Biochar: Nature’s Own Carbon Capture and Storage

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Executive Summary

This white paper explores biochar as an innovative solution to two critical global challenges: climate change and crop residue management. Derived from organic materials through a process called pyrolysis, biochar offers significant environmental and economic benefits by sequestering carbon, enhancing soil fertility, and reducing greenhouse gas emissions. The report delves into biochar’s production methods, market dynamics, and regulatory frameworks, focusing particularly on its potential in India.

The production of biochar can be scaled more easily than other carbon-sequestering methods like agroforestry. It also stands out for its ability to lock carbon in soil for centuries while improving soil health and water retention. This positions biochar as a highly versatile product with applications in agriculture, construction, and industrial sectors. Moreover, its adoption can help businesses align with sustainable development goals (SDGs) and access new revenue streams, such as carbon credits.

While biochar offers substantial environmental benefits, challenges remain. These include high initial production costs, inconsistent quality, and limited market awareness. However, the biochar market is growing rapidly, with India's market projected to expand significantly in the coming years. As biochar production technologies improve and regulatory support increases, biochar could play a key role in India’s sustainable development efforts.

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Introduction

In today's time, as we face major obstacles like waste generation and climate challenges, innovative and sustainable solutions are essential. Biochar is one such solution, offering dual benefits: organic waste management and carbon sequestering. It can also help in water and nutrient retention, and improve disease resistance in agriculture. Derived from biomass through pyrolysis, biochar also serves as a versatile construction material. This document analyses the potential for biochar in India, focusing on its production methods, applications, market dynamics and regulatory frameworks.

What is biochar?

Biochar is a lightweight, charcoal-like substance produced through the pyrolysis of biomass—organic materials such as wood chips, agricultural residues, and manure—in an oxygen-limited environment. It is a black residue, mainly composed of carbon and ash. Although it looks a lot like charcoal, biochar is produced using specific processes to reduce contamination. This process transforms the biomass into a stable form of carbon that cannot escape easily into the environment, making it useful for various environmental and agricultural applications.

In terms of physical attributes, biochar is black, highly porous, fine-grained, light-weight and has a large surface area. Approximately 70 percent of its composition is carbon. The remaining percentage consists of nitrogen, hydrogen and oxygen, among other elements. Biochar's chemical composition varies depending on the feedstocks used to make it and methods used to heat it. (https://regenerationinternational.org/2018/05/16/what-is-biochar/)

Biochar for Agriculture -

Biochar offers several benefits for agriculture, making it a valuable tool for sustainable farming practices. Here are some key advantages:

1. **Improved Soil Structure**: Biochar enhances soil structure by increasing porosity, which helps roots grow more effectively and access nutrients more easily.
2. **Water Retention**: Biochar acts like a sponge, retaining water in the soil. This reduces the need for frequent irrigation and helps plants survive during dry periods.
3. **Nutrient Retention**: Biochar helps retain nutrients in the root zone, making them more available to plants. This can lead to healthier plants and better crop yields.
4. **Enhanced Soil Fertility**: By improving soil health, biochar can increase the availability of essential nutrients, leading to more productive agricultural land.
5. **Support for Microbial Communities**: Biochar provides a habitat for beneficial soil microorganisms, which play a crucial role in nutrient cycling and plant health.
6. **Reduction in Greenhouse Gas Emissions**: Biochar can help reduce emissions of non-CO_2 greenhouse gases, such as methane and nitrous oxide, from soil.
7. **Waste Management**: Biochar production can utilize agricultural waste, such as crop residues and manure, turning them into valuable soil amendments.

Additional Uses of Biochar -

Construction

1. **Concrete and Cement**: Biochar can be added to concrete and cement to improve their properties. It enhances the strength and durability of these materials while also providing benefits like fire resistance and humidity control.
2. **Asphalt**: Biochar can be used as a modifier in asphalt binders, improving the performance and longevity of roads.
3. **Insulation**: Biochar's porous structure makes it an excellent material for insulation, helping to regulate temperature and reduce energy consumption in buildings.
4. **Bricks and Tiles**: Biochar can be incorporated into bricks and tiles, providing benefits such as improved thermal insulation and reduced weight.

