Bioflux

CRIA
CARBON REMOVAL
INDIA ALLIANCE

Scaling Biochar Carbon Removal in India:

Opportunities, Challenges, and Policy Pathways

2026

A Joint Publication By
CRIA & BIOFLUX

May 2026, New Delhi

Authors: Srishti Singh & Paul Préaux

About CRIA

The Carbon Removal India Alliance (CRIA) is the only well-recognised, non-partisan industry-led coalition and ecosystem organisation dedicated to catalysing and supporting the growth of a thriving durable carbon dioxide removal sector in India. It exists to accelerate the development, commercialisation, deployment, and co-benefits of CDR technologies in India. Through research, advocacy, dialogues and partnerships, and ecosystem-building, CRIA works at the intersection of climate action and innovation. Most of the leading Indian CDR industry players are CRIA members.

With India poised to deliver up to 30% of global durable CDR potential by 2050, CRIA plays a pivotal role in ensuring these solutions are not only climate-effective but also economically and socially transformative. CRIA focuses on solutions with long-term permanence – such as biochar, enhanced rock weathering, direct air capture, and BECCS – while promoting ecosystem-building, research, international collaboration, and robust policy engagement. The alliance actively works with government bodies, corporates, development banks, academic and research institutions and rural communities to mainstream CDR in India's carbon market and development agenda.

CRIA also advances co-benefits such as improved soil health, increased agricultural productivity, livelihoods improvement, and reduced air pollution. With over 25 active members and growing momentum in both private and public sectors, CRIA is leading efforts to make India a global hub for high-integrity, scalable carbon removal solutions.

About BioFlux

BioFlux is an independent advisory firm focused on advancing high-integrity biochar carbon removal through project design, market development, and value chain integration. The organisation works with project developers, corporates, investors, and public institutions to translate biochar from technical potential into certifiable, investable, and scalable systems.

BioFlux supports the full pathway from early-stage feasibility to market readiness, including feedstock and logistics design, MRV and certification frameworks, and alignment with leading standards and buyer expectations. Its work is grounded in the view that biochar is not only a durable carbon removal pathway, but also an operational and commercial system that must perform under real-world conditions.

With a strong emphasis on independence and technical rigour, BioFlux helps organisations navigate a rapidly evolving carbon removal landscape by providing objective guidance on project quality, market positioning, and deployment strategy. This includes supporting the integration of biochar into supply chains and industrial systems, enabling measurable, high-integrity carbon removal alongside operational and commercial benefits.

By bridging technical design, market requirements, and implementation realities, BioFlux aims to accelerate the development of credible, bankable, and scalable biochar systems, while positioning carbon removal as a practical lever for industrial transformation and long-term competitiveness.

Acknowledgment

The authors would like to express their sincere gratitude to the organisations that provided valuable insights and inputs during the development of this paper.

In particular, we thank **Circonomy, Equilibrium, LongStraw Carbon, Asvata, Clean Air Fund, Carbonfuture, The World Bank, Klimate.co, and Carbon Standards International (CSI)** for their thoughtful engagement and feedback.

Their perspectives – spanning biochar production, carbon market infrastructure, project development, and climate finance – helped strengthen the analysis and ensure that the recommendations presented in this report are grounded in practical experience and emerging global best practices.

The authors remain solely responsible for the content of this publication.

Table of Contents

Executive Summary

Biochar represents one of the most promising and immediately deployable durable carbon dioxide removal (CDR) pathways for India. By converting surplus biomass into stable carbon that can be applied to soils or used in industrial applications, biochar offers a rare convergence of climate mitigation, agricultural productivity, rural income generation, and air pollution reduction. In a country where crop residue burning remains a persistent environmental challenge and soil organic carbon levels continue to decline, biochar provides a scalable solution that transforms agricultural waste into long-term carbon storage and a valuable soil amendment.

This report examines the role biochar can play within India's emerging carbon removal ecosystem and evaluates the country's potential to become a global supplier of high-integrity biochar carbon removal. India possesses structural advantages for biochar deployment, including abundant agricultural residues, a large smallholder farming base that can benefit from soil improvements, and growing interest in carbon markets and climate-aligned technologies. Biochar production technologies are already commercially viable, ranging from decentralised modern artisanal systems suitable for rural communities to industrial-scale pyrolysis facilities capable of producing verified carbon removal credits.

Our analysis estimates that India currently has the potential to produce **~83 million tons (Mt) of biochar and deliver approximately 0.2 gigatons (Gt) of net carbon removal annually**, based on conservative assumptions that utilise only 10% of surplus agricultural residues and 5% of forestry residues. Looking ahead, modelling based on growth trajectories observed in aligned sectors within carbon markets suggests that biochar carbon removal in India could scale up to **0.45 Gt by 2030**, representing a potential market opportunity of approximately **USD 45 billion annually** at an assumed carbon price of USD 100 per ton.

Beyond climate mitigation, biochar offers multiple co-benefits for India's development priorities. It provides a viable pathway to reduce open biomass burning and associated air pollution, improves soil fertility and water retention, enhances agricultural resilience, and creates new rural enterprise opportunities through biomass aggregation and processing. Moreover, India-produced biochar enriched bio-fertilisers can help reduce dependence on imported and subsidised chemical fertilisers. These attributes position biochar at the intersection of India's climate, agriculture, waste management and economic agendas.

At the same time, the scale-up of biochar in India will depend on the development of enabling market and policy frameworks. Global demand for high-integrity carbon removal credits is expanding rapidly, with international corporates actively procuring durable removals through the voluntary carbon market. Indian biochar projects are already participating in these markets, and several Indian producers are among the leading global suppliers of biochar-based carbon removal credits. However, long-term sector growth will require stronger domestic demand signals, commercial-scale application of biochar in bio-fertilisers, clear standards for measurement and verification, access to financing for capital-intensive infrastructure, and integration with India's emerging carbon market architecture.

This whitepaper therefore examines the technological foundations of biochar, the global market landscape for durable carbon removal, India's emerging role within these markets, and the policy measures required to unlock large-scale deployment. With the right policy support, financing mechanisms, and market development strategies, biochar could become a cornerstone of India's carbon removal portfolio while simultaneously advancing agricultural resilience, rural livelihoods, and air quality improvements.

The Case for Durable Carbon Dioxide Removal

Anthropogenic activities have caused Earth's average temperature to increase by 1.1°C above pre-industrial levels in 2011-2020. In 2019, global net anthropogenic greenhouse gas (GHG) emissions were estimated at 59 gigatons (Gt) CO_2e, marking a 12% increase from 2010 levels and a 54% rise since 1990 (IPCC, 2022). The bulk of these emissions, as well as the largest growth, came from carbon dioxide (CO_2) released by fossil fuel combustion and industrial activities.

To curb warming below the 1.5°C level, global carbon dioxide emissions need to be reduced by 45% from 2010 levels by 2030 and reach Net Zero by 2050. But even after undertaking reductions and avoidance efforts, emissions would continue to occur due to limitations in hard-to-abate sectors. Additionally, there is a need to address the legacy emissions that are already in the atmosphere. Unlike emissions reductions alone, durable carbon dioxide removal (CDR) emphasises the need to permanently isolate carbon through engineered or robust natural solutions that resist rapid re-emission. Leading standards define permanent CDR as carbon stored geologically for over 1,000 years. This permanence is vital to compensate for legacy emissions and emissions from hard-to-abate sectors to create true Net Zero climate stability.

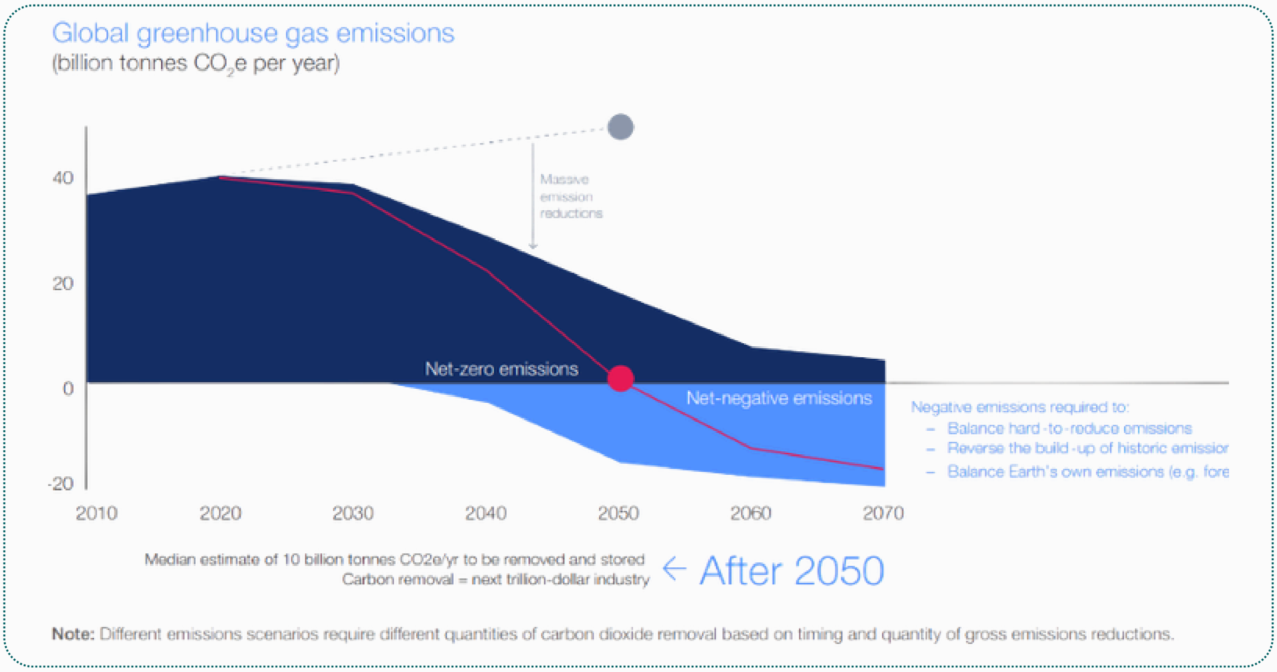

Figure 1: Beyond Net Zero – negative emissions required through carbon removals (World Economic Forum, 2024)

In the Intergovernmental Panel on Climate Change's (IPCC) sixth assessment report, all pathways include the use of carbon removal ranging from 100 to 1000 Gt CO_2 over the 21st century. Scientific consensus estimates that around 10 gigatons of CO_2 must be actively removed each year by 2050.

Carbon dioxide removal is no longer a discretionary component of climate action; it is a critical pillar required to meet 2030 and 2050 Net Zero goals. Rather than substituting for emissions reductions, CDR works alongside them by addressing residual emissions from hard-to-abate sectors that cannot feasibly reach Net Zero within realistic timeframes.

While cutting emissions must remain the top priority, CDR plays a crucial role in tackling emissions that are technologically or economically unfeasible to fully eliminate. Data from Climate Action Tracker highlights a substantial emissions gap: under current national policies and pledges, annual emissions are 19-27 Gt CO_2e higher than levels consistent with a 1.5°C pathway.

This gap underscores the urgent need to rapidly scale up CDR in parallel with deep emissions reductions. Early deployment of CDR also enhances climate credibility, helping translate national and corporate Net Zero commitments into concrete, measurable action.
There are various CDR methods that exist with different timescales and risk factors.

Engineered CDR includes methods like biochar, bioenergy with carbon capture and storage (BECCS), direct air capture (DAC), and enhanced rock weathering (ERW) – solutions which offer high permanence and scalability at high costs; while nature-based solutions (NbS) include approaches such as afforestation and reforestation – solutions with higher risk of reversal but lower costs. Removal of 10 Gt of CO_2 per year by 2050 requires maximising all solutions.

Climate physics, economic realities, and the need for credible Net Zero commitments all point to the urgency of deploying CDR alongside deep and rapid emissions reductions. Today's annual CDR deployment – around 50 million tons (Mt) – pales in comparison to the 6-16 billion tons required by 2050, implying a necessary scale-up of 120 to 300 times (Smith, et al., 2023). Each year of delay increases overall costs, narrows the range of viable Net Zero pathways, and makes long-term climate goals harder to achieve.

Understanding Biochar as a Carbon Removal Pathway

Biochar is a charcoal-like material produced by heating biomass in the absence of oxygen through a process called pyrolysis. A wide range of biomass sources can serve as feedstock for biochar production, including agricultural crop residues, woody waste, food processing by-products, manure, and sewage sludge.

It is a valuable tool for climate and environmental action, offering long-term carbon storage alongside multiple co-benefits. This scalable solution is both cost-effective and capable of storing carbon for hundreds to thousands of years when applied to soil or buried in depth.

When produced under controlled industrial conditions and applied in traceable end-use matrices, biochar carbon can achieve mean residence times exceeding 100-1,000 years under conservative durability assumptions. Leading certification bodies apply discounting, buffer mechanisms, and monitoring requirements to ensure that credited removals reflect high-confidence, low-reversal-risk storage.

