

Biochar:

A Multifaceted Solution for Environmental and Agricultural Challenges



Biochar is a carbon-rich, porous material produced by thermochemically converting biomass in low-oxygen conditions. Its diverse applications and environmental benefits have garnered significant attention across multiple sectors. This versatile material improves soil fertility, enhances water retention, removes contaminants from water, and serves as an effective carbon sequestration tool. According to the Intergovernmental Panel on Climate Change (IPCC), global estimates suggest biochar could remove significant amounts of CO₂ annually if widely implemented. The overall climate benefit depends on feedstock, production conditions, and application method.

Production and Properties

Biochar is produced through heating organic materials at high temperatures (above 500°C) with limited oxygen (gasification) or no oxygen (called “pyrolysis”). Production quality varies significantly based on feedstock type, temperature, and equipment. Purpose-built systems with controlled conditions consistently produce high-quality biochar with fixed carbon content of 82-89%, while less specialized systems may yield inconsistent results. Woody feedstocks generally produce biochar with higher carbon content than manures or grasses, which instead have higher ash content and pH levels beneficial for concrete applications.

Carbon Sequestration and Environmental Benefits

Biochar effectively sequesters carbon by transforming plant-captured CO₂ into a stable form resistant to decomposition for centuries or even millennia. Its recalcitrant carbon structure, particularly in biochar produced at higher temperatures, resists microbial breakdown when added to soil. When added to soil, biochar can further stabilize carbon by forming mineral complexes with the soil.

The long-term carbon sequestration potential of biochar in aquatic or disturbed environments, however, is debated. While laboratory studies show biochar can persist for centuries under stable geologic conditions, exposure to water, erosion, or landslides can cause rapid mass loss and degradation. Submersion in waterlogged environments can lead to mass loss within 24 hours, and erosion or physical movement can accelerate breakdown. Additionally, biochar’s ability to suppress greenhouse gases like N₂O may decline in flood-prone soils, raising questions about its long-term stability in such settings.

Agricultural Applications

As a soil amendment, biochar delivers multiple benefits: it improves physical soil structure by reducing bulk density and enhancing aeration; chemically raises soil pH and increases cation exchange capacity; and biologically encourages beneficial microbial activity. Biochar with surface areas between 50-100 m²/g are particularly effective. According to Dr. Lang from University of New England and associates, biochar can also reduce methane emissions when used in manure management by creating aerobic conditions and altering microbial communities to inhibit methane-producing microbes. As a livestock feed additive, it may reduce methane by changing rumen microbial populations and adsorbing methane or its precursors.

Water Quality Applications

Beyond agricultural benefits, biochar shows promise as a versatile tool for addressing water contamination, particularly against persistent pollutants like “per- and polyfluoroalkyl substances” (PFAS). These “forever chemicals,” commonly found in industrial products and water supplies, bind to biochar’s porous structure. The material’s effectiveness stems from its high surface area and customizable pore sizes—features enhanced through modifications like iron oxide coatings or potassium bicarbonate activation. Practical applications are already emerging, ranging from household filtration systems to municipal treatment plants.



Regulatory Landscape and Market Considerations

Recent regulatory changes have improved biochar’s adoption pathway. In 2024, the EPA removed Title V permitting requirements for certain biochar-producing systems, while also that year California’s Senate Bill 1522 established standardized definitions for biochar products. The EPA also reclassified clean cellulosic biomass used in biochar production as a “traditional product” rather than waste under the Clean Air Act, removing burdensome regulations. Despite these legal advances, significant challenges remain, including high production costs (\$200–\$1,000 per ton), logistical constraints in transporting feedstock, and variable efficacy across different soil types.

The future success of Biochar is highly dependent on the actions of federal agencies and legislation. As of May 2025, biochar policy and carbon removal incentives in the U.S. reflect a mix of challenges and opportunities. The Section 45Q tax credit continues to exclude biochar projects despite bipartisan advocacy for inclusion. This exclusion persists alongside legislative uncertainty, as Representative Perry’s proposed “45Q Repeal Act of 2025” seeks to dismantle the entire CCUS tax credit program, though bipartisan support for 45Q remains strong due to its benefits for energy-producing states. Concurrently, the “Carbon Dioxide Removal Investment Act” introduced in November 2024 with proposed incentives of up to \$250/ton CO₂e for CDR technologies like biochar—remains under congressional review, though its passage is complicated by post-election administrative shifts.

The USDA’s Natural Resources Conservation Service, National Organic Program (NOP), offers farmers up to \$700/acre for biochar application through programs like EQIP and CSP, with strict quality criteria ensuring project integrity. However, carbon market barriers endure under this program, as projects must produce ≥25,000 metric tons over a decade to justify verification costs, putting smaller producers at a disadvantage despite aggregation protocols and USDA grants covering 50% of verification expenses.

Future Outlook

Biochar retains its cost-effectiveness (\$80–200/ton CO₂e) and technological readiness, earning recognition from the World Economic Forum as the most economical CDR option, though feedstock limitations constrain scalability. Federal limitations such as the 45Q exclusion and carbon market receptivity pose hurdles, USDA initiatives and potential legislative developments suggest a dynamic policy landscape, with biochar’s near-term viability hinging on regulatory clarity and scalable solutions.

With California’s 35.1 million bone-dry tons of annual biomass resources, the state has significant potential for biochar production that could address forest management challenges, agricultural needs, and climate goals simultaneously. Myles Gray, programme director at the US Biochar Initiative (USBI), presented a sixfold increase projection for biochar production by 2025, though its trajectory will depend on continued regulatory streamlining, technological innovations to reduce costs, and education efforts to address lingering skepticism with scientific evidence.