochar production operators within 6 months of a biochar carbon code published update.

This section will be reviewed every 6 months or whenever new academic evidence is published in the public domain, whichever comes first.

7.7.3 The percentage organic carbon content

Using the sampling protocol in Appendix 1, samples will be sent to a suitable laboratory where elemental and other analyses will be undertaken to determine the Organic Carbon content expressed as mass percentage. The methods used are given in Appendix 2.

[29] Evaluating the two-pool decay model for biochar carbon permanence - Link

The method for Organic Carbon removes inorganic/carbonate carbon. Inorganic/carbonate carbon would be removed over time by interaction with the rain.

The Organic Carbon content will be calculated as an average of all the test results that fall into the defined time period.

7.7.4 The final calculation

Total tCO2e sequestered = (Molar ratio x % Organic Carbon x % Permanence x Total tonnes of biochar sequestered) - (Total emissions burden) - (Total embodied carbon burden/3)*

**Once a calendar year, for 3 years only.*

Number of BCUs to be issued = Total tCO2e sequestered

8. Biochar Carbon Units (BCUs) - Issuance and Registry

8.1 A Biochar Carbon Unit (BCU)

A Biochar Carbon Unit represents 1 tonne of carbon dioxide (tCO2e) equivalent based on batches of biochar that have been produced, transported and sequestered. A fractional BCU is also permitted and can be issued e.g. 0.5 BCU.

8.2 Point of issuance

Biochar Carbon Units can only be created if data evidence has been presented by the biochar production operator of the end to end process and a 3rd party LCA auditor has approved the process used. Biochar production operators will receive all the BCUs created and will have the opportunity to either retire them on the registry for use within their business or sell to 3rd parties.

8.3 BCU status

BCUs have three types of status “pre sold’, ‘issued’ and ‘retired’. All BCUs start with an ‘issued’ status. Issued BCU’s must be changed to ‘retired’ status within 3 years of issuance date.

8.4 Pre sold BCUs

Purchasers can buy BCUs that haven't been created using the pre-sold BCU mechanism. A signed agreement will be necessary between would like to purchase 100 tonnes of CO2e, this will be made up of 100 BCU's. As above smaller quantities can be defined in fractional BCUs.

8.5 Sale & transfer of BCUs

If a biochar production operator sells their issued BCUs to a third party, a BCU transfer form will need to be filled in to register the new owner.

8.6 Registry and registration

All BCUs will be published on its public CapChar registry.

8.7 Double counting

The purpose of the registry is to stop the practice of double counting.

To prevent double counting, each BCU is assigned a unique identification number (ID), ensuring traceability of any sequestrations and that each one is only used once. The Registry provides evidence of the owner of the BCUs, the biochar production operation that produced them and dates.

Biochar is a physical product and its associated BCUs are a digital product. The owner of these can be the same or different parties.

A biochar production operator may also use the biochar and sequester it themselves; in this case they own both the physical and the digital asset. However, if a biochar production operator sells the biochar to a third party then a sales agreement, which acknowledges that the carbon sequestration value of the biochar has been sold to another party will need to be signed. So any claims cannot subsequently be made by them and they can't sell it on another platform.

Glossary

Additionality
The concept that a biochar production operation must result in emission reductions or removals beyond what would have occurred without the project.

Arborist Arisings
Material from tree surgery, including branches, shrubs, clippings, and tree stumps, suitable as biochar feedstock.

Aromatic Compounds
Chemical compounds characterised by stable ring-like structures, contributing to biochar's long-term stability.

Batch Pyrolysis
A process where a defined quantity of feedstock undergoes pyrolysis in a single cycle.

Biochar
Carbon-rich material produced through the pyrolysis of organic matter in the absence of oxygen.

Biochar Carbon Unit (BCU)
A unit representing one metric tonne of carbon dioxide equivalent sequestered via biochar production and sequestration.

