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# CONSIDERATIONS REGARDING CONSTRUCTIVE SOLUTIONS FOR THE REALIZATION OF INSTALLATIONS FOR OBTAINING BIOCHAR

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**Abstract:** Biochar is a product obtained using thermal conversion of biomass and can be a viable option for the valorization of plant resources. The technology for exploiting plant resources in the form of biochar develops significant potential for improving soil quality, reducing greenhouse gas emissions, and promoting sustainable waste management practices. There are several methods of producing biochar, including slow pyrolysis, fast pyrolysis, and gasification. The choice of technology will depend on factors such as the type and availability of raw materials, the desired end product, and the economic aspects of the process. The process of producing biochar can also generate syngas, a mixture of carbon monoxide and hydrogen that can be used as a fuel.

**Keywords:** biochar, plant–based resources, pyrolysis, gasification

## INTRODUCTION

Biochar is a type of charcoal used for soil improvement or restoration, regardless of whether it comes from wood or unused plant residues (*https://ro.frwiki.wiki/wiki/Biochar)*.

Biochar is obtained by baking any form of organic biomass in a controlled process called gasification (limited oxygen) or pyrolysis (without oxygen) at a high temperature, often above 450 degrees in the absence of oxygen. Biochar has a high carbon content of up to 90% and binds the carbon material reliably, long–term, and without negative side effects. It is characterized by special physical and chemical properties and has a positive effect on biochemical processes. (https://anzbig.org/about/about–biochar/).

Biochar is also known as vegetal charcoal, and in general, it is produced by pyrolysis, which represents a process of chemical transformation or decomposition of organic substances at high temperatures and in the absence of air. It has been established that various biomass materials have been used to produce biochar, which involves agricultural waste, forest waste, garden waste, food waste, manure, sewage sludge, and aquatic organisms (*Woolf et al., 2010; Wu P. et al., 2021; Wu P. et al, 2023*).

Biochar has received increasing attention for its potential benefits in carbon capture, climate change mitigation, waste management, bioenergy production, soil improvement, and pollution control due to its unique properties (*Nidheesh et al., 2021; Xiao et al., 2018, Nenciu et al., 2022*). Biochar has a high content of recalcitrant carbon (C) and a strong capacity for carbon dioxide (CO2) adsorption (*Shafawi AN. et al, 2021; Ma Q. et al, 2021; Cao Y. et al. 2021; Nan Q. et al. 2021*). Its sustainable production and field applications allow for great potential for long–term carbon storage and reducing carbon emissions, thereby mitigating climate change (*Feng et al. 2021; Yang et al. 2021; Zhang et al. 2022; Nenciu et al., 2023*).

The production of coal and biochar has a common root. Before the appearance of fossil coal, the word coal meant – the black fuel made from wood.

The basis of all coal and biochar production is pyrolysis: essentially, the decomposition of wood into its chemical constituents by heat, with or without oxygen. With the development of cylindrical metal vessels and high–temperature refractory materials, various equipment for producing biochar has emerged.

High–quality biochar has high porosity, an extended microstructure, and adsorption capacity that allow for beneficial interactions between microorganisms, nutrients, and water in the soil (*http://www.carbon–negative.us/Burners.htm, https://biocharkilns.com*).

## MATERIALS AND METHODS

Biochar is an essential part of the next industrial revolution, creating a more sustainable future and leading to greater economic prosperity, increased job opportunities, and continued quality of life for humanity (Figure 1).

The use of biochar has resulted in improved soil quality and yield in agriculture and horticulture. It is also widely used as an additive for animal feed, can be used in construction materials such as concrete or asphalt, for air and water purification, helps regulate moisture, absorbs toxins, and promotes beneficial microbial life (Figure 2).