Environmental Applications

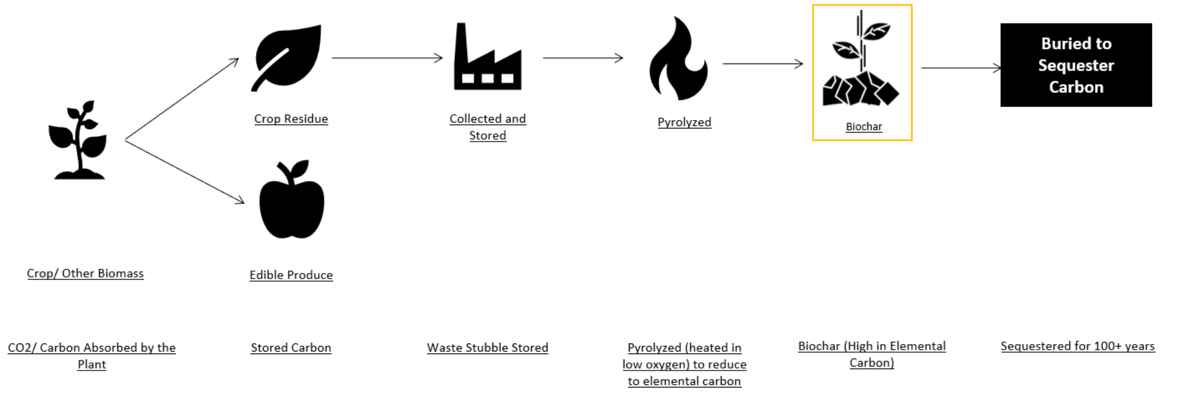
1. **Water Filtration**: Biochar is effective in filtering contaminants from water, making it useful for water treatment and purification.
2. **Land Reclamation**: Biochar can be used to remediate polluted soils and restore degraded land, improving soil health and productivity.

Other Uses

1. **Composting**: Adding biochar to compost can enhance the composting process and improve the quality of the final product.

2. **Animal Husbandry**: Biochar can be used as a feed additive for livestock, improving digestion and reducing methane emissions.

How does Biochar reduce atmospheric carbon dioxide?



Biochar vs other common nature-based carbon reduction techniques

Biochar vs. Agroforestry

1. **Scalability**: Biochar production can be scaled up more easily than agroforestry, which requires significant land and time to establish tree systems.
2. **Carbon Sequestration**: Biochar can sequester carbon for hundreds to thousands of years, whereas agroforestry systems sequester carbon in biomass that eventually decomposes.
3. **Co-benefits**: Both biochar and agroforestry improve soil health and crop yields, but biochar can be applied to a wider range of soils and agricultural systems.

Biochar vs. Mechanical CCS

1. **Establishment**: Biochar is a more established technology with numerous pilot projects and commercial applications already in place.
2. **Cost**: Biochar production is generally less expensive than mechanical CCS, which involves high costs for capturing, transporting, and storing CO2.
3. **Co-benefits**: Unlike mechanical CCS, biochar provides additional benefits such as improved soil fertility and water retention.

Biochar - How is it being received by corporations

Biochar is gaining significant attention among decarbonization experts due to its potential to sequester carbon and provide multiple co-benefits. Research highlights that biochar can play a crucial role in global emissions reductions, potentially removing up to 6% of global emissions annually. Experts emphasize its ability to improve soil health, increase water and nutrient retention, and displace fossil fuels. The World Economic Forum also recognizes biochar as a versatile carbon removal solution, noting its durability and cost-effectiveness compared to other carbon removal technologies.

Regarding companies with carbon sequestration targets in their ESG reports, several leading firms have made notable commitments:

1. **Accenture, Bank of America, and IBM**: These companies, among others, have implemented sustainability reporting metrics that include carbon sequestration targets.
2. **KPMG Survey**: The latest findings reveal that 71% of the top 100 companies in each country have set carbon reduction targets.