Production Process

Pyrolysis refers to the heating of an organic material, such as biomass, in the absence of oxygen. Biochar can be produced through two main approaches: artisanal and industrial methods. Both rely on the principle of pyrolysis but differ in scale and technology.

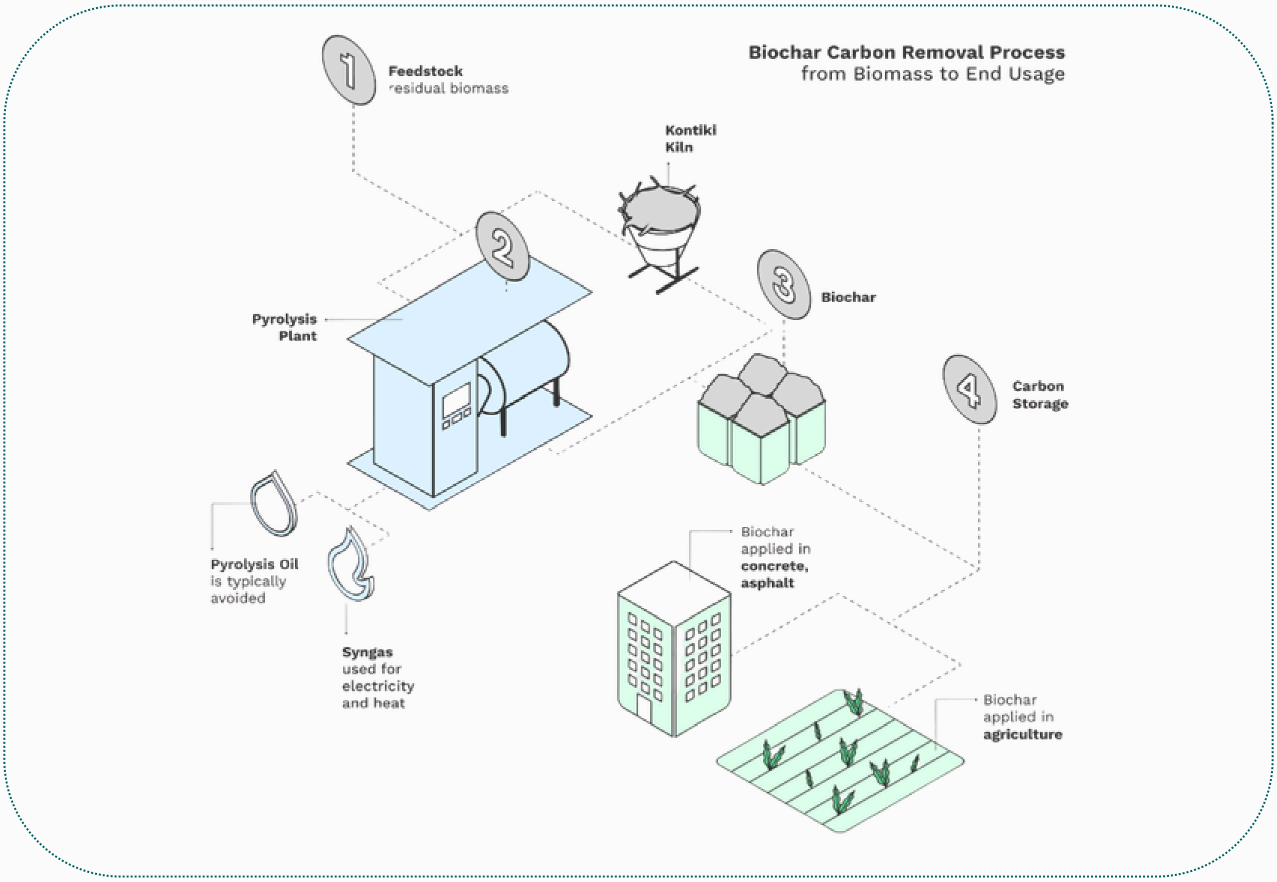

Figure 2: Biochar Carbon Removal (Carbonfuture, 2024)

Production Pathways: Artisanal and Industrial Systems

Artisanal biochar is made using small-scale, often traditional methods that are accessible to rural and agricultural communities. This low-cost method combines effective carbon sequestration with minimal infrastructure requirements, making it well-suited for rural communities. Farmers and farmer producer organisations (FPOs) can produce biochar by using small covered kilns.

Artisanal biochar bridges indigenous practices with modern sustainability goals, offering a practical solution for decentralised, community-led climate action.

Industrial biochar, on the other hand, employs advanced engineering and controlled processes to produce high-quality biochar at scale. It is particularly effective in regions with significant agricultural or organic waste and provides a reliable, large-scale method of carbon removal. Industrially produced biochar can be used in a wide range of applications – from soil amendments to construction materials – maximising both its carbon storage potential and environmental co-benefits. This approach supports scalable climate mitigation through consistent, high-volume production.

Processes and Operational Conditions

To maximise biochar yield, slow pyrolysis is typically used – a process that operates at relatively high temperatures (usually between 350°C and 600°C) with extended residence times. This method allows more of the biomass carbon to be converted into stable biochar rather than being released as gases or liquids. In addition to biochar, the pyrolysis process produces valuable co-products: syngas and bio-oil. These byproducts can be used to generate heat and power. The energy produced from syngas and bio-oil is used to power the pyrolysis system itself, significantly reducing external energy inputs and making the overall process self-sustaining.

Feedstock

Sources of Biomass

Biochar uses biomass for its production. There exist diverse sources of biomass suitable for this purpose, including:

- **Agricultural Biomass**: Encompassing both crop residues, which are considered and optimised as primary raw materials, and the cultivation of rapidly regenerating biomass varieties like miscanthus, hemp, switchgrass, and silphium.
- **Organic Residues**: Derived from food processing or secondary utilisation of biomass, examples include grape marc, nut shells, fruit stones, coffee chaff, and coffee dregs.
- **Wood Resources**: Sourced from landscape management, short rotation plantations, agroforestry practices, forest gardens, field margins, and urban areas.
- **Forest Biomass**: Harvested as part of forest management practices, with a critical requirement being that the volume of new growth in the forest surpasses the amount of biomass removed.
- **Waste Wood**: Including residues from paper mills and sawmills, as well as reclaimed timber from construction and demolition sites.

Competing Uses of Biomass

The major resource of India’s biomass lies within the agricultural sector since large quantities of crop residues are generated. India predominantly uses its crop residues for cattle fodder, cooking fuel, and housing thatch material. Cattle feed primarily relies on crop residues derived from cereals and pulses. In rural areas, cereal crop residues are mainly used as animal feed, leaving only specific residues like rice husk/straw, maize stalks and cobs, and woody materials available for potential energy generation (Purohit & Dhar, 2015).

As climate awareness expands and government initiatives align with Nationally Determined Contributions (NDCs), a deliberate effort has emerged to transition towards environmentally sustainable practices and fully optimise the nation's resources – including biomass, which could present an opportunity for its use for biochar production, among other end-use solutions.

Power Generation
An alternative use for non-fodder and non-fertiliser agricultural residues lies in biomass power and bagasse cogeneration.

The Ministry of New and Renewable Energy (MNRE) has promoted biomass power and cogeneration technologies since the 1990s to enable electricity generation from India's biomass resources and supply it to the grid.

India's estimated biomass power potential is around 18,000 MW, offering the capacity to produce 146,500 million units of electricity annually (MNRE, 2021). The Biomass-based Cogeneration Programme, launched in May 2018, aimed to optimise biomass utilisation in sugar mills and other industries such as rice and paper mills, and has since been expanded to support the production of biomass pellets and briquettes for power generation (MNRE, 2025). As of March 2023, installed biomass-based power capacity in India stood at 10,232 MW (IBEF, 2025).

At the same time, the growing deployment of biochar and other CDR pathways requires careful consideration of feedstock allocation. In several sugarcane-producing regions, bagasse and other high-calorific residues are already committed under long-term cogeneration and biomass power contracts. As a result, biochar projects typically avoid competing with established power plants and instead prioritise alternative residues.

Feedstock assessments also increasingly recognise local energy security considerations. Agricultural residues that are essential for household cooking or heating in rural communities are generally excluded from biochar supply chains. Only residues that are surplus to local needs, and are often openly burned, are considered suitable for conversion to biochar.

Biofuels
India is the world's third largest emitter of carbon dioxide, with 12% of these emissions attributed to the transportation sector (Usmani, 2020). Biofuels are viewed as a potential remedy for issues related to supply insecurity and greenhouse gas emissions. They can easily integrate with petroleum fuels across various blending ratios (Cherubini, et al., 2009).

The Ministry of Petroleum and Natural Gas (MoPNG) notified the National Policy on Biofuels in 2018, with amendments in 2022, to promote the availability of biofuels in the market and progressively increase their blending levels in conventional fuels. Under the policy, oil companies are mandated to sell Ethanol Blended Petrol (EBP) with ethanol content of up to 20% nationwide, with blending levels set to increase gradually over time. A target of 20% ethanol blending in petrol has been proposed, alongside an indicative target of 5% biodiesel blending in diesel or direct biodiesel sales by 2030 (MoPNG, 2022).

Potential feedstocks for biofuel production include a wide range of biomass resources such as bagasse, wood waste, agricultural and forestry residues (e.g. rice straw, cotton stalks, corn cobs, sawdust), as well as sugar- and starch-based materials including sugar beet, sweet sorghum, corn, and cassava (MoPNG, 2022).

Several high-value residues listed under the National Biofuel Policy – particularly bagasse and certain sugar- and starch-derived materials – are already in strong demand from second-generation (2G) biorefineries and established industrial users. In regions where these residues are contractually tied up or command high prices, biochar projects typically avoid direct competition and instead prioritise underutilised or openly burned residues such as paddy straw and cotton stalks.

Biomass Pellets
Derived from organic feedstocks such as wood and agricultural residues, biomass pellets are emerging as a cleaner and more sustainable alternative to coal for heat and power generation. Life cycle assessment studies indicate that substituting coal with pellets can significantly reduce emissions and improve the overall environmental footprint of energy production. In India, the Ministry of New and Renewable Energy (MNRE) supports this transition through its Biomass Programme, which includes a scheme to promote the manufacturing of briquettes and pellets. This scheme provides Central Financial Assistance (CFA) to project developers, along with service charges for implementing and inspection agencies involved in setting up manufacturing plants.

The biomass pellet sector in India is witnessing rapid growth, driven by the availability of agricultural residues as well as government mandates requiring coal-fired power plants to co-fire with 5-7% biomass.

Biogas
Biomass – including agricultural residues, animal manure, food waste, and sewage – is converted into biogas through anaerobic digestion in oxygen-free tanks, producing a methane-rich gas that can be used for heat and power or upgraded to renewable natural gas for transport and pipelines. India's biogas sector is gaining momentum, driven by supportive policies and the country's abundant supply of biomass.

India has actively promoted the production and scale-up of biogas and compressed biogas (CBG) through a range of targeted policy initiatives such as blending of CBG with compressed natural gas (CNG) for transport and with piped natural gas (PNG) for domestic use.

Programmes such as MNRE's Biogas Programme, the Sustainable Alternative Towards Affordable Transportation (SATAT) scheme, and the CBG–CGD Synchronisation Scheme under the GOBARdhan initiative support the scale up of biogas production. Key feedstocks for biogas production include agricultural residues such as rice paddy straw, sugar industry byproducts, urban organic waste, sewage sludge, and livestock manure.

Cost of Biomass

Global green energy firms are increasingly investing in the India's biomass market. India's businesses are in growing need of clean and reliable power, and biomass is anticipated to be a key player in fulfilling this demand. However, estimating the costs associated with agricultural and forestry residues is difficult due to the lack of established markets for these materials and the highly localised nature of biomass supply chains. In practice, the delivered cost of residues to bioenergy or biochar facilities is far more influenced by collection, aggregation, baling, and transport logistics than by the price paid to farmers at the field edge.

These costs vary significantly across regions depending on residue density, landholding patterns, transport infrastructure, and proximity to processing facilities.

Residues are commonly differentiated based on their existing uses and market demand. Some materials – such as paddy straw in open-burning hotspots – are considered "problem residues" and can be sourced at very low cost once collection systems are in place. In contrast, residues already integrated into biomass power generation or industrial use, such as bagasse and certain woody wastes, face strong competition and therefore command higher prices. This segmentation strongly influences which feedstocks are directed toward biochar, power generation, or biofuel production.

Biomass prices also exhibit substantial spatial and temporal variability. The same residue may have markedly different costs across neighbouring districts due to differences in fodder demand, local industry presence, or policy incentives. Seasonal factors further affect costs, with labour shortages and monsoon conditions increasing collection and transport expenses. As a result, robust cost assessments typically require district- and season-specific analysis rather than uniform national averages.