CapChar
The organisation responsible for developing the Biochar Carbon Code and associated tools.

Carbon Dioxide Equivalent (CO2e)
A standard unit for measuring carbon footprints, representing the impact of a given quantity of greenhouse gas in terms of the amount of CO2 that would create the same warming effect.

Carbonisation
The process of converting organic matter into carbon through thermal decomposition, typically under oxygen-limited conditions.

Carbon Sequestration
The process of capturing and storing atmospheric carbon dioxide to mitigate climate change.

Cation Exchange Capacity (CEC)
A measure of a material's ability to hold and exchange cations, influencing soil fertility and nutrient retention.

Civil Infrastructure (Civils)
Physical infrastructure required for biochar operations, such as concrete pads and drainage systems.

Condensed Aromatic Rings
Highly stable molecular structures in biochar that contribute to its persistence in the environment.

Digital Monitoring, Reporting, and Verification (dMRV)
A digital tool used to record and verify data from biochar production and sequestration operations.

Emissions Burden
The total greenhouse gas emissions associated with a process or activity.

End of Waste Status
A designation for materials that have completed a recovery process and can be used as non-waste.

Feedstock
Raw material used for biochar production, such as woody biomass or agricultural residues.

Forestry Brash
By-products of tree harvesting, including branches and tops, often used as biochar feedstock.

H/Corg Ratio
The molar ratio of hydrogen to organic carbon in biochar, used as an indicator of stability and carbonisation.

Low Risk Waste Position (LRWP)
UK regulatory framework for managing certain waste materials under low-risk conditions.

Net Zero
A state in which greenhouse gas emissions are balanced by removals from the atmosphere.

Organic Rankine Cycle
A process that uses organic fluids for energy recovery, often applied to waste heat utilisation in biochar operations.

Permissible Fuel
Fuel types allowed for starting and operating pyrolysis systems, such as woody biomass.

Permanent Sequestration
Long-term storage of carbon in a stable form, preventing its release back into the atmosphere.

Polycyclic Aromatic Hydrocarbons (PAHs)
Chemical compounds that can form during pyrolysis and must be measured to ensure environmental safety of biochar.

Pyrolysis
The thermal decomposition of organic material in the absence of oxygen to produce biochar and other by-products.

Quantification
The measurement and calculation of carbon dioxide equivalent removed through biochar processes.

Recalcitrant Carbon
Carbon in biochar that is resistant to decomposition and remains stable over long periods.

Sequestration Types
Permitted uses of biochar for carbon storage, such as soil amendment or compost integration.

Sustainability
The ability to maintain environmental, social, and economic balance over time.

Thermochemical Process
A chemical process involving heat, such as pyrolysis, to convert organic materials into biochar.

Transparency
The practice of providing clear, accessible, and verifiable information about biochar production and its environmental impact.

Virgin Woody Materials
Untreated wood or forest residues used as feedstock for biochar production.

Appendix 1 - Biochar sampling protocol

1. Introduction

1.1 Scope

This method is for obtaining representative samples for the chemical and physical analysis of biochar produced from wood based feedstocks.

1.2 Safety

1.2.1 Safe working procedures

Read the Material Safety Data Sheet (MSDS) for the product and ensure that you are familiar with the site safety procedures. If visiting the site to take samples ensure that you obtain permission of the Site Operating Manager or other responsible person, so you are aware of the Site Safety Procedures and any short term issues that could impact your safe working. Remain compliant with local safety procedures while carrying out this procedure.

1.2.2 Safety risks

Biochar carries low risk if it has been fully cooled and has been dampened with water. A saturation of 10-20% with water by weight will be sufficient to reduce the risk from dust and spontaneous ignition. Literature[30] shows there can be risks of spontaneous combustion even when biochar has been dampened. This sample protocol will be updated as necessary as operating experience develops further.

Dry biochar, especially when ground into fine powder, carries a risk from inhalation of the dust and at high concentrations from an explosion hazard. Avoid dispersing biochar dust.