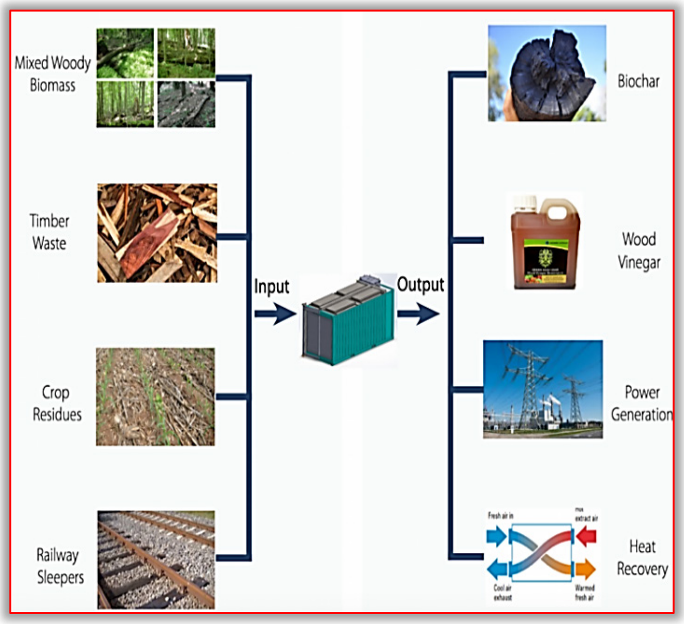


Figure 1 – Presentation of the main transformations of different raw materials (https://anzbig.org/about/about–biochar/)

It is a highly valuable resource and can be an essential part of the next industrial revolution, creating a more sustainable future and paving the way for greater economic prosperity, increased job opportunities, and continued quality of life for humanity. (*https://anzbig.org/about/about–biochar/*)

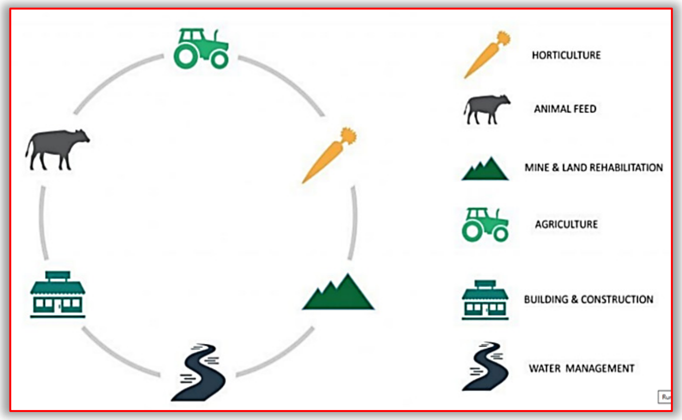


Figure 2 – The main beneficiaries of using biochar (https://anzbig.org/about/about–biochar/)

It is surprising how many people transport their yard waste (renewable biomass) to landfills or burn it in open fires until only ash remains. The technology for obtaining biochar is simple, and any farmer can produce it.

Biochar is similar to traditional charcoal, and they are identical in many respects, but the difference lies mainly in how they are used. Coal is used as fuel, and crushed coal mixed into the soil as soil amendment is biocarbon. As a soil additive, biochar offers numerous benefits. Unlike fertilizers, biochar has an extremely long life in the soil. Coal is rich in carbon and gives it the ability to persist in the soil indefinitely, being not susceptible to biological degradation.

Biochar attracts beneficial microbes and fungi, holds onto nutrients that are introduced into the soil, meaning biochar works better in the second and third year than in the first year. One of the major challenges in agriculture is to make plant nutrients available in the soil when the plant can benefit from them. Fertilizers can often only be applied at the beginning of the growing season, before the crop canopy closes and field operations are no longer feasible. Unfortunately, between the time fertilizer is applied and the crop takes it up, fertilizers can disappear from the soil or lose their characteristics through excess precipitation, consumed by weeds, or metabolized through microbial activity in the soil. Biochar helps conserve plant nutrients by storing them in its matrix and making them available when the crop needs them. This happens because of a property of biochar, certain clays, and organic matter in the soil known as cation exchange capacity.