Feedstock price volatility is widely recognised as a key risk for biomass-based projects. Competition from MNRE-supported biomass power, cogeneration, and biofuel facilities can rapidly drive up residue prices in certain regions, affecting long-term project viability. To manage this risk, projects increasingly prioritise multi-feedstock flexibility and contract structures that limit price escalation. There is also broad alignment around sourcing only surplus biomass – excluding residues required for fodder, bedding, or household fuel – which, while constraining total volumes, often lowers cost and social risk by focusing on residues with limited existing markets.

Biochar Applications Across Sectors

Biochar not only removes carbon from the atmosphere but also produces a versatile material with applications across agriculture, the built environment, and beyond. Its multifunctional potential spans carbon sequestration, soil improvement, wastewater treatment, contaminant removal, air quality management, and waste management. These benefits arise from biochar's high carbon content, porous structure, abundant surface functional groups, and inorganic components. While many applications are still emerging, biochar has already demonstrated strong performance across a range of uses, several of which are outlined in the following sub-sections.

Agriculture

Biochar has demonstrated significant potential as an agricultural soil amendment, particularly in degraded, acidic, and low-soil organic carbon systems. Its porous structure and surface functional groups enable the retention of water, nutrients, and agrochemicals, improving soil physical, chemical, and biological properties over time (Awad, Lee, Kim, Ok, & Kuzyakov, 2018).

Unlike conventional organic amendments, biochar is highly stable in soils – persisting for centuries to millennia – allowing soil benefits to accumulate over long timescales (Wang, Xiong, & Kuzyakov, 2016).

Empirical evidence shows that biochar application reduces soil bulk density and increases porosity, improving the movement of water, air, and heat within soils. A synthesis across 22 soil types found reductions in soil bulk density of 3-31% (average ~12%) and increases in porosity of 14-64% following biochar addition (Blanco-Canqui, 2017).

These changes support improved root penetration, aeration, and microbial activity. Biochar's alkalinity further enhances its effectiveness in acidic soils by increasing pH, reducing aluminium toxicity, and improving nutrient availability (Liu, et al., 2022). Yield responses to biochar are strongly context dependent. Meta-analyses indicate that yield improvements are modest in fertile, well-managed soils, but substantially higher in degraded, acidic, or nutrient-poor soils (Jeffery, Verheijen, van der Velde, & Bastos, 2011).

Across global studies, average yield increases of ~20% have been reported, driven by improvements in soil pH, cation exchange capacity, organic carbon content, and the availability of nitrogen, phosphorus, and potassium (Biederman & Harpole, 2013). Several studies also show that yield benefits often strengthen over multiple cropping cycles rather than in the first season, reflecting gradual changes in soil structure and microbial processes (Major, Rondon, Molina, Riha, & Lehmann, 2010). It's crucial to acknowledge that the response of different soils to biochar may not be the same, and outcomes may take up to a year to reflect.

Biochar also plays a significant role in improving soil water dynamics. Its high surface area and porosity increase soil water-holding capacity, improve infiltration, and reduce runoff and erosion (Blanco-Canqui, 2019). Meta-analyses report average reductions of approximately 16% in soil erosion and 25% in surface runoff following biochar application, with particularly strong effects observed in tropical and subtropical systems (Gholamahmadi, et al., 2023). These properties make biochar especially valuable in rainfed and drought-prone regions facing increasing climate variability.

These properties collectively position biochar as a soil rehabilitation and resilience-building input rather than a short-term fertiliser substitute. Taken together, the agricultural value of biochar lies in its ability to improve core soil functions – structure, pH balance, organic carbon content, nutrient retention, and water regulation – while simultaneously delivering durable carbon removal. This dual role supports climate-smart agriculture by enhancing long-term productivity, reducing input sensitivity, and improving resilience to climate stress, particularly in regions with degraded soils and water constraints.

Fertilisers

Biochar has a long history as a soil fertility enhancer, most notably in ancient Amazonian systems, and is increasingly recognised today as a durable soil amendment that complements modern nutrient management. Biochar's influence on soil health endures longer compared to conventional chemical and mineral fertilisers.

Unlike conventional chemical fertilisers – whose repeated use can contribute to soil salinisation, compaction, and structural degradation – biochar improves soil physicochemical properties over much longer timescales (Zhang, et al., 2023). Its application can enhance water retention, raise pH in acidic soils, increase porosity, and reduce bulk density, thereby improving nutrient availability and crop resilience rather than simply supplying soluble nutrients.

Biochar features a porous surface structure and chemical properties that enable it to capture and retain tiny particles. This capability allows it to attract and hold nutrients, moisture, and agrochemicals, while also providing a habitat for microorganisms and fungi (USBI, 2016). In addition to their high nutrient content, biochar fertilisers contain a substantial amount of carbon that is highly resistant to decomposition. Unlike soluble mineral fertilisers, when biochar-based fertilisers are added to the soil, they promote carbon incorporation and enhance carbon sequestration (Ndoung, Figueiredo, & Ramos, 2021).

Project developers emphasised that farmers are already acutely aware of the declining returns from long-term urea use, even if they do not describe the issue in technical terms.[1] Accordingly, biochar is rarely positioned as a direct replacement for mineral fertilisers, but rather as a complementary amendment that buffers soils, improves fertiliser efficiency, and enables gradual reductions where agronomically appropriate.[2] Field pilots reported that farmers who observed improved crop health and stability were willing to pay for biochar-based products in subsequent seasons, suggesting perceived fertiliser-like value rather than reliance on free inputs.[3]

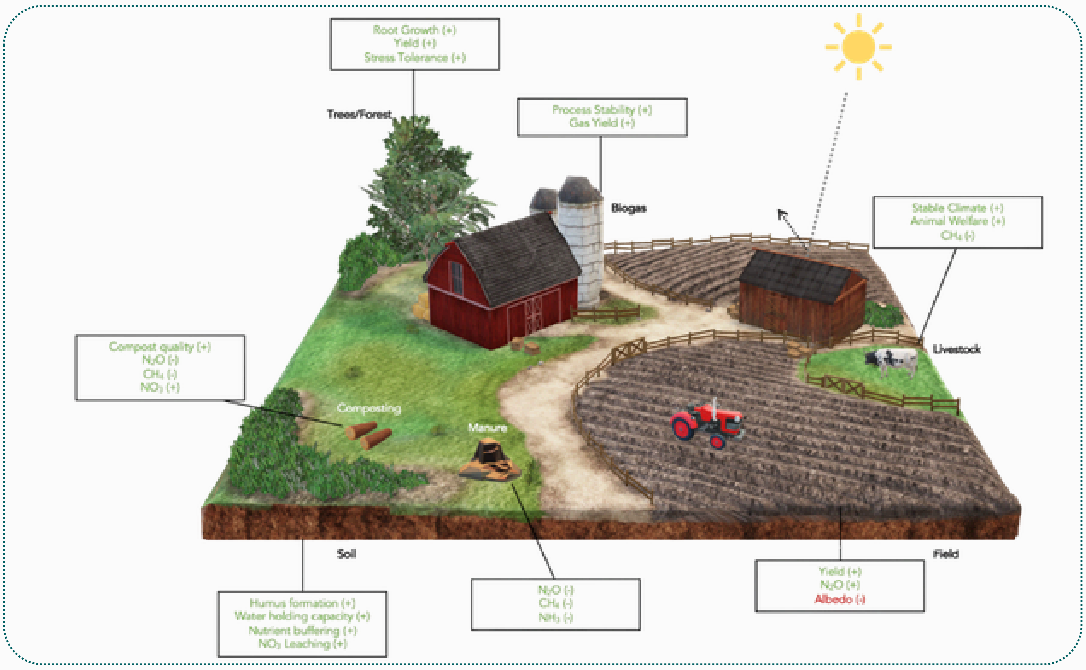

Figure 3: Biochar can be used in the following systems: stable, manure, biogas plant, composting, field, trees/forest and soil. The framed text boxes show which effects biochar has in each system. The characters in the brackets (+)/(-) show how biochar influence

[1, 2, 3] Based off interviews with stakeholders

Built Environment

The Global Alliance for Buildings and Construction (2017) reports that the construction and building industry alone generates nearly 40% of energy-related CO_2 emissions. Among construction materials, cement production emerges as the foremost contributor, responsible for roughly 8% of total anthropogenic CO_2 emissions (Habert, et al., 2020). This has prompted various initiatives to explore alternative materials that can both reduce emissions and store carbon durably.

Biochar, recognised as a carbon-negative material, has emerged as a promising option for substituting cement in construction materials (Akinyemi & Adesina, 2020). It has the potential to act as a carbon-sequestering additive in cement mortar, enhancing both its strength and sustainability (Gupta, Kua, & Low, 2018). Studies show that biochar can enhance the compactness and mechanical performance of cement-based composites, improving early-age strength and delivering even greater gains in long-term strength, while lowering the net global warming potential of mortars and concretes (Sirico, et al., 2021). Biochar-based bricks have also demonstrated improved insulation properties, adequate structural performance, and reduced water absorption, alongside lower energy requirements during production compared to conventional clinker-intensive materials (Maxwell, Joshua, Patel, & Aime, 2020).

Owing to its high porosity and low thermal conductivity, biochar further improves thermal performance, reducing cooling energy demand – an important advantage in hot climates such as India (Osman, et al., 2024).

Interviews with carbon removal buyers and certification bodies highlighted that biochar used in concrete, bricks, and building panels offers particularly strong permanence characteristics, as carbon is physically encapsulated within the building envelope, resulting in minimal risk of disturbance or reversal.[4]

This “lock-in” storage was viewed as especially attractive compared to soil applications, despite the latter’s long mean residence times. From a monitoring and verification perspective, interviewees also noted that construction-based applications enable clearer end-use traceability, as biochar volumes can be linked to specific batches, facilities, and building projects, simplifying auditing and certification.[5]

Although current deployment volumes remain small and largely confined to pilot projects, interviewees identified biochar in construction as a strategic growth area for the coming decade, particularly as green building standards and carbon-storing material credits expand.[6]

India’s rapidly growing demand for cement, bricks, and affordable housing was repeatedly cited as a strong future opportunity for scale-up, provided material quality standards are met.[7]

Interviewees cautioned, however, that only biochar with consistent properties and low contaminant levels is suitable for structural applications, and that diversification across soils, construction, and niche uses will be critical for managing market and deployment risks as the sector matures.[8]

In summary, integrating biochar as a carbon-negative material in construction holds significant promise for furthering the goals of attaining carbon neutrality. By incorporating biochar into building materials, there is potential for reducing global warming potential and effectively reusing waste. Although biochar production requires energy, its ecological impact remains superior to traditional methods.

[4, 5, 6, 7, 8] Based off interviews with stakeholders

Benefits

Environmental

Rising greenhouse gas concentrations are the primary driver of climate change, with carbon dioxide accounting for more than 77% of total emissions (Oni, Oziegbe, & Olawole, 2019). Biochar is widely regarded as an effective carbon sequestration strategy because of its high stability in soils, where it can persist for centuries to millennia. Estimates suggest that biochar derived from agricultural residues can sequester up to 1.2 tons of carbon/ha annually (Yrjälä, Ramakrishnan, & Salo, 2022), while manure-based biochar may achieve sequestration rates of approximately 0.6 ton of carbon per ha per year (Rehman, et al., 2020). Other studies report comparable values, with sequestration potentials of up to 0.8 ton/ha annually (Lal, et al., 2018). A broader literature review indicates an average carbon sequestration capacity of around 0.7 ton/ha per yr, with reported values ranging from 0.1 to 2 tons ha^{-1} yr^{-1} (Majumder, Neogi, Dutta, Powel, & Banik, 2019).

Carbon dioxide emissions from soil respiration are estimated to be nearly ten times greater than those from fossil fuel combustion (Nguyen, Lehmann, Hockaday, Joseph, & Masiello, 2010). Reducing CO_2 emissions from agricultural soils is therefore critical for climate change mitigation. Biochar is widely recognised for its ability to enhance soil carbon sequestration while simultaneously reducing nitrous oxide (N_2O) and methane (CH_4) emissions from soils (Leng & Huang, 2018).

Biochar can mitigate nitrous oxide emissions from agricultural soils by increasing soil pH, alleviating compaction, and promoting beneficial microbial activity (Kabir, Kim, & Kwon, 2023). A meta-analysis found that biochar application reduced N_2O emissions by an average of 26% (Shakoor, et al., 2021). In contrast, the application of animal manure alone was associated with a 17.7% increase in N_2O emissions, whereas soils amended with biochar exhibited a significant reduction of 19.7% (Shakoor, et al., 2021). Growing evidence also highlights biochar's potential to reduce methane emissions. A meta-analysis of 43 studies reported that biochar application led to an average reduction of 37.9% in CH_4 emissions from East Asian rice fields (Lee, et al., 2023).