There are physical risks involved with working with piles, large bags or shipments of biochar, these include for example, trips or slippage under foot, slippage of the piled material and slippage of barriers used to contain the pile. In addition moving equipment in the area may create a risk to personnel carrying out the sampling operation. Prior discussion with the Site Operations Manager or persons operating equipment nearby will help to ensure these risks are adequately managed.

[30] The phenomenon of spontaneous combustion - Link

Most operations will involve storage of biochar in large bags or metal drums but occasionally biochar will be held in piles. Personnel should avoid clambering onto the sides of a pile of biochar (or wood chip) to take a sample. Samples should be taken at operational stages before the material is in a stored pile. If this cannot be achieved, several samples from around the safely accessible side should be obtained see Section 3 below.

1.2.3 Safety equipment

Biochar (wet or dry) can quickly contaminate clothing during handling; it is recommended that a coverall is worn during sampling and handling procedures. Nitrile, latex rubber or other gloves will provide hand protection for handling cold materials. The site may require operators to wear protective work boots, hard hats and eye protection, it would be prudent to use this safety equipment while following this protocol.

Where the biochar is dry or where dust is evident, inhalation protection should be worn. On the basis that the operator is just in the dusty environment taking samples for a short period <1 hour a FFP3 dust mask would be appropriate. The manufacturer's advice on mask hygiene and longevity should be followed.

1.3 Method summary

To establish the quality of the biochar for commerce as a physical product as well as for calculating its carbon removal potential it is necessary to obtain a representative sample. Samples from a range of locations within the produced batch need to be taken and amalgamated to create a composite sample.

CapChar methodology requires collecting a **2.5 litre** sample for routine analysis and 10 litres when a full suite of tests (chemical and physical analysis) is planned, including trace metals, PAHs, dioxins etc and physical measurements. This is based on the requirements of the test laboratory. A second sample should be retained for any follow-up analyses or dispute management i.e. **2.5 litres** as above. Retained samples should be held for one month, after this time a subsample should be decanted into a separate 30 litre container and this new monthly sample should be held for one year, see Section 4 below for storage and labelling requirements. Retained sample excess can be returned to stock.

1.3.1 Theory

This protocol has been developed to provide a method to obtain a representative sample of biochar such that one or more subsequent analyses can yield answers that describe the total mass of the product with an acceptable level of accuracy to buyers and sellers.

The protocol aims to achieve the two objectives below:

- ensure that the sample is representative of the bulk material, which means all parts of the material being sampled must have an equal probability of being collected and becoming part of the final sample for analysis
- ensure that the sample does not undergo any chemical or physical changes after completion of the sampling procedure and during the storage prior to analysis

The first bullet is key for ensuring the credibility of the commercial process to determine the value of the carbon (dioxide) offset. Another challenge is that the actual analytical sample used is very small, just a few milligrams with the current elemental analysers. It is this factor that means getting an accurately representative sample is paramount.

Biochar can be derived from many starting materials and in different sized pieces - this protocol relates to wood based feedstocks. Biochar can be made from wood chip or from log wood of different sizes; it can also be made from wood yard offcuts or from other timber businesses where the timber has had NO chemical treatment.
The smaller batch plants will produce biochar in smaller quantities that need an appropriate sampling regime. So several factors need to be considered before the final detailed method can be developed. Material sizes eg log wood vs wood chip, quantity of lot to be sampled and moisture content. This latter may influence handleability in the sampling and processing steps prior to achieving the samples for testing.

For biochar that is made from larger starting materials then some reduction in size will be necessary as the first step.

The coal and coke industry has established methods for sampling in many national jurisdictions[31]. The International Energy Agency (IEA) Clean Coal Centre (CCC) reviewed “Coal sampling and analysis standards” in a report published[32] in 2014 authored by Qian Zhu. In that report they noted “about 80% of the total variances involved at the different stages of sample collection, preparation and analysis come from errors during its collection”. The ISO standards organisation have sampling methodology for coal, coke and biofuels[33][34]. In due course these standards may be updated to cover biochar.