This property, the cation exchange capacity (CEC), is a measure of the biochar's ability to retain ions, such as ammonium and potassium cations, in an exchangeable form that is available to plants. CEC not only helps conserve fertilizers added to the crop during the growing season, but also enhances the soil's capacity to capture and retain nutrients from other available sources at other times. For example, at the end of the growing season, crop residues are often left in the fields to decompose. When this organic matter decomposes, biochar captures some of the released nutrients, leaving these nutrients for the next growing season.

Biochar in the soil also has the ability to retain soil moisture, leading to significant cost savings in irrigation (*Mansoor S. et al. 2021; Zhu H. et al, 2020*). Biochar alters soil performance by retaining moisture and making it available during periods of low rainfall and warm and dry soil conditions. This is possible because biochar have very large internal surfaces. This internal surface absorbs moisture when water availability in the soil is high and releases it back into the soil when water availability is low. One might think that biochar, being black in color, heats up from the sun, but biochar helps keep the soil moist even in full sunlight.

Biochar also has a significant impact on soil drainage. Clayey soils, which are usually poorly aggregated, are too compact and do not drain efficiently. Inefficient drainage results in long periods of inadequate soil aeration. Other soils, especially sandy soils, can drain too efficiently. Excessively efficient drainage can shorten the benefits of periodic watering.

In both cases, adding biochar compensates for the deficiencies of the soil: clayey and poorly aggregated soils become less compacted and provide better aeration, and sandy soils gain additional moisture storage capacity.

Biochar also makes a significant contribution to mycorrhiza by promoting microbiota populations. Mycorrhiza is a fungus that has a symbiotic relationship with plant roots and contributes to a healthy exchange of soil–plant nutrients.

In a world dependent on fossil energy, it is easy to see the benefits of biochar carbon capture as compensation for current and future emissions from fossil fuels. Experts in the field believe that there is already an excess of carbon dioxide in the atmosphere, which requires measures to reduce it. It has been established that the main factors contributing to the increase of carbon dioxide, about 34% of emissions, have been attributed to land deforestation.

Therefore, in a way, the primary objective of biochar is to restore lost carbon to the soil due to decades of agricultural practice. After that, the exceptional durability of biochar will allow for the accumulation of more carbon in the soil, with additional fertility benefits.

Coal and biochar have the potential to sequester gigatons of atmospheric carbon per year, making it the most powerful atmospheric cleaning engine we have. If only a small portion of the carbon captured by plants can be pyrolyzed and transformed into coal (biochar), humanity's prospects will be much better, making a transition to a lower carbon emission economy. *(http://www.carbon–negative.us/Burners.htm, https://biocharkilns.com/)*

Among the main equipment used for producing biochar, we can mention:

- Ovens are commonly used for small–scale biochar production and can be constructed from a variety of materials, including brick, steel, or concrete. Ovens can be powered by a variety of heat sources, including wood, propane, or electricity.
- Slow pyrolysis reactors are used for the production of biochar on a larger scale and can be built from materials such as steel, concrete, or ceramics. Slow pyrolysis reactors are often heated using wood or other biomass as a heat source.
- Fast pyrolysis reactors are used for the production of large volumes of biochar and can be built from materials such as steel or ceramics. Fast pyrolysis reactors are fuelled by high–temperature heat sources such as gas or oil.
- Raw material preparation equipment: Biochar production requires the use of organic raw materials, which must be prepared before pyrolysis. This may include equipment for grinding, drying, or pelletizing raw materials.
- Systems used in biochar exploitation: Soil amendment systems for incorporating biochar into the soil can include equipment for mixing biochar into soil, compost, or other organic materials, as well as tools for applying the mixture to fields or gardens.

Carbon sequestration systems for burying biochar in soil or incorporating it into products may include specialized equipment for mixing and applying biochar, as well as tools for monitoring and measuring carbon sequestration over time.