Additionally, a significant environmental benefit of biochar production lies in its ability to divert surplus biomass – particularly agricultural residues – from open burning. In many regions of India, residues such as paddy straw, cotton stalks, and sugarcane trash have limited on-farm value once primary uses (fodder, bedding, fuel) are met. This surplus biomass, often regarded as waste, typically finds itself subject to incineration due to a lack of alternative applications, contributing to air pollution and environmental degradation. Redirecting this surplus biomass into controlled pyrolysis for biochar production avoids emissions of particulate matter ($PM_{2.5}$), black carbon, and other harmful pollutants, while converting a disposal problem into a productive input for agriculture and other sectors.[9] From a project design perspective, developers increasingly prioritise regions with high burning intensity and align residue collection efforts with peak burning windows, when alternatives are most urgently needed and farmer engagement is highest.

From a project design perspective, developers increasingly prioritise regions with high burning intensity and align residue collection efforts with peak burning windows, when alternatives are most urgently needed and farmer engagement is highest.

Social

Biochar deployment delivers a range of social co-benefits that extend beyond climate mitigation and farm-level productivity, particularly in rural and peri-urban contexts. By improving soil structure, water retention, and nutrient efficiency, biochar contributes to greater yield stability under climate stress, which is increasingly recognised as a critical social outcome in smallholder systems exposed to erratic rainfall and heat stress (Blanco-Canqui, 2019). More resilient soils reduce the risk of crop failure in adverse years, supporting food security and lowering farmers' vulnerability to climate shocks.

[9] Based off interviews with stakeholders

Biochar-based interventions are also associated with public health benefits through air pollution avoidance. The diversion of surplus crop residues from open burning reduces emissions of fine particulate matter ($PM_{2.5}$), carbon monoxide, and other toxic pollutants that are strongly linked to respiratory and cardiovascular disease (Lan, Eastham, Liu, Norford, & Barret, 2022). Given that $PM_{2.5}$ exposure from agricultural residue burning is highly seasonal and geographically concentrated, biochar projects that intercept residues during burning periods can generate tangible local health improvements, particularly for children, the elderly, and outdoor workers.[10]

Field experience suggests that air-quality and public health benefits often resonate more strongly with local communities and policymakers than carbon removal alone. Reduced smoke exposure during harvest seasons – linked to fewer respiratory symptoms, improved visibility, and lower disruption to daily life – has emerged as a key domestic rationale for biochar deployment, with CO_2 removal framed as an important but secondary global benefit.

At the community level, biochar production creates local employment across biomass collection, transport, processing, and field application. Unlike highly mechanised mitigation options, biochar systems – especially in smallholder landscapes – are relatively labour-intensive and can generate repeatable, place-based work opportunities in rural areas. These activities often provide off-season or supplementary employment, supporting livelihood diversification and reducing reliance on environmentally harmful practices such as residue burning or informal waste disposal.[11]

Finally, the visibility of biochar's local co-benefits – cleaner air, improved soil workability, and better crop performance under stress – has been identified as critical for social acceptance. Interviewees consistently noted that framing biochar around health, soil rejuvenation, and resilience resonates more strongly with communities and local authorities than abstract carbon metrics alone, helping build trust and sustained participation.

Economic

Biochar-based carbon removal presents a compelling economic proposition for India by combining farm-level productivity gains with export-oriented climate finance and domestic value-chain development. Recent techno-economic and life-cycle assessments indicate that biochar systems can deliver positive net economic returns when multiple revenue streams – carbon credits, biochar product sale, and energy co-products – are integrated into project design.

Farm-level Economic Gains

At the farm level, biochar application has been shown to increase crop yields while reducing dependence on synthetic fertilisers, translating to higher net returns per hectare. These gains are reinforced by reduced input costs and improved nutrient-use efficiency, leading to more stable farm incomes across seasons.

Interviewed developers reported that, in Indian pilot settings, the combination of yield uplift and fertiliser saving can result in a 25-30% improvement in net economic benefit on treated pilots, especially when biochar is integrated into broader soil health programmes.[12]

Several projects have demonstrated farmer willingness to pay for biochar-based amendments once agronomic benefits are visible, suggesting that biochar need not remain a purely subsidy-driven intervention.[13] This repeat-purchase dynamic strengthens long-term demand and reduces reliance on public support.

Project-level Revenues and Export Potential

At the project level, carbon credits remain the primary revenue source, but developers emphasised that carbon alone is insufficient for financial viability. Instead, Indian biochar developers typically rely on stacked revenue models that combines CDR offtakes with sales of biochar products and, where feasible, energy recovery from syngas.[14]

[10, 11, 12, 13, 14] Based off interviews with stakeholders

From a macroeconomic perspective, biochar CDR functions largely as an export-oriented industry. High-quality offtake agreements with European and North American buyers generate foreign-currency revenues and effectively operate as a form of quasi-foreign direct investment (FDI) inflows, financing capital expenditure and early operating expenses through advance purchase commitments rather than equity.[15] Interviewees stressed that the true constraint on revenue growth is not biomass availability, but the depth and durability of demand from credible buyers willing to sign multi-year contracts.

Employment, Value Chains, and Induced Effects

Biochar systems are relatively labour intensive per ton of CO_2 removed, particularly in smallholder contexts where residue collection and handling cannot be fully mechanised. Employment is generated across the value chain, including biomass aggregation, transport, plan operations, field extension, and monitoring, reporting and verification (MRV). Beyond direct jobs, biochar projects stimulate upstream demand for domestic manufacturing, engineering, and fabrication – especially as developers pursue strategies to localise reactor production and system integration.[16]

Emerging requirements for digital MRV also creates niche employment in data management, GIS, and software development, broadening the economic footprint of the sector beyond traditional rural schemes.

[15, 16] Based off interviews with stakeholders

Biochar for India

Multiple Benefits. One Sustainable Solution.

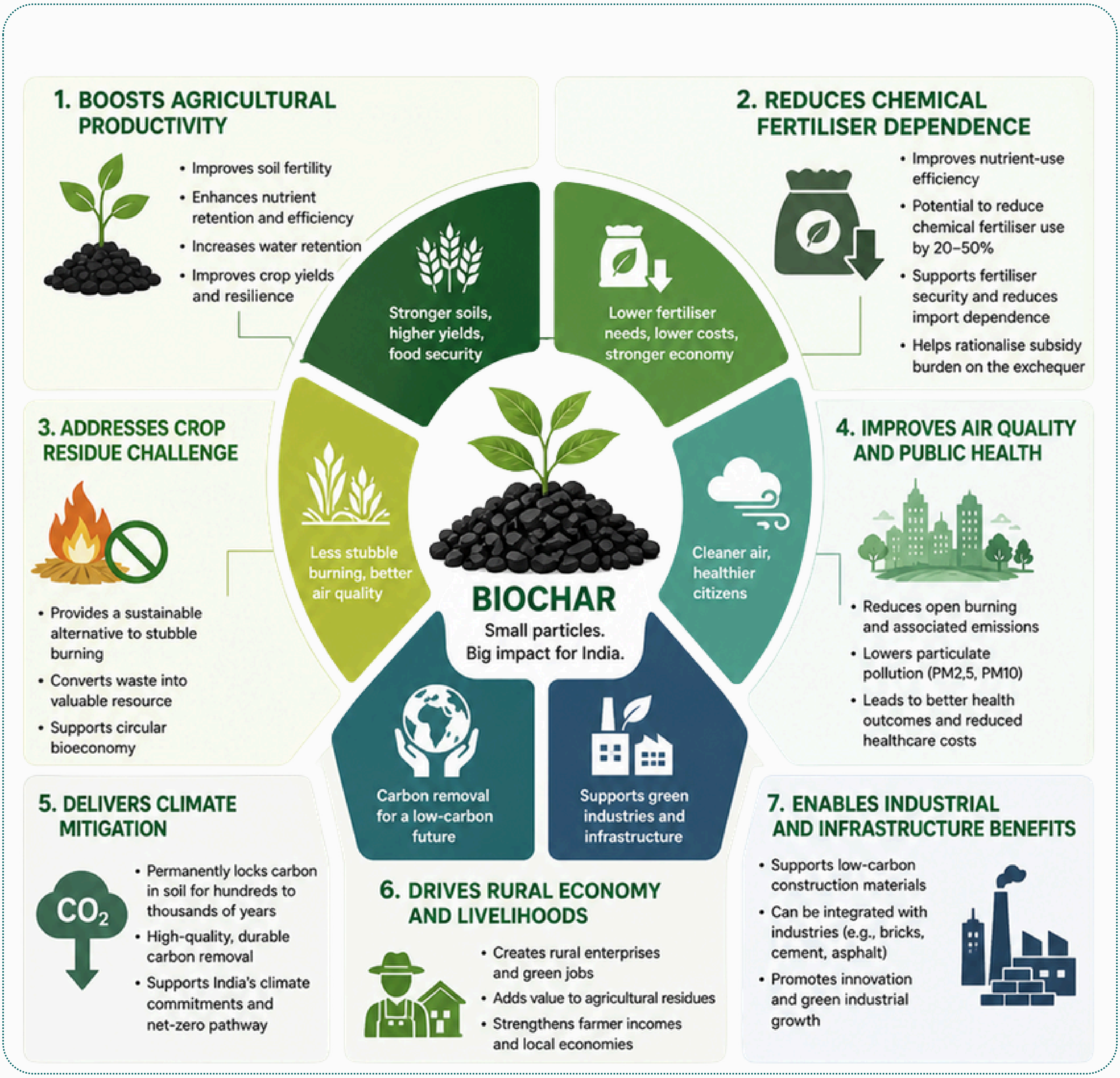

Figure 4: Benefits of Biochar in the Indian Context (CRIA, 2026)

The Strategic Relevance of Biochar in India

On a planet with finite resources, ensuring CDR is deployed in regions where it is most resource efficient and has the greatest societal benefit will be a crucial component in mitigating climate change. India has the potential to lead the world in the responsible removal and durable storage of carbon through a portfolio of these approaches. CDR has the potential for substantial inflows of foreign exchange, generation of jobs for the young people entering the Indian workforce each year, and the growth of an export market. The deployment of CDR approaches such as Biochar can provide extensive co-benefits to rural communities and farmers in India. Notably, India is positioned to offer a monumental contribution at massive scale.

Why Undertake Biochar in India?

1. Abundant Biomass Availability Lowers Cost and Enables Scale: India generates about 754 million tons of crop residues each year. Much of this biomass (~87Mt) is under-utilised or openly burned, creating pollution rather than value. Biochar converts this surplus biomass into a durable carbon sink, a soil amendment that improves agricultural systems, and a marketable CDR product for global buyers. This abundance gives India a structural cost advantage over most of Global North biochar producers.

2. Direct Solution to Crop Residue Burning and Air Pollution: Open biomass burning is a major contributor to India's $PM_{2.5}$ crisis, with severe health and economic impacts. Biochar provides a credible and scalable alternative by using surplus biomass as feedstock, avoiding emissions of harmful pollutants, and creating value from waste.

3. Strong Agronomic Benefits for Indian Soils and Farmers: India's soils face declining organic carbon, rising fertiliser dependency, and increasing climate stress. Extensive literature and field evidence show that biochar can increase soil organic carbon and nutrient retention, improve water retention, reduce fertiliser use, and increase crop yields (Blanco-Canqui, 2017). This makes biochar particularly attractive in smallholder-dominated agricultural systems, where resilience and input efficiency matter as much as yields.

4. High Policy Alignment with Existing Indian Priorities: Biochar naturally complements several Indian policy frameworks, including the National Policy for Management of Crop Residues, National Mission for Sustainable Agriculture, GOBARdhan Scheme, National Clean Air Programme, and air pollution mitigation efforts at state-level. Crucially, biochar does not require a new policy paradigm – it can be integrated into existing agricultural, waste, and climate instruments.

Biochar sits at the intersection of India's climate, agriculture, air-quality, and rural development priorities, making it one of the few climate solutions that simultaneously addresses multiple structural challenges. It is one of the most mature, scalable, and low-cost durable CDR options available today, particularly in agrarian economies. India has the potential to become a global hub for high-quality, high-integrity durable CDR.

India's continued population growth, industrial expansion, and rising energy demand will drive sustained increases in economic activity, and with it, residual emissions that cannot be fully eliminated in the near term. Managing this structural emissions growth requires solutions that complement decarbonisation without constraining development. Durable carbon removal provides critical climate infrastructure capable of balancing these residual emissions while safeguarding long-term industrial competitiveness. Global demand for high-integrity removals is expanding rapidly, creating parallel economic opportunity. In this context, biochar aligns closely with India's agricultural strengths, manufacturing scale, infrastructure growth, and export ambitions.

The question, therefore, is not whether CDR is required, but which pathways can deliver scale, durability, and economic alignment within India's development context.

India's Biochar Carbon Removal Potential

We undertook an independent analysis to understand the carbon sequestration potential of biochar within the context of India. This study evaluates the carbon removal potential on a conservative, residue-driven deployment model. The assessment focuses exclusively on surplus agricultural crop residues and forestry residues. Surplus biomass specifically refers to the residues or byproducts that are not essential for direct food production or other primary uses.