Having a robust sampling protocol will serve the industry and support the credibility of its products whether for agriculture, construction materials or for carbon sequestration. Other approaches to carbon offsetting have come under pressure for a lack of robustness.

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[31] ISO 18283:2022(en) Coal and coke — Manual sampling - Link
[32] Coal sampling and analysis standards” in a report published in 2014 authored by Qian Zhu: (IEA CCC Ref: CCC/235 ISBN 978–92–9029–555–6).
[33] ISO 18283 - Link
[34] ISO 18135 - Link

Within the coal and coke industry the sampling ratio (mass of lot vs mass of sample for characterisation taken) varies depending on the size of the coal. Coal is classified into Run of Mine Coal 0-23 cm, Large Coal 5-15 cm and Small Coal 0-5 cm. The corresponding sampling ratios are: 1:714, 1/:1428, 1:3333. With Small Coal being broadly comparable with biochar derived from wood chips in particle size a similar sampling ratio (1:3000) is proposed for biochar.

The sampling ratio of 1:3000 (by mass of dry product) should be used.

Buchelli et al[35] examined the heterogeneity of biochar and consequences for its representative sampling. They found that grab sampling combined with repeated mixing and "mass reduction" did provide a method giving largely representative analysis for elements, but less so for PAHs.

CapChar has conducted its own assessment of the sampling protocol described here taking samples from a pile of c.a. 20 tonnes of wet biochar. That showed that the core analytical methodology for Total Carbon had a repeatability of 1.3%. Further the drying method used for measuring moisture had a repeatability of 2% as relative standard deviation.

2. Equipment

2.1 Equipment

- Sampling Spear e.g. Sampling Systems, Grain Spear 1 or 1.5m device. (Part 1942A -1000 or 1500). The opening size should be commensurate with the particle size of the biochar. The model described is adequate for biochar at 2cm or smaller particle size.
- Scoop (plastic or stainless steel)
- Shovel or trowel (stainless steel)
- Clean plastic sheet, tarpaulin or stainless steel tray to enable samples to be mixed post initial sampling
- Sample containers eg polythene buckets with airtight lids
- All the above equipment and materials should be cleaned of impurities and earlier sample residues to avoid contamination
- Marker pens and suitable labels

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[35] The heterogeneity of biochar and consequences for its representative sampling; Thomas D. Bucheli , Hans Jörg Bachmann , Franziska Blum, Diane Bürge,Robin Giger, Isabel Hilber, Johanna Keita, Jens Leifeld and Hans-Peter Schmid, Journal of Analytical and Applied Pyrolysis 107 (2014) 25–30.

- Preferably a label printer with a system to generate labels with serial sample numbers and dates.

Where the biochar is either sampled from a pile or from a vessel there is a need to take an appropriate number of subsamples, see Section 3 below, using either a sampling spear, scoop or shovel. The sampling spear is preferred in that samples can be conveniently collected from the interior of the pile. Wet biochar may prove difficult to sample as it may not “flow” into the spear cavities following insertion. In this case sampling may need to be adapted using scoops or shovels, taking samples from throughout the mass of biochar.

2.2 Equipment for mixing and partitioning collected samples

- Cone and Quartering, is a standard technique for dividing larger amounts of material into smaller quantities in a way that preserves the validity of the sample taken. The technique uses clean plastic sheet and shovel or purpose made cruciform mandible to separate the pile into equal quarters. One quarter is taken for the sample and one for the reserve or stored sample. The remainder is returned to stock.
- A sample riffler is an excellent means for dividing samples. Sometimes known as a spinning riffler or rotary sample divider this type of equipment can provide a reproducible method of obtaining a sample for analysis with efficiency and little bias. The actual operation of the riffler with typical samples should be tested prior to purchase. Some wet or sticky samples of biochar may be difficult to handle with this equipment.
- Spinning riffler example[36]:

All the above equipment and materials should be cleaned of impurities and earlier sample residues to avoid cross contamination.
The sample containers should be clean and dry before use.