Research on the thermochemical processing of vegetable waste obtained from agriculture has shown that advanced technologies can produce superior chemical compounds, biofuels and significantly reduce the negative impact on the environment (*Nenciu F. et al. 2022; Mircea, C. et al. 2020*).

Bioenergy production systems for using biochar as a fuel or feedstock can include boilers, combustion systems, or reactors for converting biochar into bio–oil or other bioenergy products (*Chi NTL. et al. 2021; ChoS–H. et al. 2021; Low YW. and Yee KF. 2021*).

**RESULTS**

In figures 3 a) and 3 b), a simple setup can be observed, a container in which the plant mass is burned, and biochar is obtained after the combustion.

The advantage of this biochar production system is that it can be implemented in small households by all farmers who want to use this product called biochar.

One version of an Australian company for producing biochar is presented in Figure 4, called Carboniser (Exeter Retort Kiln). The raw material used for heating the retort is biomass.

Figure 3 – a) and b) – simple small–scale production system in open field: a) Biomass burning; b) Biochar obtained after burning

Figure 4 – Fixed unit for biochar production – Carboniser

This system converts woody waste into a valuable soil amendment called BIOCHAR and can also produce cooking charcoal. These biochar production units are much more environmentally friendly than traditional kilns because they emit fewer harmful emissions (*https://www.facebook.com/*).

In figure 5a) a mobile unit for producing charcoal and biochar can be seen, which can be transported to the location where the raw material (woody waste) is located, as shown in figure 5b). The weight of such a mobile unit is 1860 kg, and it has the advantage of being easily towed. The overall dimensions of the assembly are: 3737 mm in length x 2200 mm in width x 2400 mm in height, plus 1.5 m for the furnace chimney.

The oven is completely insulated with ceramic material to operate in any type of climate. The oven has a capacity of 1.7 cubic meters. The burning time is approximately 8 hours depending on the type of wood used as raw material. The amount of material obtained after burning is about 170 kg. The raw material used for burning, also called pyrolysis (*Dutta S. et al. 2021; Lian F. et Xing B. 2017, Mircea et al., 2022; Oprescu et al., 2023*), can be made from any type of wood, from logs to twigs.

Figure 5 – a) and b) Mobile biochar production unit (https://www.biocharretort.com/): a) Mobile coal and biochar production plant; b) The finished product obtained after firing

In operation, it releases up to 75% fewer pollutants than conventional variants, and ash and waste are reduced to zero. The temperature used in the pyrolysis process is controlled with the help of an integrated digital thermometer. It has loading and unloading doors at both ends for quick access and is also easy to handle – no special skills are required (*https://www.biocharretort.com/)*.

Biochar is of increasing interest due to concerns about climate change caused by carbon dioxide (CO2) and other greenhouse gas (GHG) emissions. Biochar is a way in which carbon can be extracted from the atmosphere and is a solution to reduce the global impact of agriculture (and all agricultural waste). Because biochar can capture carbon from the soil for hundreds to thousands of years, it has received considerable interest as a potential tool to slow global warming.

The burning and natural decomposition of trees and agricultural matter contribute a large amount of CO2 released into the atmosphere. Biochar can store this carbon in the soil, which can lead to a significant reduction in GHG levels in the atmosphere; at the same time, its presence in the soil can improve water quality, increase soil fertility, and increase agricultural productivity. Biochar is biomass (wood, leaves, straw, or other biosolids) heated to high temperatures without oxygen. This process, known as pyrolysis, concentrates carbon in a form that is highly resistant to biological decomposition. When applied to soil and other products, much of its carbon content is sequestered for over 100 years (*https://biocharkilns.com/biochar/)*.

The BKI ovens are now lined with refractory ceramics and equipped with an arm crane to load and unload the base material and lift the insulation cover, as shown in figure 6.