Key Assumptions

Feedstock Assumptions

To avoid overestimation, only 10% of surplus agricultural residues and 5% of forestry residues are assumed to be available for biochar production. This conservative allocation reflects practical constraints in biomass aggregation and alternative end uses. Biochar yield is assumed at 35% of input biomass, consistent with comparable investigations and on-ground operations.

System Boundaries and Emissions Assumptions

The analysis evaluates emissions from the transportation and processing of surplus biomass, excluding emissions from the planting or cultivation stage. This assumption is based on the fact that 100% of the surplus biomass used is from residues which are considered waste and would otherwise be combusted/left to decompose; therefore, it does not contribute to environmental impacts and hence no emissions are calculated. This stance aligns with analogous life cycle assessment studies based on waste-derived inputs and is consistent with Puro.earth's protocol for quantifying carbon removal (Puro.earth, 2022).

Process Energy and Operational Assumptions

Under steady state operation, the pyrolysis system is designed to be largely self-sustaining. It is assumed that the proportion of syngas produced during the pyrolysis process is 30%, of which 20% is used for heat. Natural gas is used only during reactor start-up. Electricity from the grid is used for the mechanical operation of the pyrolysis reactor.

All biochar produced is assumed to be applied to agricultural soils, with manual field application. The intended use is to enhance soil carbon stocks and improve soil quality in crop systems.

Net Carbon Removal Potential

Based on these assumptions, the estimated **biochar production potential** is approximately **83 million tons** (0.08 Gt).

The corresponding **net CO_2 removal potential** from biochar in India is estimated at **0.2Gt (~200 million tons)** under current conditions (2025 baseline). This implies that, on average, each ton of biochar produced results in the permanent sequestration of approximately 2.5 tons of CO_2.

This estimate represents the net removal after accounting for transportation, process emissions, and operational energy use within the defined system boundaries.

To estimate forward-looking market potential, the study models biochar carbon removal growth using an analogous trajectory to the Forestry and Land Use carbon credits market.

Applying a comparable compound annual growth rate (CAGR), the analysis suggests:
- Potential biochar carbon removal of **0.45Gt by 2030**
- At an assumed conservative average price of USD 100 per carbon credit, this corresponds to a potential market size of approximately **USD 45 billion by 2030**

This modelling indicates that biochar could evolve from a niche carbon removal pathway to a significant contributor to India's climate mitigation portfolio, while also generating substantial economic value.

Together, these findings underscore that biochar represents not only a technically viable carbon removal pathway, but also a strategically scalable opportunity for India – provided enabling policy frameworks, supply chain systems, and market infrastructure are developed in parallel.

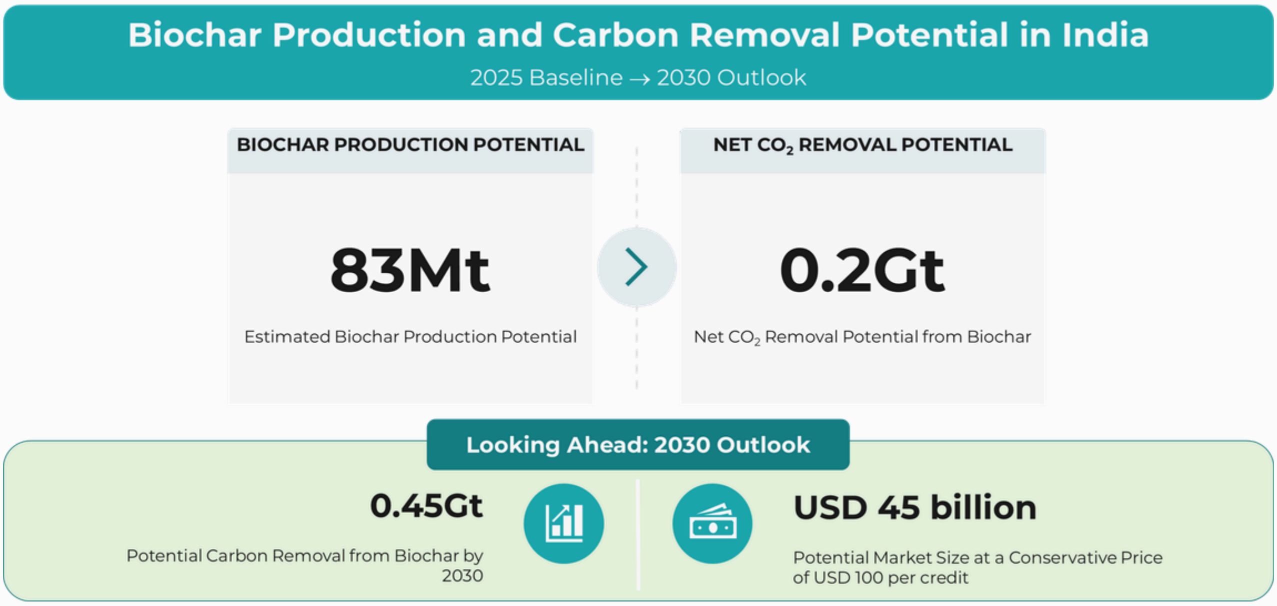

Figure 5: Biochar Carbon Removal Potential in India (CRIA, 2026)

Procurement Models and Digital MRV Systems

Global Demand for Durable Carbon Removal

While India has substantial technical potential for biochar-based carbon removal, the extent to which this potential can be realised in practice depends on how projects are designed, verified, and positioned within the international voluntary carbon market.

Global interest in biochar carbon removal has grown significantly in recent years, with contracted demand for biochar carbon removal (BCR) credits surpassing 3 million tons between 2022 and mid-2025, and approximately 1.6 million tons contracted in the first half of 2025 alone (cdr.fyi, 2025).

Over the same period, durable carbon markets have shown strong year-on-year growth in contracted volumes, deliveries, and retirements, with biochar continuing to account for the majority of durable CDR delivered globally, representing approximately 80-90% of delivered credits each year. As a result, market value has expanded accordingly, increasing from approximately USD 14.6 million in 2022 to USD 181.5 million in 2024, a more than tenfold increase over two years, reflecting both growing buyer engagement and increasing economic scale.

Buyer Typologies in Durable Biochar Carbon Removal

Demand for biochar carbon removal within the voluntary carbon market is concentrated among a limited set of buyer groups, each with distinct motivations and risk considerations.

1. Technology companies and large multinational corporates have been the earliest and most consistent buyers of durable CDR, motivated by long-term Net Zero strategies and the recognition that residual emissions will persist even under ambitious abatement pathways. Corporate buyers view biochar as a scalable, near-term removal option that can be credibly disclosed and defended, particularly when supported by conservative accounting, controlled end use, and robust verification.

2. Financial institutions and sustainability-focused investment vehicles form a second buyer segment, often motivated by portfolio-level climate commitments and risk management considerations. Durable CDR procurement is increasingly viewed as a hedge against future regulatory tightening and reputational exposure associated with low-integrity offsets. This segment places a strong emphasis on standardisation, auditability, and methodological alignment.

3. Intermediaries and carbon market platforms play an increasingly influential role as well, by aggregating demand, conducting due diligence, and setting minimum quality thresholds for market access. Such intermediaries often act on behalf of corporate buyers and have become key gatekeepers, reinforcing convergence around shared expectations for permanence, traceability, and governance across biochar projects.

Across all segments, buyer preferences have shifted decisively toward quality-assured removals rather than volume-driven offsetting. This has favoured biochar projects that demonstrate delivery certainty, conservative permanence assumptions, and the ability to withstand close scrutiny.

Purchasing Mechanisms and Contracting Structures

Purchasing mechanisms for biochar carbon removal have evolved in parallel with buyer sophistication. Early market activity was dominated by one-off, spot purchases of credits whilst current demand has matured, and procurement has shifted toward contractual structures that support scale-up and reduce delivery risk.

1. Multi-year offtake agreements and advance purchase commitments have become the dominant procurement mechanism for high-quality biochar carbon removal. According to market analysis published by Supercritical, approximately 62% of available high-integrity biochar carbon removal capacity for 2025 had already been secured through long-term offtake agreements by March 2025. This indicates that the market for quality-assured biochar removals is increasingly supply-constrained, with buyers using early contracting not only to de-risk project development but to secure access to limited volumes that meet stringent permanence, verification, and end-use criteria. This dynamic is particularly consequential for capital-intensive industrial biochar facilities, where early offtake commitments can be decisive in enabling projects to reach commercial scale.

2. Forward contracts and structured offtakes, which often incorporate milestone-based payments, are increasingly used by financial buyers and intermediaries to balance risk allocation between developers and purchasers. These structures enable early-stage deployment by providing conditional revenue certainty, while allowing buyers to manage delivery risk and capital exposure. In some cases, buyers accept delayed delivery schedules in exchange for preferential pricing or priority access to future production capacity, reflecting a growing willingness to trade immediacy for assured long-term supply.

3. Finally, **platform-based procurement and aggregation models** have similarly expanded access for smaller corporates by pooling demand and standardising contractual terms. While these mechanisms lower transaction costs and simplify participation, they also function as quality filters, imposing stricter eligibility criteria on projects. As a result, access to platform-based demand increasingly depends on demonstrable robustness in MRV, controlled end use, and governance, reinforcing convergence around higher integrity standards across the biochar market.

Taken together, these buyer typologies and procurement mechanisms define the conditions under which biochar carbon removal projects are able to access international demand.
For India, this implies that market participation is shaped less by technical potential alone and more by a project's ability to meet evolving expectations around delivery certainty, integrity, and governance. The following section examines how these dynamics translate into India's position within global procurement markets, and what this means for biochar projects operating in Indian contexts.

India's Emerging Role in Global Biochar Markets

Despite this global momentum, demand for high-durability carbon removal credits linked to biochar projects in India is currently driven predominantly by international buyers, with limited participation from Indian corporates. Domestic corporate climate action has focused primarily on emissions reduction, energy transition, and compliance-oriented mitigation, while voluntary procurement of durable carbon removal remains at an early stage.

As a result, Indian biochar projects seeking to monetise carbon removal operate within a global procurement context from the outset as demand for durable carbon dioxide removal is led primarily by international corporates and intermediaries (US and EU-based). In practical terms, this means that project design, verification, and governance must be aligned early with international expectations, regardless of where deployment occurs.

Digital MRV and Market Participation

Digital measurement, reporting, and verification (dMRV) plays a central role in building buyer confidence across biochar carbon removal projects in India. For both industrial and decentralised systems, dMRV enables traceability from feedstock sourcing through production to final end-use, reducing uncertainty around emissions, permanence, and misuse. In industrial facilities, this typically involves monitoring feedstock inputs, process conditions, emissions, and batch-level outputs; in decentralised systems, it supports aggregation, consistency checks, and verification of application across multiple sites. In both cases, dMRV functions as a practical enabler of comparability and credibility rather than a purely compliance-driven reporting layer.

Importantly, the market is not constrained by a lack of dMRV solutions. A range of established international and India-based platforms already provide digital monitoring, data management, and audit-ready reporting for biochar projects. The key challenge lies not in developing new tools, but in integrating existing systems early into project design and operations, so that verification requirements are met without undermining financial viability or operational simplicity.

Looking ahead, broader engagement by Indian corporates will be important to unlocking the full strategic value of biochar carbon removal. Greater domestic participation can reduce reliance on export markets, align carbon removal with national priorities such as agriculture, air quality, and rural development, and support learning-by-doing within India's corporate ecosystem. Creating enabling conditions for such engagement will require clearer guidance on the role of durable carbon removal alongside emissions reduction – particularly considering evolving frameworks such as the Science Based Targets initiative's (SBTi) upcoming net-zero guidelines which emphasise the use of permanent carbon removal to counterbalance residual emissions (SBTi, 2026) – along with early domestic pilot procurements and credible frameworks that allow Indian firms to participate without reputational risk. Over time, stronger domestic anchoring could complement international procurement and contribute to a more resilient and scalable biochar carbon removal ecosystem in India.

Taken together, these dynamics highlight that India's biochar sector is already operating within a mature global procurement environment, even as domestic demand remains early-stage. Project credibility, buyer confidence, and capital mobilisation are therefore shaped less by local conditions alone than by internationally established expectations around quality, verification, and claims integrity. Understanding how these expectations emerged and how other regions have successfully aligned policy, markets, and project design provides important context for how India's biochar ecosystem can scale sustainably.

Learning from International Experience

International experience with durable carbon dioxide removal shows that markets do not scale on technical potential alone. Demand has emerged where carbon removals are clearly positioned within climate policy frameworks, supported by shared credibility standards, and aligned with broader economic and environmental priorities. Across regions, financing for biochar carbon removal has increasingly been shaped by expectations around durability, traceability, and the defensibility of climate claims.