3. Procedure

The output from batch processes can vary substantially; typical ranges are given below in Figure 4 Sampling Protocol Schemes. Analysis can be a significant component of the overall manufacturing cost. Samples from productions of more than one tonne should be sent for analysis to manage this cost element.

Where the biochar presents in a pile or a collection box there is a need to obtain a representative sample. This is done by taking a series of sub-samples ensuring the top, middle, bottom and around all sides of the pile. As the quantity increases from say, one to multiple

[36] Benefits of accuracy and efficiency - Link

tonnes of biochar there will be a need to obtain samples from the centre of the pile. This can be done using a thief/spear or pipe sampler, see drawing in the link[37].

It would be better to sample the biochar from the smallest batch available before it is added to a holding pile. In this way material from the whole of the batch may be conveniently collected.

The samples taken using this equipment are pooled prior to the next step. The samples taken should be about 1:3000 of the mass of the pile, see section 1.3.1 above. Specifically, the dry mass equivalent should be used if the biochar has been dampened.

As an example a total of 333g should be sampled for a **one tonne** lot. This would amount to approximately 1200 ml depending on the specific gravity. To provide enough sample for both analysis and retention, the total minimum quantity would be 2.5 litres (rounded up). An appropriate sampling spear would be needed to take ca 20-25g per use with 15 samples taken from the one tonne pile. These numbers should be scaled in proportion for larger production sizes. The sub-samples should then be pooled giving the final sample for analysis and retention.

If the biochar particles are larger than 2cm either a larger sampling spear or shovels should be used in a similar manner to ensure a representative sample is secured. This may result in a larger total sample being collected. In that case the collected sub-samples should be collected on a clean surface such as plastic sheet or other, see apparatus list. The material should be thoroughly mixed and scooped into a heap. The heap should then be separated into quarters using a shovel, trowel or similar - the cone and quarter method. Opposite quarters should be combined into the sample for analysis and the other two quarters combined as the sample for retention. Any excess material should be returned to the stockpile.

Where log or lump material has been used directly for turning into biochar i.e. no prior grinding, chipping or shredding then it may be appropriate for operators to remove samples at random from the charred mass sufficient to obtain a representative sample. This will require removal of approximately five times the mass in separate pieces. Those pieces must then be reduced by crushing and sieving to obtain sufficient material to select the sample for analysis. Use of cone and quartering or riffling to reduce the quantity (1:3000) to provide the sample for analysis. The cone and quartering method may need to be used more than once to reduce the sample to the size needed for laboratory testing.

Some plants may have on-site crushers to make this process easier and more reproducible.