Other ways companies are getting involved -

1. **Integration into Business Models**:
   - Companies are increasingly integrating carbon sequestration into their core business strategies. This involves setting clear targets for carbon removal and incorporating these targets into their overall sustainability goals. For example, companies like Microsoft have committed to being carbon negative by 2030, which includes significant investments in carbon removal technologies.
2. **Investment in Carbon Removal Technologies**:
   - Businesses are investing in a variety of carbon removal technologies, such as direct air capture, biochar, and enhanced weathering. These investments are often part of a broader strategy to diversify their carbon removal portfolio and ensure long-term sustainability. For instance, a McKinsey report highlights the importance of scaling carbon dioxide removal (CDR) technologies to meet net-zero targets.
3. **Partnerships and Collaborations**:
   - Many companies are forming partnerships with research institutions, non-profits, and other businesses to advance carbon sequestration technologies. These collaborations can help accelerate the development and deployment of new technologies. For example, the Boston Consulting Group discusses how energy and industrial companies can benefit from early investments in carbon capture and storage (CCS) technologies.
4. **Policy Advocacy and Support**:
   - Corporations are also engaging in policy advocacy to support the development of carbon sequestration technologies. This includes lobbying for favorable regulations and incentives that can make carbon removal more economically viable. The Business Case for Carbon Capture report by BCG

emphasizes the need for supportive policies to drive the adoption of CCS technologies.

5. **Monitoring and Reporting**:
    - Transparent monitoring and reporting of carbon sequestration efforts are crucial for building trust and accountability. Companies are adopting rigorous reporting standards to track their progress and demonstrate their commitment to carbon removal. This is often reflected in their Environmental, Social, and Governance (ESG) reports, where they outline their carbon sequestration targets and achievements.

How is biochar produced?

Biomass can be turned into renewable fuels through biochemical and thermochemical conversion techniques. Biochar is produced mostly at lower temperatures of pyrolysis (400-500 degrees C) in slower processes and typically yields about 20% of the total process output (up to 50% in ideal conditions). Its properties vary depending upon feedstock and pyrolysis conditions. Other methods to produce biochar are as follows:

Pyrolysis: This process involves heating biomass in the absence of oxygen. The temperature typically ranges from **300°C to 700°C**, resulting in a stable carbon product with varying surface area and porosity based on feedstock type and production conditions. It can be slow, intermediate, fast or flash, depending on the time taken for the process.

Gasification: The process involves treating carbon-based feedstock with gasifying agents like steam, air, or CO_2 at temperatures (>750°C) with limited oxygen, producing syngas along with biochar. It is less common for biochar production but can yield high-quality char with specific characteristics.

Hydrothermal Carbonization (HTC): Converts wet biomass into hydro char using high temperatures (180°C to 250°C) and pressure in water. This method is efficient for processing wet feedstocks and has potential for nutrient recovery

The strengths and weaknesses of different methods can be synthesized as follows:

Biochar Preparation Technique	**Temperature Range**	**Main Products**	**Advantages**	**Disadvantages**
Pyrolysis	300°C - 800°C	Biochar, syngas, bio-oil	High-quality biochar; flexible process	Requires careful control; may need pre-treatment

Gasification	700°C - 1000°C	Biochar, syngas	Efficient for large-scale operations	Complex system; requires homogeneous feedstock
Hydrothermal Carbonization	180°C - 250°C	Hydrochar	Effective for wet feedstocks; high yield	Energy-intensive; requires pressure systems

The quality of biochar also significantly depends on the feedstock type. The production technologies vary from small-scale systems for farmers to large industrial setups:

Technology	**Production Time**	**Quality**	**Price range**	**Vendors**
Traditional kilns	5-6 hours	Low to medium	2,000 - 10,000	Local fabricators
Two-drum Method	3-5 hours	Medium	2,000 - 10,000	Local Fabricators
TLUD gasifier stoves	2-3 hrs	High	3,000 - 15,000	Ankur Scientific, Prakti Design
BioLite Stoves	1-2 hrs	High	5,000 - 10,000	BioLite
Retort Systems	3-6 hours	Medium	10,000 - 50,000	Custom Fabricators
Continuous Pyrolysis units	1-4 hrs	High	5,00,000 - 25,00,000	Ankur Scientific, Airex energy
Rotary kiln	(Continuous) 1-3 hrs	High	10,00,000 - 50,00,000	Thermax
Batch Pyrolysis systems	6-8 hrs	Medium to high	2,00,000 - 10,00,000	Pyrocat Systems, Klaren Tech