Carbon Removal Scales when Policy Recognises Residual Emissions

A consistent lesson across Europe, the United States, and parts of Asia is that meaningful demand for carbon removals followed formal recognition that emissions reductions alone are insufficient to meet long-term climate targets. This recognition has increasingly been reflected in national climate strategies and regulatory discussions in the EU, United States, and Japan, where carbon removals are being addressed as a separate policy category alongside mitigation.

In the European Union, this recognition is embedded in legally binding climate-neutrality objectives and has most recently been reinforced through the adoption of the EU Carbon Removal and Carbon Farming Regulation (CRCF). The CRCF establishes EU-wide quality criteria for certified carbon removals, including requirements on additionality, permanence, monitoring, and verification. While the framework does not directly regulate corporate claims, it creates a harmonised reference point for high-integrity removals within the EU market and is expected to influence procurement standards, disclosure practices, and future compliance-linked applications.

At the member-state level, countries such as Denmark are moving a step further by developing targeted national strategies to operationalise carbon removal. Denmark's Pyrolysis Strategy and Work Programme aims to accelerate the widespread agricultural adoption of biochar within its broader climate policy architecture. The country's administration pledged to a USD ~1.4 bn investment to promote the adoption of biochar in agriculture, hoping to cut down approximately 1.8Mt of carbon dioxide by 2030.

In more recent news, the evolving EU–India climate and trade relationship further illustrates how carbon removal is increasingly embedded within broader economic policy frameworks. Under the EU-India Strategic Agenda, both sides have committed to technical dialogue on carbon pricing, monitoring, and border adjustment measures, including consideration of how India's emerging carbon market architecture may interact with the EU's Carbon Border Adjustment Mechanism (CBAM). While CBAM primarily applies to emissions-intensive goods such as steel, cement, aluminium, and fertilisers, its implementation underscores a broader shift: climate performance and carbon accounting standards are becoming directly linked to export competitiveness.

For India, this convergence reinforces the importance of building high-integrity domestic carbon market infrastructure aligned with international durability and verification standards. As global trade increasingly incorporates carbon transparency requirements, early alignment with evolving EU certification and monitoring frameworks may strengthen both market access and investor confidence.

In the United States, federal initiatives including Department of Energy CDR research and procurement programmes and advance market commitments have reduced early-stage risk and signalled that removals are a legitimate component of climate action (U.S. DOE, 2025). Similarly, in Japan, carbon removals are increasingly framed within long-term industrial decarbonisation and Green Transformation (GX) strategies, linking removals to competitiveness and industrial resilience rather than offsetting alone (METI, 2024). Japan's Joint Crediting Mechanism (JCM), including its bilateral cooperation with India, further reflects a growing model of cross-border carbon collaboration in which technology deployment and emissions reductions are jointly credited. While historically focused on mitigation technologies, such frameworks signal an institutional foundation that could support future high-integrity removal pathways.

Across these contexts, the critical shift was not the immediate creation of compliance markets for removals, but rather the policy legitimisation of removals as a necessary complement to emission reduction efforts. This reduced reputational risk for early corporate buyers and created space for voluntary procurement to grow alongside emissions-reduction efforts.

Credibility Frameworks Reduce Risk Before They Maximise Volume

Another key lesson is that early market growth depended on reducing uncertainty and boosting the credibility of carbon removal initiatives rather than maximising the supply of carbon removal credits. Similarly to how compliance markets operate, organisations financing voluntary carbon removal programs expect a common, credible framework for projects to operate under.

In voluntary markets, this role was initially filled by independent standards such as Puro.earth, Verra, Carbon Standards International (CSI), and more recently Isometric and Rainbow. These organisations translated evolving scientific consensus into conservative accounting rules, durability assumptions, and third-party audit processes for biochar carbon removal. Importantly, these methodologies have been progressively shaped and stress-tested through buyer-led integrity frameworks and procurement criteria promoted by organisations such as ICROA and, more recently, through benchmark initiatives like the Integrity Council for the Voluntary Carbon Market (ICVCM).

Together, these layers of governance have helped converge expectations around what constitutes a credible, high-integrity carbon removal, regardless of where projects are implemented.

More recently, such standards have informed public policy-making initiatives such as the EU CRCF, which builds on established voluntary market practices to create a common public reference for carbon removals, without replacing existing standards or regulating corporate claims directly (European Commission, 2025).

The implication for India is not the need to invent new carbon-removal systems, but rather the need to recognise that market confidence has historically emerged where public policy codifies and reinforces practices already accepted by buyers, investors, and auditors.

Green Claims Scrutiny Reshaped Buyer Behaviour

Demand for durable carbon removal has been shaped by broader scrutiny of corporate sustainability claims, rather than carbon markets in isolation. Across multiple jurisdictions, regulators, courts, and civil society actors have increasingly challenged vague or misleading climate claims, particularly those relying on low-integrity credits to justify “carbon neutral” or “Net Zero” assertions.

Well-documented concerns such as those from methane-avoidance credits in rice systems, where baseline inflation and weak additionality undermined credibility, as well as afforestation and reforestation claims affected by permanence, leakage, and land-tenure risks, have contributed to a reassessment of what constitutes a defensible climate claim (CarbonPlan, 2024; West et al., 2023).

These failures have raised the legal and reputational cost of relying on credits that lack clear additionality, durability, or traceability. In response, corporates have become more selective across sustainability interventions, prioritising solutions that can be credibly disclosed and independently verified. This shift is reflected in buyer surveys indicating that 83% of companies are willing to pay a premium for higher-integrity carbon credits, signalling a preference for credibility and durability over volume (IETA, 2024).

In this context, durable CDR pathways such as biochar have gained traction because they are easier to account for and verify. Well-designed biochar projects rely on conservative accounting, clear control over end use, and routine monitoring. Carbon storage can be linked to measurable material properties, production conditions can be audited, and biochar application can be tracked using digital MRV systems. Together, these features reduce uncertainty around permanence and attribution.

At the same time, stricter scrutiny increases risk for poorly designed projects, particularly where production and application are spread across many sites. In decentralised biochar systems, credibility depends less on scale and more on the ability to demonstrate consistent process control, traceability, and governance. Where these elements are weak, buyer confidence declines quickly, regardless of technical potential. As a result, scrutiny increasingly rewards projects that can demonstrate durability, additionality, and verifiable controls, while disadvantaging those that cannot.

These dynamics have clear implications for India's biochar ecosystem, where projects operate at scale but must meet global expectations on quality, traceability, and governance from the outset.

What it Means for India's Biochar Ecosystem

India already has several policy and market foundations that align with high-integrity carbon removal deployment, even if carbon removal has not yet been foregrounded as a separate national priority.

The Government of India has legislated an Indian carbon market through the Energy Conservation (Amendment) Act 2022, which enables a structured carbon credit trading scheme that includes voluntary offset mechanisms alongside compliance trading (e.g., Carbon Credit Trading Scheme under the Carbon Credit Trading Scheme (CCTS)) as part of its broader climate agenda. These developments indicate the intent to develop a domestic market infrastructure for carbon assets and credentials, including potential linkage to international markets (Ministry of Law and Justice, 2022).

Notably, methodologies relevant to biochar production and application have been included under the approved list of sectors within the Offset Mechanism, particularly under Agriculture and Waste Handling & Disposal. This inclusion signals early regulatory recognition of biochar as an eligible carbon activity within India's emerging market architecture, providing a potential pathway for domestic credit issuance aligned with international durability and verification standards.

Complementary initiatives such as the Green Credit Programme further encourage voluntary environmental actions that deliver air-quality and climate co-benefits, even where carbon removal is not explicitly targeted (MoEFCC, 2023). At the sub-national level, early pilots and state-supported initiatives, including the first state-supported biochar programmes linked to residue management and rural livelihoods, indicate growing policy interest in biomass-based climate solutions (ProClime, 2025).

International experience suggests that access to capital and credible buyers depends on projects meeting a consistent set of quality expectations. For biochar, these typically include the use of surplus biomass, auditable production conditions, controlled end use, conservative permanence assumptions, and integrated digital MRV (Puro.earth, 2025; Isometric, 2026).

These design principles are already being adopted by Indian developers as well as international developers who operate in India under global procurement and verification norms.

Most importantly, the coexistence of domestic and international developers under similar constraints highlights a broader implication: project participation in global CDR markets is less a function of geography than of project design, discipline, and governance.

However, to reduce dependence on foreign investments to finance CDR initiatives in India, there must be a local strengthening of key enabling conditions; through clearer guidance on carbon claims, early domestic procurement or piloting, and continued alignment between agricultural, air-quality, and climate policy. Increased scrutiny and alignment of such policies could accelerate the scale of national voluntary carbon markets while reinforcing, rather than distracting from, national development priorities.

Taken together, international experience indicates that national-level durable CDR markets emerge where policy recognition, credibility frameworks, and real-economy benefits reinforce one another. India enters this landscape with strong structural advantages and a growing base of capable developers, positioning it to scale high-quality biochar carbon removal more rapidly than many early-mover regions, provided these lessons are applied deliberately and rapidly.

Scaling the Biochar Carbon Removal Market

Market Sizing: From Global Momentum to India's Addressable Opportunity

Carbon markets for durable CDR have started to move from concept validation to early commercialisation, creating a credible demand signal for biochar. However, market growth is best measured by the expansion of repeatable delivery capacity such as noted by projects that can consistently (i) secure surplus biomass, (ii) operate within stable process parameters, and (iii) place biochar into verifiable end matrixes.

For India, scaling the biochar opportunity is best defined by the pace at which potential is translated into financeable, standard-aligned operations, rather than by technical sequestration potential alone.

A second defining feature of growth is that biochar sits at the intersection of two distinct, but related markets, namely: voluntary carbon removals and environmental remediation efforts such as through the introduction of biochar into soils and other durable materials.

While domestic procurement of durable CDR remains at an early stage, India already exhibits strong underlying demand drivers aligned with biochar deployment - namely soil health restoration, reduction of crop residue burning, and industrial decarbonisation. These factors can underpin substantial domestic demand for biochar as a material input, independent of carbon crediting. In practice, such product markets can drive volume and operational learning, lowering unit costs and strengthening supply chains, while carbon markets play a complementary role by providing early revenue certainty and financing for high-integrity deployment.

Recent Market Developments in Indian Biochar Carbon Removal

- **Large-scale international offtakes:** Between 2023 and 2025, major global buyers including Google and Microsoft contracted more than 200,000 tCO_2e of durable biochar carbon removal from Indian developers under multi-year agreements, representing some of the largest biochar transactions globally.

- **Cross Border Project Partnerships:** A collaboration between Green Carbon (Japan), Varhad Capital (India), and Carbonfuture (Switzerland) is developing biochar facilities, expected to supply approximately 120,000 tCO_2e of high-durability credits to international markets. Altitude has partnered with Engrow to secure 425,000+ tons of CDR credits from biochar facilities in Southern India. Alcom will develop industrial-grade biochar projects across several state of India across DeHaat's farmers network, aiming up to 1 million tCO_2e of durable CDR in the coming years.

- **Domestic Partnerships**: Circonomy and Narmada Bio-Chem Ltd. (NBCL) have partnered up to develop an industrial-scale biochar facility in India, integrating biochar production directly into NBCL's fertiliser manufacturing and distribution network – utilising agricultural waste for sustainable soil enhancement products.

- **Shift Towards Forward Contracted Supply:** A growing share of Indian biochar credits are being secured through long-term offtake agreements rather than spot transactions, reflecting buyer preference for delivery certainty and high-integrity standards.

Trends in Biochar Deployment & Commercialisation

Several market trends are shaping how biochar deployment is evolving globally and, by extension, how Indian projects are likely to develop.

1. Scale concentration in fewer, larger facilities.

Early biochar deployment was largely characterised by pilots and small demonstration units (typically below 5,000 tons of annual biochar output). In contrast, recent market growth has been driven by industrial-scale facilities (often exceeding 15,000 tons per year) that are explicitly designed for sustained delivery, operational reliability, and long-term scale-up. These projects are built to supply consistent volumes over multiple years and, in some cases, are framed around million-ton scale ambitions over time.

As a result, buyers increasingly prioritise suppliers that can demonstrate delivery certainty, operational maturity, and credible expansion pathways.

In parallel, decentralised production models are evolving toward fewer, better-governed projects, with strong aggregation, quality control, and clear accountability, replacing earlier approaches based on fragmented and loosely coordinated deployments.

2. Biochar is increasingly being productised rather than sold as a raw material.

A clear shift is underway toward biochar-based products such as compost blends, fertiliser carriers, pellets, and construction inputs. While large-scale demand for these products is still emerging, end users (particularly farmers) often readily understand their value due to improved soil performance and reduced input costs.

Productisation simplifies biochar handling and application, reduces the risk of misuse, and improves traceability, factors that are increasingly important for both buyers and certification bodies. However, productisation does not remove the need for strong end-use governance: maintaining a clear chain of custody and tracking the final carbon-containing matrix remain essential to ensuring integrity.