[37] Images of Sampling Thieves - Link

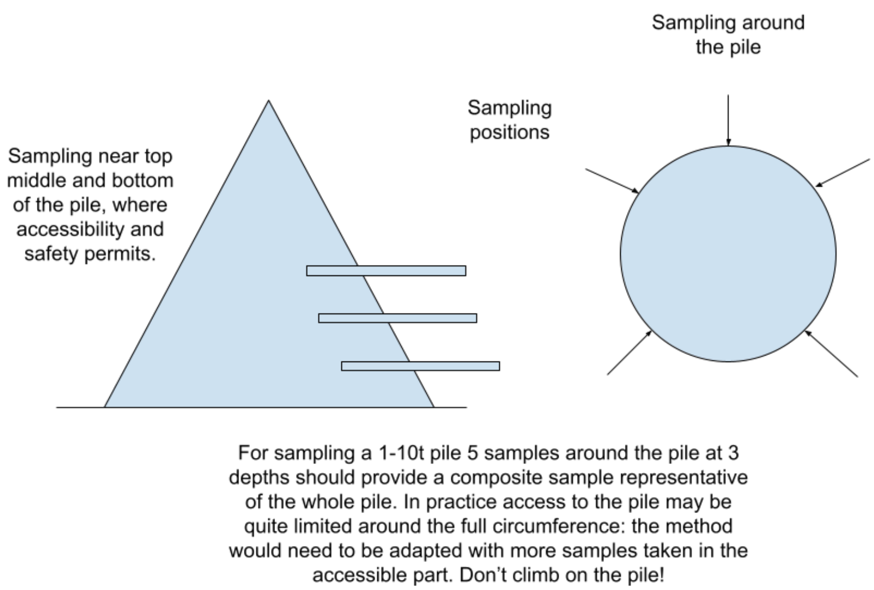

Figure 3 - Sampling a pile

The sampling ratios are typical of those used in the coal industry refs[38] [39] [40] [41], see also section 1.3.1.

4. Sample retention and labelling

Retaining a sample from production to enable further analyses in case of errors or disputes is a standard industry practice. The combined subsamples taken as described above will be divided into a sample for analysis and a sample for retention. These retention samples, collected daily will be combined, pooled and mixed at the end of the month. A 30 litre portion of this pooled sample will be labelled and retained. Any uncontaminated material from these daily samples can be returned to stock.

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[38] Coal sampling and analysis - Link
[39] Sampling methods for different types of goods - Link
[40] Methods for Sampling and Inorganic Analysis of Coal - Link
[41] IS 436-1-1 (1964): Methods for Sampling of Coal and Coke, Part 1: Sampling of Coal, Section 1: Manual Sampling [PCD 7: Solid Mineral Fuels] - Link

The labelling system should be ideally automated and capture: Date, Batch Detail, Quantity, Feedstock Detail, Operators Name.

Storage should provide protection from the weather, tampering and contamination.