Biochar reactors	2-4 hrs	High	5,00,000 - 50,00,000	TERI
Mobile biochar units	4-6 hrs	Medium to high	4,00,000 - 15,00,000	Ankur Scientific
Fluidized Bed systems	(Continuous) 30-90 mins)	High	15,00,000 - 1,00,00,000	Agni Green Power

Allowed feedstock for Biochar production

European Biochar Certificate (EBC) guidelines

- **Biomass** from the EBC positive list can be used for biochar production, with no fossil carbon unless explicitly approved. Mixed biomass and fossil carbon feedstock may be approved for non-agricultural uses with proper tracking.
- **No contaminants** like paint, solvents, or toxins are allowed for biochar intended for soil and agriculture (EBC-FeedPlus, EBC-Agro, etc.).
- Plastic and rubber impurities must be below 1% for agricultural biochar; up to 10% is allowed for industrial biochar, with special approval.
- Forest wood must be sustainably sourced, with PEFC or FSC certification.
- **Animal by-products** (e.g., manure) and biosolids are allowed under controlled pyrolysis conditions (≥500°C for 3 minutes) but are typically unsuitable for agricultural biochar due to heavy metal content.
- **Mineral additives** require declaration and approval, especially for non-agricultural biochar

Other details and a detailed EBC positive list are available in the references and sources section.

World Biochar Certificate (WBC) guidelines

- All biomasses included in the WBC Positive List may be used individually or in combination as feedstock to produce WBC biochar. Feedstock restrictions apply to each certification class (WBC-Premium, WBC-Agro, and WBC-Material), as certain feedstocks require additional rules for quality management, which are set out in the WBC Positive List.

- Within a batch, the type of biomass may not be changed, and the mixing ratios may not change by more than 20%. According to the WBC Positive List, mineral additives may add up to 10% of the mass.

Other details and a detailed WBC positive list are available in the references and sources section.

PURO Earth guidelines

- Biochar must be produced from sustainable biomass: sustainably sourced biomass, or waste biomass such as agricultural waste, biodegradable waste, urban wood waste or food waste.

- For agricultural waste, at least 30% must be left in the field to maintain soil health and support crop levels.

- Timber that has been damaged by natural disasters (e.g., fire, pests, floods) and cannot be economically recovered is eligible for biochar production.

- Invasive plant species can be used as biomass for biochar under certain conditions

Additional information has been added to the references and sources section

Benefits of biochar

Biochar supports several SDGs, making it a valuable addition to corporate sustainability strategies:

SDG 13 (Climate Action): By sequestering carbon and reducing greenhouse gas emissions
SDG 15 (Life on Land): Through improved soil health and biodiversity conservation.
SDG 12 (Responsible Consumption and Production): Promoting waste utilization and resource efficiency.
SDG 2 (Zero Hunger): By enhancing agricultural productivity and food security through improved soil fertility.

With vast utility and applications across varied industries, biochar offers a potential solution to various environmental issues.

Economic benefits of biochar

While the initial cost of implementing biochar may be high, its long-term benefits, such as reduced input costs, improved product yields, and energy savings, outweigh these expenses. By incorporating biochar into operations, companies can significantly reduce their carbon footprint, contributing to corporate sustainability goals and gaining a competitive edge.

Long-term cost savings: Owing to its agricultural benefits, biochar can save costs by reducing fertilizer costs, increasing crop yields and lowering water usage.

Revenue from carbon credits: Biochar sequesters carbon in the soil for long periods, allowing companies to earn carbon credits. These credits can be sold in carbon markets, creating a new revenue stream while meeting carbon reduction targets.

Innovation and product development: Biochar opens avenues to develop new, sustainable products; thereby creating new revenue streams and capturing emerging markets in sustainability and green tech.

Regulatory incentives: Implementing sustainable technologies like biochar can be eligible for tax breaks, subsidies, or grants, lowering their operational costs and improving financial performance.

In total, biochar offers both financial benefits and strategic advantages, making it a valuable addition to sustainability practices.

Potential

The Biochar market stands at the cusp of significant growth, presenting exciting possibilities for sustainable agriculture, waste management, and climate change mitigation. Although still in early stages, the sector is experiencing growth in interest and adoption across various industries. The Biochar market size was valued at US$ 320.83 million in 2023 and is expected to expand at a CAGR of 14.05% during the forecast period (2024 - 2032) reaching US$ 705.9 million by 2032.