3. Co-products are regaining importance in project economics.

The utilisation of bio-oil, process heat, electricity from syngas, and even by-products like wood vinegar is also increasingly viewed as integral to project viability rather than a secondary benefit. Integrated biochar-energy systems can materially improve project economics, particularly when co-located with agro-processing, brick kilns, food processing, or other heat-intensive industries.

This trend is especially relevant in India, where energy reliability remains uneven, fossil fuel dependence is high, and industrial heat demand often overlaps with biomass availability. In this context, carbon revenue is best understood as a catalytic income stream rather than the sole foundation of a business model.

4. Buyer preferences are tightening around integrity rather than volume.

As scrutiny of climate claims has intensified, buyers have become more selective, favouring biochar projects that demonstrate conservative accounting, controlled end use, and robust verification. Rather than prioritising rapid scale or headline volumes, procurement increasingly rewards projects that can withstand close technical and reputational scrutiny.

This trend reinforces a broader market signal: durable participation depends less on how quickly credits are issued and more on whether projects can consistently meet evolving high integrity thresholds over time.

Demand Drivers for Biochar

India's biochar demand is accelerating, with robust growth in the domestic product market for soil and environmental applications alongside surging international appetite for its carbon credits. This dual demand positions biochar as a key enabler for India's climate-smart agriculture and Net Zero ambitions.

Product Demand Drivers

India generates around 754 million tons of crop residues each year, of which nearly 90Mt is burned (TERI, 2021), creating a clear and immediate opportunity for biochar as a sustainable alternative for both soil amendment and residue management. Over 30% of soil suffers from degradation (Menon, 2023), driving farmer interest in biochar's proven benefits: boosting crop yields, nutrient efficiency, reduced fertiliser usage, and enhanced water retention in drought-prone areas.

Beyond these agronomic drivers, a critical structural factor underpinning long-term demand is India's dependence on chemical fertilisers, both in terms of imports and subsidy expenditure. Biochar can significantly improve fertiliser efficiency and reduce overall application requirements, positioning it as a complementary input within India's agricultural system and a potential lever for reducing subsidy burdens while improving soil health outcomes.

At the production and market level, key project developers are scaling biochar production while tailoring products for local soils and integrating them with compost and other organic inputs for nutrient-rich variants. However, the standardisation of biochar quality and application protocols remains a critical enabler for large-scale adoption. The development of India-specific product standards – potentially aligned with evolving frameworks under the Carbon Credit Trading Scheme (CCTS) or other regulatory pathways – will be essential in building farmer confidence and enabling mainstream uptake.

Policy support through crop residue management initiatives and air quality programs continues to boost demand, especially in northern states like Punjab and Haryana, where open biomass burning is a recurring issue. International standards enable Indian project developers to tap export markets, with trends favouring scaled facilities and productised biochar.

In addition to agriculture, the construction sector represents a significant emerging demand driver. The scale of future infrastructure development presents an opportunity for integrating biochar into construction materials such as concrete and asphalt. As India moves toward low-carbon construction and circular material use, biochar-based applications could become an important demand channel.

Overall opportunity could scale to millions of tons annually if domestic corporates increase procurement alongside global buyers.

Carbon Credits Demand

Biochar Carbon Removal is widely regarded as a credible and highly durable CDR pathway, underpinned by a strong suite of co-benefits. Buyer confidence is driven by robust, high-integrity MRV systems and the availability of insurance and risk-mitigation mechanisms. Together with its technological readiness and relatively low cost, this positions BCR as a scalable, near-term solution that supports large-volume, commercially attractive offtake commitments.

Global buyers contracted over 3 million tons of biochar CDR credits between 2022 and 2025-H1, with four out of the top 20 suppliers being India-based biochar producers (cdr.fyi, 2025). Demand exceeds supply, driven by EU/US corporates seeking durable removals; Indian credits fetch premiums for co-benefits like agricultural gains and livelihoods improvement.

Looking ahead, the next phase of demand growth will be shaped by policy-driven market creation mechanisms. Internationally, Article 6.2 of the Paris Agreement presents a significant opportunity to unlock demand through bilateral agreements for high-integrity removals. Inclusion of biochar within India's Article 6.2 strategy could enable access to compliance-linked international demand, providing early revenue certainty and supporting sector scale-up.

Domestically, CCTS opens doors, but exports dominate amid demand gaps. As methodologies mature and product standards are formalised, biochar could be integrated into compliance frameworks, complementing voluntary market demand. This would reduce reliance on export markets and align carbon removal deployment with national priorities.

Recommendations

Building on the technical, economic and policy analysis presented in this paper, unlocking the full potential of biochar in India will require coordinated action across policy, markets, and finance. The following recommendations aim to catalyse scalable, high-integrity biochar deployment in India.

Policymakers

1. Integration of Biochar into Existing National Schemes

Biochar should be formally recognised as a bio-fertiliser and soil amendment within relevant regulatory and agricultural frameworks, enabling its integration into existing national programmes.

- National Mission for Sustainable Agriculture: to make agri-systems sustainable and climate resilients.
- Galvanising Organic Bio-Agro Resources Dhan (GOBARdhan): to support decentralised biomass valorisation and rural enterprise development.
- National Policy for Management of Crop Residues (NPMCR): biochar can be positioned as a scalable and economically as a viable alternative to stubble burning.
- National Clean Air Programme (NCAP): recognising avoided open burning as a measurable air pollution co-benefit.

Integrating biochar into these frameworks would situate it at the intersection of agricultural productivity, waste management, and climate mitigation policy.

There should also be a strong focus on promoting biochar-enriched fertilisers. Biochar can play an important role in improving nutrient-use efficiency and reducing dependence on chemical fertilisers (20-50%), while maintaining or even increasing crop yields. This is particularly critical in the current context, where ensuring fertiliser availability, price stability, and fiscal sustainability of subsidies remains a priority for the Government of India.

2. Develop India-Specific Product Standards and Application Protocols

Policymakers should prioritise the development of standardised, India-specific guidelines for biochar quality and its application. This should be supported by large-scale, regionally representative field trials to establish evidence on optimal dosage, crop-specific benefits, and long-term soil impacts.

While drawing on international best practices, these standards must be adapted to Indian farming systems and local conditions. In parallel, dissemination and farmer adoption should be enabled through institutional channels such as Krishi Vigyan Kendras (KVKs), which can play a critical role in demonstration, training, and extension services.

3. Align Domestic Carbon Market Architecture with International Integrity Frameworks

As global standards for carbon removal converge, including under the EU Carbon Removal and Carbon Farming Regulation (CRCF) and emerging integrity benchmarks, India's Carbon Credit Trading Scheme (CCTS) should prioritise methodological compatibility.

Alignment with international durability, additionality, and verification requirements would enhance export competitiveness, facilitate potential future market linkages, and strengthen investor confidence in Indian-issued carbon credits.

4. Establish Domestic Demand Signals for Durable Carbon Removal

Beyond the physical product, it will be essential to stimulate domestic demand for durable carbon removal credits. Biochar-based CDR should be gradually integrated into India's emerging compliance carbon market framework, with differentiated recognition for high-durability removals.

Policymakers may also consider voluntary procurement targets or green public procurement mechanisms to support early-stage market development.

Corporates and Industry

5. Integrate Durable Carbon Removal into Industrial Decarbonisation Strategy

Hard-to-abate sectors such as steel, cement, aluminium, and chemicals are likely to retain residual emissions even under ambitious mitigation pathways. Durable carbon removal methods such as biochar should be formally recognised as a complementary component of long-term industrial decarbonisation strategies.

Clarifying the role of high-integrity removals within corporate climate frameworks, particularly for export-oriented sectors exposed to carbon border measures, would provide strategic certainty and encourage early investment.

6. Create Demand for Biochar and Carbon Removal

The long-term viability of India's biochar sector will depend on the creation of predictable and sustained demand.

Corporate procurement of biochar – particularly within agri-linked value chains such as FMCG, food processing, and textiles – can be encouraged as part of Scope 3 decarbonisation strategies.

Creating early domestic buyers will reduce overreliance on export markets and strengthen India's positioning as a credible CDR hub.

7. Encourage Industrial Co-Location and Cluster-Based Deployment

Biochar production can be integrated with agro-processing units, brick kilns, food processing facilities, and other heat-intensive industries to improve energy efficiency and project economics.

Co-location within industrial clusters may reduce lifecycle emissions, strengthen supply chain resilience, and accelerate the development of commercially viable, integrated biochar-energy systems.

Financiers

8. Facilitate Access to Blended Finance and Risk Mitigation Mechanisms

Given the capital-intensive nature of industrial-scale pyrolysis systems and the nascency of revenue streams from carbon markets, blended finance and targeted risk mitigation instruments will be critical to enable scale-up.

Concessional finance windows may be established through public financial institutions to lower the cost of capital for early projects. Credit guarantees, viability gap funding, or first-loss capital structures can further de-risk investments during the sector's formative phase. Such mechanisms will help crowd in private investments while supporting the transition from pilot scale operations to commercially viable, large-scale deployment.

9. Support Aggregated Offtake and Revenue Visibility

Aggregated long-term offtake platforms for durable carbon removal can improve revenue predictability and enable project financing at scale.

Structured procurement models, including partnerships between corporates, financiers, and project developers, can reduce early-stage market risk and accelerate capital deployment.

Development and Implementation Ecosystem

10. Strengthen Farmer Adoption and Product Market Development

On the product side, targeted pilot demonstrations, agronomic field trials, and strengthened extension services should be undertaken to build farmer awareness and confidence in biochar's soil health and yield benefits. Carefully designed incentives or subsidies may further catalyse early adoption.

Product-driven demand can support early volume creation, operational learning, and supply chain development alongside carbon market revenues.

11. Develop Early Domestic Procurement Platforms for Durable Carbon Removal

While international demand currently drives most durable CDR procurement, structured domestic procurement pilots, including through public-sector enterprises or voluntary corporate coalitions, could deepen India's internal market.

Aggregated demand would improve revenue visibility, reduce reliance on export markets, and strengthen India's position as a durable CDR supplier.

Key Recommendations

POLICYMAKERS

1. Integration of Biochar into Existing National Schemes
2. Develop India-Specific Product Standards and Application Protocols
3. Align Domestic Carbon Market Architecture with International Integrity Frameworks
4. Establish Domestic Demand Signals for Durable Carbon Removal

CORPORATES & INDUSTRY

5. Integrate Durable Carbon Removal into Industrial Decarbonisation Strategy
6. Create Demand for Biochar and Carbon Removal
7. Encourage Industrial Co-Location and Cluster-Based Deployment

FINANCIERS

8. Facilitate Access to Blended Finance and Risk Mitigation Mechanisms
9. Support Aggregated Offtake and Revenue Visibility

DEVELOPMENT & IMPLEMENTATION ECOSYSTEM

10. Strengthen Farmer Adoption and Product Market Development
11. Develop Early Domestic Procurement Platforms for Durable Carbon Removal

Figure 6: Recommendations Across Stakeholder Groups to Scale Biochar Carbon Removal (CRIA, 2026)

Conclusion

Biochar represents a uniquely aligned climate solution for India – one that addresses multiple structural challenges simultaneously. By converting surplus biomass into a stable carbon sink, biochar enables durable carbon removal while improving soil health, reducing air pollution from open biomass burning, and creating new economic opportunities across value chains. Few climate technologies offer this level of co-benefit alignment across climate mitigation and developmental priorities.

The analysis presented in this report demonstrates that India possesses significant technical potential to scale biochar-based carbon removal. Even under conservative assumptions regarding biomass availability and operational parameters, India could produce **83 million tons of biochar** and deliver approximately **0.2 Gt of annual carbon removal** today, with the potential to reach **0.45 Gt by 2030** as deployment expands and market demand grows. At current carbon market price assumptions, this represents a multi-billion-dollar economic opportunity while simultaneously contributing to India's long-term climate goals.

India is also well positioned to become a global hub for high-integrity biochar carbon removal. The country benefits from abundant biomass resources, competitive production costs, a rapidly growing ecosystem of carbon removal innovators, and increasing participation in global carbon markets. Early signals from the voluntary carbon market indicate strong international demand for biochar-based removals, with buyers prioritising projects that deliver both durability and tangible co-benefits.

However, the scale at which this opportunity can be realised will depend on the development of enabling market and policy frameworks. Biochar deployment must be supported by clear regulatory recognition, robust monitoring and verification systems, access to affordable capital for project developers, and the creation of predictable demand signals for both biochar products and carbon removal credits. Integrating biochar into existing policies could accelerate early adoption while strengthening linkages with national priorities such as crop residue management and air pollution mitigation.

Looking ahead, durable carbon removal will become an increasingly important component of global climate strategies as countries confront the challenge of managing residual emissions in hard-to-abate sectors. For India, biochar provides a pathway to participate actively in this emerging global carbon removal economy while advancing domestic development objectives.