5. Schematic showing sequences

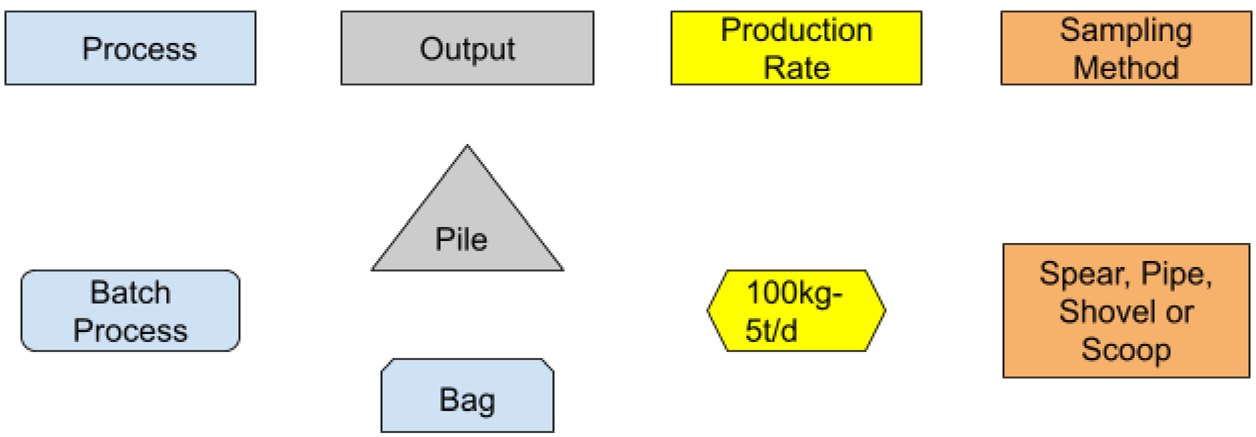

Figure 4 - Sampling protocol schemes

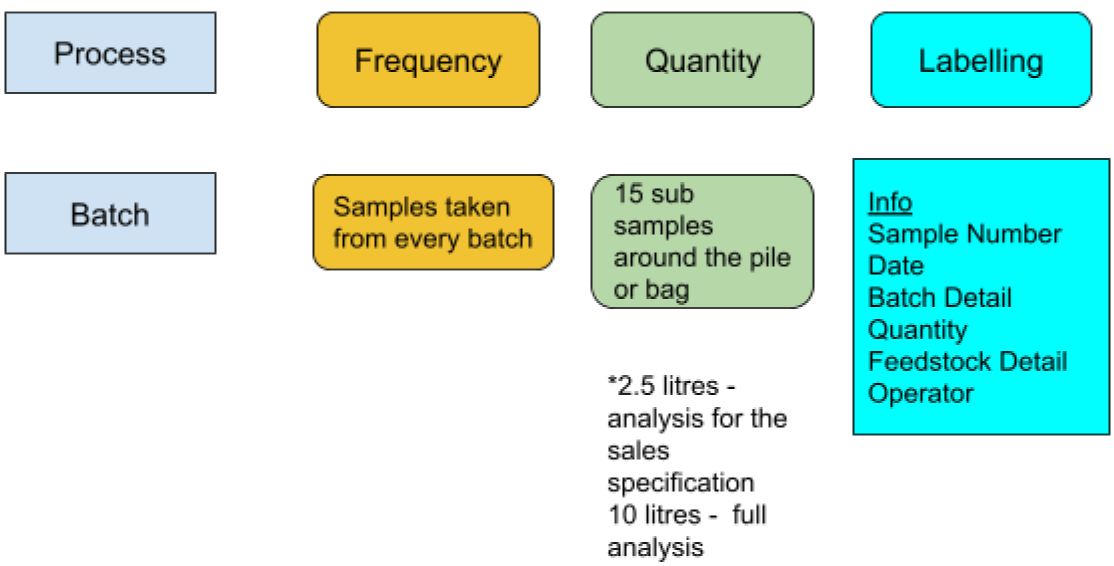

Figure 5 - Sampling frequencies and quantities at the biochar production operation site

6. Caveat

This protocol has been prepared on the basis that the people using it have been trained in sampling operations and are aware of the hazards that can occur in such operations and how to mitigate them.

This protocol has been prepared in good faith and based on the information available to CapChar Ltd at the time of preparation. The protocol may be amended as new information comes to hand or if the scope of the protocol is amended.

CapChar Ltd will not accept any liability for loss or damage originating from the use of the information contained in this protocol.

Appendix 2 - Biochar Sales Specifications and Test Methods

Tests and Test Methods for Biochar

Measurement	Analyte	Method	Name of Test Method	Comments	Typical values in wood based biochar
Elemental Composition plus ratios	*Carbon, Total Carbon, TC	EN 16948,2015	ISO 16948:2015(en) Solid biofuels — Determination of total content of carbon, hydrogen and nitrogen		40-80%
	Hydrogen	EN 16948, 2015	ISO 16948:2015(en) Solid biofuels — Determination of total content of carbon, hydrogen and nitrogen		2-4%
	Corg Total Organic Carbon (TOC)	BS EN 15936:2022 (new method)	Characterisation of waste - Determination of total organic carbon (TOC) in waste, sludges and sediments;	This method corrects for inorganic carbon (carbonates) which is included in the TC figure	
	*H/Corg	Calculation		Ratio is a surrogate for longevity of biochar in the environment	0.2-0.7 The smaller the value the greater the fused aromatic content and greater the longevity

Core Properties	* Water - Moisture	BS EN ISO 18134-1: 2022	Solid biofuels. Determination of moisture content - Reference method		10-75%
	* Loose Bulk Density	BS EN ISO 17828, 2015	Solid biofuels — Determination of bulk density		
	* Particle size distribution	Using dried sample with progressive sieving			

The test methods currently being used do not specifically mention biochar. It is likely they will be updated over time by the standards issuing organisations.