Figure 6 – BKI–type ovens, assembly view
*(https://biocharkilns.com/biochar/)*

In Figure 7 a) and b), a mobile biochar production plant and a biochar grinding plant can be seen, which can be manually adjusted to produce particles between 2 and 20 mm.

The combustion vessel can have a capacity of up to 3 cubic meters and is also equipped with a temperature indicator (*https://biocharkilns.com/*).

Biochar has a microporous structure and also chemically attracts organic molecules and water and tends to hold them in place. In order to make them available to plants, it must be softened or saturated with all these elements before entering the soil, otherwise it will compete with plants for water, microbes, and nutrients and may harm plants if used in its raw state. Therefore, we recommend mixing biochar with soil or a good active organic compost before it reaches the soil, so that it can absorb its full complement of water, nutrients, and microbes, so that it can make them immediately available to plants once it is added to the soil. Final concentrations after repeated application of biochar will function up to approximately 8 to 10% biochar by weight of the soil content (Peter Hirst, New England Biochar).


Figure 7 a) and b) – Bio Feeder mobile pyrolysis unit
(https://biocharkilns.com/products/):
a) Bio Feeder overview; b) Biochar crushing plant

Biochar also attracts organic molecules and water, tending to hold them in place. In order to make them available to plants, it must be soaked or saturated with all of these elements before being introduced into the soil, otherwise it will compete with plants for water, microbes, and nutrients and may harm plants if used in its raw state. Therefore, is recommended mixing biochar with soil or a good active organic compost before it reaches the soil, so that it can absorb its full complement of water, nutrients, and microbes, so that it can immediately make them available to plants as soon as it is added to the soil.

Final concentrations after repeated application of biochar will function up to about 8 to 10% biochar by weight of soil content (*Peter Hirst, New England Biochar*). The pyrolysis of wood in such a device practically takes place in 4 different stages: evaporation of the moisture present in the wood occurs as the initial phase, up to an average temperature of 170°C (338°F). At this stage, gas production is minimal. As the fire builds up inside the kiln, the temperature rises and at around 280°C (536°F) the exothermic reaction begins. Gas consisting almost entirely of carbon monoxide and carbon dioxide is released, and a certain amount of acetic acid is formed together with small amounts of wood naphtha and tar. Then, the exothermic reaction continues during which the carbon concentration in biochar takes place. Large amounts of hydrocarbons, acetic acid, and wood naphtha and tar are produced, while temperatures rise to 380 to 400°C (716 to 752°F) (*https://biocharkilns.com/biochar/*).


(a) (b) (c)

Figure 8 – a), b), c) – Mobile Bio Feeder pyrolysis unit with a capacity of 3 cubic meters *(https://biocharkilns.com/biochar/)*: a) wood; b) biochar; c) Overall view of the mobile unit

The weight of biomass can vary from softwood, hardwood logs to bamboo, and the moisture content also varies. Depending on the size and air gaps between the branches, it is better to speak only from a volume perspective when determining the amount of biochar, as it may weigh more on a wet day.

Often, mixing biochar with water is preferred to inoculate and protect microorganisms, so the weight will vary. Due to the presence of water and its natural evaporation, biochar should never be evaluated based on weight. In figure 8, we have a mobile pyrolysis unit with a capacity of 3 cubic meters, figure 8 c) and images of the material used to obtain biochar (figure 8 a) and the final product obtained, biochar, figure 8 b) (*https://biocharkilns.com/biochar/*).

## CONCLUSIONS

The production and operation of biochar require the use of specialized equipment and systems, including ovens, pyrolysis reactors, raw material preparation equipment, soil amendment systems, carbon retention systems, and bioenergy production systems.

The choice of equipment design and systems will depend on the specific requirements of the biochar production and operation process, as well as the size and scope of the operation. The use of biochar in agriculture can be a profitable long–term investment, although the initial costs for biochar production and application in soil may be higher than those of other organic or mineral amendments, the long–term benefits of using biochar can offset these costs.

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