The opportunity therefore extends beyond carbon removal alone. With thoughtful policy design, market development, and continued technological innovation, biochar can become a foundational element of India's climate strategy – transforming agricultural waste into a resource, strengthening rural economies, and positioning the country as a leader in the global transition toward high-integrity carbon removal.

References

Akinyemi, B., & Adesina, A. (2020). Recent advancements in the use of biochar for cementitious applications: a review. J Build Eng.

Awad, Y. M., Lee, S. S., Kim, K.-H., Ok, Y. S., & Kuzyakov, Y. (2018). Carbon and nitrogen mineralization and enzyme activities in soil aggregate-size classes: Effects of biochar, oyster shells, and polymers. Chemosphere, 40-48.

Biederman, L. A., & Harpole, W. S. (2013). Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis. Bioenergy, 5(2), 202-214. doi:https://doi.org/10.1111/gcbb.12037

Blanco-Canqui, H. (2017). Biochar and soil physical properties. Soil Sci. Soc. America J., 687-711.

Blanco-Canqui, H. (2019). Biochar and Water Quality. Journal of Environmental Quality, 2-15.

Carbon Gap. (2025). Government Procurement for Carbon Removal in the EU and US. Retrieved from https://tracker.carbongap.org/regional-analysis/eu-us-comparison/government-procurement/

Carbon Plan. (2024). Forest offsets. Retrieved from https://carbonplan.org/research/forest-offsets?utm_source

Carbonfuture. (2024). Biochar Carbon Removal. Retrieved from https://www.carbonfuture.earth/cdr-insight-technologies/biochar-carbon-removal

cdr.fyi. (2025, September 9). Biochar Carbon Removal Market Snapshot | 2025. Retrieved from cdr.fyi: https://www.cdr.fyi/blog/biochar-carbon-removal-market-snapshot-2025

Cherubini, F., Bird, N. D., Cowie, A., Jungmeier, G., Schlamadinger, B., & Woess-Gallasch, S. (2009). Energy-and greenhouse gas-based LCA of biofuel and bioenergy systems: Key issues, ranges and recommendations. Resources, Conservation and Recycling, 434-447.

European Commission. (2025, November 21). COMMISSION IMPLEMENTING REGULATION (EU) 2025/2358. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202502358

Gholamahmadi, B., Jeffery, S., Gonzalez-Pelayo, O., Prats, S. A., Bastos, A. C., Keizer, J. J., & Verheijen, F. G. (2023). Biochar impacts on runoff and soil erosion by water: A systematic global scale meta-analysis. Science of the Total Environment.

Gupta, S., Kua, H. W., & Low, C. Y. (2018). Use of biochar as carbon sequestering additive in cement mortar. Cement and Concrete Composites, 110–129. doi:https://doi.org/10.1016/j.cemconcomp.2017.12.009

Habert, G., Miller, S. A., John, V. M., Provis, J. L., Favier, A., Horvath, A., & Scrivener, K. L. (2020). Environmental impacts and decarbonization strategies in the cement and concrete industries. Nature Reviews Earth & Environment, 1(11), 559-573.

IBEF. (2025, June 26). India's Booming Biomass Energy Industry: A Powerful Catalyst for Sustainable Energy Growth. India Brand Equity Foundation.

IETA. (2024). ARTICLE 6 IN ACTION: BUSINESS INSIGHTS & IMPLEMENTATION TRENDS

IPCC. (2022). Climate Change 2022 - Mitigation of Climate Change: Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Isometric. (2026). Biochar Production and Storage. Retrieved from https://registry.isometric.com/protocol/biochar/1.2

Jeffery, S., Verheijen, F., van der Velde, M., & Bastos, A. (2011). A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. Agric. Ecosyst. Environ., 175-187.

Kabir, E., Kim, K.-H., & Kwon, E. E. (2023). Biochar as a tool for the improvement of soil and environment. Front. Environ. Sci., 11(1324533). doi:https://doi.org/10.3389/fenvs.2023.1324533

Lal, R., Smith, P., Jungkunst, H. F., Mitsch, W. J., Lehmann, J., Nair, P. R., & al., e. (2018). The carbon sequestration potential of terrestrial ecosystems. J. Soils Water Conserv., 73(6), 145A–152A. doi:10.2489/jswc.73.6.145a

Lan, R., Eastham, S. D., Liu, T., Norford, L. K., & Barret, S. R. (2022). Air quality impacts of crop residue burning in India and mitigation alternatives. Nature Communications.

Lee, J.-M., Jeong, H.-C., Gwon, H.-S., Lee, H.-S., Park, H.-R., Kim, G.-S., & al., e. (2023). Effects of biochar on methane emissions and crop yields in East Asian paddy fields: a regional scale meta-analyses. Sustainability, 15(12). doi:10.3390/su15129200

Leng, L., & Huang, H. (2018). An overview of the effect of pyrolysis process parameters on biochar stability. Bioresource Technology, 627-642. doi:https://doi.org/10.1016/j.biortech.2018.09.030

Liu, Z., Xu, Z., Xu, L., Buyong, F., Chay, T. C., Li, Z., . . . Zhu, Y. (2022). Modified biochar: synthesis and mechanism for removal of environmental heavy metals. Carbon Research. doi:https://doi.org/10.1007/s44246-022-00007-3

Major, J., Rondon, M., Molina, D., Riha, S. J., & Lehmann, J. (2010). Maize Yield and Nutrition during 4 Years after Biochar Application to a Colombian savanna Oxisol. Plant Soil.

Majumder, S., Neogi, S., Dutta, T., Powel, M. A., & Banik, P. (2019). The impact of biochar on soil carbon sequestration: meta-analytical approach to evaluating environmental and economic advantages. J. Environ. Manage, 250. doi:10.1016/j.jenvman.2019.109466

Maxwell, B., Joshua, K., Patel, B., & Aime, L. (2020). Biochar Bricks for Building Materials. Rochester, New York. Retrieved from https://www.hajim.rochester.edu/senior-design-day/biochar-bricks-for-building-materials

Menon, R. (2023, October). Soil degradation in India spells doom for millions. Retrieved from https://india.mongabay.com/2023/10/soil-degradation-in-india-spells-doom-for-millions/#:~:text=According%20to%20the%20National%20Bureau,the%20world's%20population%20to%20feed.

METI. (2025, October 8). GX Policy: Achieving Decarbonization and Economic Growth Together. Retrieved from https://www.enecho.meti.go.jp/en/category/special/article/detail_214.html

Ministry of Law and Justice. (2022, December 19). THE ENERGY CONSERVATION (AMENDMENT) ACT, 2022. Retrieved from https://powermin.gov.in/sites/default/files/The_Energy_Conservation_Amendment_Act_2022_0.pdf

MNRE. (2021). EVALUATION STUDY FOR BIOMASS POWER AND BAGASSE COGENERATION POTENTIAL IN INDIA. New Delhi: Ministry of New and Renewable Energy (MNRE).

MNRE. (2025, October). Bio Energy Overview. New Delhi.

MoEFCC. (2023). Green Credit Programme. Retrieved from https://www.moefcc-gcp.in/

MoPNG. (2022, June 15). Ministry of Petroleum & Natural Gas. Retrieved from https://mopng.gov.in/files/article/articlefiles/Notification-15-06-2022-Amendments-in-NPB-2018.pdf

Ndoung, O. C., Figueiredo, C. C., & Ramos, M. L. (2021). A scoping review on biochar-based fertilizers: enrichment techniques and agro-environmental application. Heliyon. doi:https://doi.org/10.1016/j.heliyon.2021.e08473

Nguyen, B. T., Lehmann, J., Hockaday, W. C., Joseph, S., & Masiello, C. A. (2010). Temperature Sensitivity of Black Carbon Decomposition and Oxidation. Environmental Science & Technology, 4(9). doi:https://doi.org/10.1021/es903016y

Oni, B. A., Oziegbe, O., & Olawole, O. O. (2019). Significance of biochar application to the environment and economy. Annals of Agricultural Sciences, 64, 222-236. doi:https://doi.org/10.1016/j.aoas.2019.12.006

Osman, A. I., Farghali, M., Dong, Y., Kong, J., Yousry, M., Rashwan, A. K., & Yap, P.-S. (2024). Reducing the carbon footprint of buildings using biochar-based bricks and insulating materials: a review. Environmental Chemistry Letters, 71-104. doi:https://doi.org/10.1007/s10311-023-01662-7

ProClime. (2025, August 27). Himachal CM launches India's first state-supported biochar programme. Himachal Pradesh, India. Retrieved from https://www.proclime.world/news-media/news-and-media-16

Puro.earth. (2022). Biochar Methodology - Edition 2022 Version 2.

Puro.earth. (2025, March 27). Biochar in Concrete: A Sustainable Solution for the Construction Industry. Retrieved from https://puro.earth/our-blog/Biochar-in-Concrete-A-Sustainable-Solution-for-the-Construction-Industry

Puro.earth. (2025, June). Biochar Methodology for CO2 Removal Edition 2025 V1. Retrieved from https://7518557.fs1.hubspotusercontent-na1.net/hubfs/7518557/Puro%20Biochar%20Methodology%20-%20Edition%202025%20-%20Approved%20Version%20-%20Pending%20Copy%20Edit.pdf

Purohit, P., & Dhar, S. (2015). Biofuel Roadmap for India. UNEP.

Rehman, A., Nawaz, S., Alghamdi, H. A., Alrumman, S., Yan, W., & Nawaz, M. Z. (2020). Effects of manure-based biochar on uptake of nutrients and water holding capacity of different types of soils. Case Stud. Chem. Environ. Eng., 2. doi:10.1016/j.cscee.2020.100036

SBTi. (2026). SBTi CORPORATE NET-ZERO STANDARD Version 1.3.1.

Shakoor, A., Shahzad, S. M., Chatterjee, N., Arif, M. S., Farooq, T. H., Altaf, M. M., & al., e. (2021). Nitrous oxide emission from agricultural soils: application of animal manure or biochar? A global meta-analysis. J. Environ. Manage, 285(112170). doi:10.1016/j.jenvman.2021.112170

Sirico, A., Bernardi, P., Sciancalepore, C., Vecchi, F., Malcevschi, A., Belletti, B., & Milanese, D. (2021). Biochar from wood waste as additive for structural concrete. Construction and Building Materials. doi:https://doi.org/10.1016/j.conbuildmat.2021.124500

Smith, S. M., Geden, O., Nemet, G. F., Gidden, M. J., Lamb, W. F., Powis, C., . . . Minx, J. C. (2023). The State of Carbon Dioxide Removal - 1st Edition. The State of Carbon Dioxide Removal. doi:10.17605/OSF.IO/W3B4Z

Supercritical. (2025). Delivered or delayed?

TERI. (2021). Development of Spatially Resolved Air Pollution Emission Inventory of India. New Delhi: Project Management Cell, The Energy and Resources Institute [TERI].

USBI. (2016, November). Soil & Water Benefits of Biochar.

Usmani, R. A. (2020). Potential for energy and biofuel from biomass in India. Renewable Energy.

Wang, J., Xiong, Z., & Kuzyakov, Y. (2016). Biochar Stability in Soil: Meta-analysis of Decomposition and Priming Effects. GCB Bioenergy, 512-523.

West, T. A., Wunder, S., Sills, E. O., Börner, J., Rifai, S. W., Neidermeier, A. N., & Kontoleon, A. (2023). Action needed to make carbon offsets from tropical forest conservation work for climate change mitigation.

World Economic Forum. (2024, January). Carbon Dioxide Removal: Best-Practice Guidelines. Cologny/Geneva, Switzerland: WEF.

Xie, T., Student, D., Reddy, K., & Wang, C. (2014). Characteristics and applications of biochar for environmental remediation : a review. Crit. Rev. Environ. Sci. Technol., 37-41. doi:https://doi.org/10.1080/10643389.2014.924180

Yadav, V., & Khare, P. (2020). Impact of Pyrolysis Techniques on Biochar Characteristics: Application to Soil. Biochar Applications in Agriculture and Environment Management, 33–52. doi:https://doi.org/10.1007/978-3-030-40997-5_2

Yrjälä, K., Ramakrishnan, M., & Salo, E. (2022). Agricultural waste streams as resource in circular economy for biochar production towards carbon neutrality. Curr. Opin. Environ. Sci. Health, 26. doi:10.1016/j.coesh.2022.100339

Zhang, M., Liu, Y., Wei, Q., Liu, L., Gu, X., Gou, J., & Wang, M. (2023). Chemical Fertilizer Reduction Combined with Biochar Application Ameliorates the Biological Property and Fertilizer Utilization of Pod Pepper. Agronomy. doi:https://doi.org/10.3390/agronomy13061616

Zhang, Y., He, M., Wang, L., Yan, J., Ma, B., Zhu, X., . . . Tsang, D. C. (2022). Biochar as construction materials for achieving carbon neutrality. Biochar. doi:https://doi.org/10.1007/s42773-022-00182-x