India produces about 500-550 metric tons of crop residues annually, even 1% of which when converted to biochar offers a whole plethora of opportunities for future applications and expansions. The India biochar market is projected to register a CAGR of 18.40% in terms of revenue and 15.77% in terms of volume during the forecast period, 2022-2028.

Current Research

1. **Improved Soil Structure**:
    - Biochar can increase soil porosity and improve soil structure, leading to a 46% increase in soil pH, a 20% increase in cation exchange capacity, and a 27% increase in organic carbon.
2. **Water Retention**:
    - Biochar can increase water retention in sandy soils by up to 22%[2]. In some studies, specific water savings of 37.9% have been observed in biochar-amended soils.
3. **Nutrient Retention**:

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- Biochar can boost cation exchange capacity by 20–50 meq/100g, enhancing nutrient availability for plants[4]. Additionally, soil total and available nitrogen, phosphorus, and potassium levels can increase by 36%, 34%, and 15%, respectively.

4. **Enhanced Soil Fertility**:
    - Biochar can increase soil electrical conductivity by 124.6% and reduce soil acidity by 31.9%. It also improves soil fertility by increasing nutrient availability and retention.
5. **Support for Microbial Communities**:
    - Biochar application can increase the diversity of bacterial communities, with the ACE index and Chao 1 index increasing by 5.83–8.96% and 5.52–8.53%, respectively.
6. **Reduction in Greenhouse Gas Emissions**:
    - Biochar amendment can reduce CO_2 emissions by 11%, methane (CH_4) emissions by 31.7%, and nitrous oxide (N_2O) emissions by 22.8%. Overall, biochar production could offset up to 12% of global greenhouse gas emissions.
7. **Waste Management**:
    - Biochar production can utilize agricultural waste, such as crop residues and manure, effectively turning them into valuable soil amendments. This process can significantly contribute to waste management and sustainability efforts.

Conclusion

Biochar presents a promising solution to address critical global challenges such as climate change and organic waste management. By sequestering carbon, enhancing soil fertility, and reducing greenhouse gas emissions, biochar offers significant environmental and economic benefits. Its versatility extends beyond agriculture, with applications in construction, water filtration, and land reclamation. Despite challenges like high initial production costs and market awareness, the growing interest and advancements in biochar production technologies position it as a key player in sustainable development. As regulatory support increases and market dynamics evolve, biochar has the potential to make substantial contributions to India's sustainability efforts and global carbon reduction goals.

Appendix: Companies in Biochar industry in India

Category	Description	Examples
Developers	Companies generating carbon credits with own or other's biochar production	1. ASQI Technologies 2. Varaha
Producers	Companies that produce biochar for various applications.	1. ARSTA Eco 2. Anant BioCnergy Pvt Ltd 3. Farm2Energy 4. Greenway Grameen Infra 5. Sampuran Agri Ventures Pvt. Ltd
Raw Material Suppliers	Sources of biomass feedstock for biochar production.	1. Agricultural Residue Aggregator 2. Municipal Bodies 3. Forestry 4. Timber Industries
Manufacturers (Pyrolysis Equipment)	Companies producing equipment used in biochar production.	1. PyroCCS 2. Praj Industries 3. Alcom 4. Rees Agritech
Technology Solution Providers	Institutions conducting research and development on biochar.	1. Indian Institutes of Technology (IITs) 2. Council of Scientific and Industrial Research (CSIR) 3. Agricultural Universities

References and Sources

1. Biochar Overview and key concepts
2. Biochar market in India
3. Biochar and its uses
4. Biochar case studies and findings
5. Biochar Certification Standards in Europe
6. European Biochar Positive List for Applications
7. Technical Standards for Biochar Certification
8. Carbon Standards for Biochar Projects
9. PURO Earth: Biochar Carbon Removal Methodology
10. Biochar Applications in the Construction Industry
11. Opportunities in the Indian Biochar Market
12. Potential for scalability, carbon sequestration, establishments, cost and co-benefits.

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The information presented in this white paper is based on a particular blockchain use case. It is intended to provide a general overview of the technology and its potential applications. This document, in no way, seeks to be the exact method in which a use case may be implemented. Industry scale deployment would take discovery sessions along with pilot studies.

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