Sales Specifications for wood based biochar

The Biochar Carbon Code uses a limited but sufficient set of parameters to define the quality and quantity of the biochar for trading and BCU purposes.

Carbon content (Organic carbon,TOC) - Actual Value (min 60 wt%) + RSD
Hydrogen/TOC ratio - Actual Value (below 0.7) + RSD
Moisture Content - Actual Value (wt%) + RSD: Minimum 25% to facilitate safe transport

Loose Bulk Density - Actual Value kg/m^3
Odour of the dry biochar - Odourless
Particle Size Distribution - If required - range in mm.
Other parameters - if required by the customer

RSD = Relative Standard Deviation based on six replicates

Appendix 3 - Laboratory Test Protocols

The test methods used in this Code use internationally recognised test procedures as outlined in Appendix 2. There is a need to define the steps prior to using these methods to ensure repeatable answers that can be used to validate the claims made and support biochar carbon unit (BCU) sales.

Outline sequence of steps

On receipt of the sample, it is given a laboratory reference with a computer generated sequential number.

A sufficient sample, typically 10g, is taken to enable a moisture content to be obtained.
The weighed sample is heated in a moisture balance at 100ºC until a stable weight is recorded indicating that the sample has had the moisture removed. The method specifies 90ºC, the slightly higher figure used in our work is not deemed to be significant given the stable nature of biochar. Drying is necessary to ensure complete combustion and ensure accuracy in the subsequent measurement of hydrogen in the elemental analysis step. Drying also ensures the biochar is more readily ground for homogenisation.
The moisture content is recorded.

The dried sample from the above step is ground in mortar and pestle and homogenised
Five separate samples are taken at random from this material; each is measured according to method EN 16948,2015 and values for total Carbon (TC), Hydrogen, Nitrogen and Sulphur are recorded. A further series of tests on the five samples is carried out to determine the Organic carbon (TOC) content according to test method BS EN 15936:2022.

The molar ratio of hydrogen/organic carbon is calculated and recorded.

Repeatability of the above methods and procedures

Repeated tests have been made on single samples to determine the repeatability of the test methods. The following have been determined:

Moisture measurements - RSD 2%
This figure was achieved on very moist biochar (75%). With drier samples the repeatability, as RSD, is likely to be higher.

TC RSD 2%
TOC RSD 3%

Change Log

Version Number	Section	Change Summary	Rationale	Impact
1.1 Dated (05/01/2026)	7.6	The Biochar Carbon Code has updated the carbon emissions depreciation period from three (3) years to seven (7) years to reflect improved alignment with long-term operational realities, durability expectations, and conservative carbon accounting principles. Section 7.6 numbering and structure has changed to incorporate the new methodology.	The embodied carbon emissions depreciation period has been extended from three (3) years to seven (7) years to better reflect the minimum expected operational lifetime of biochar production sites, which is anticipated to be seven years or longer under normal commercial and infrastructure conditions. Biochar facilities typically involve permanent or semi-permanent capital infrastructure, long-term feedstock supply agreements, and ongoing monitoring and verification obligations. A seven-year depreciation horizon therefore provides a more realistic temporal alignment between operational emissions and biochar output, while maintaining conservative carbon accounting. In addition, the adoption of a day-based depreciation approach, including explicit treatment of leap years, improves precision and transparency in emissions allocation across sequential production batches. This ensures emissions are attributed proportionally to actual production timelines and prevents front-loading or truncation of emissions in early project years. Overall, this update strengthens methodological robustness, aligns the Biochar Carbon Code with real-world project lifecycles, and supports long-term credibility and comparability of issued biochar carbon units.	Previously issued biochar carbon units will be recalculated and any new available BCUs redistributed to 3rd party buyers.