DEFOSSILISING STEEL & METALLURGY: BIOCHAR'S POLICY PRIORITIES FOR THE EUROPEAN UNION

BIOCHAR EUROPE (BCE) WHITE PAPER

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BIOCHAR EUROPE

EXECUTIVE SUMMARY

Europe's metallurgical sector is vital to its economy and strategic autonomy but remains heavily dependent on fossil coal, generating significant emissions and relying on imports. While electrification and hydrogen can reduce emissions, many metallurgical processes still require solid carbon, making full decarbonisation technically unfeasible. Thus, highlighting the need for defossilisation—replacing fossil carbon with renewable alternatives.

Biochar, produced from biomass via pyrolysis, offers a promising solution. It can substitute fossil coal in key processes such as silicon, ferroalloy, and steel production, delivering substantial emissions reductions with valuable heat, energy and syngas co-products while supporting domestic value chains and rural economies. With growing technological maturity and a robust biomass base backed by strong climate policy frameworks, Europe is well positioned to lead the global transition toward renewable carbon in metallurgy.

Despite this potential, adoption remains limited due to economic and structural barriers. Targeted policy action is required to unlock biochar's role in defossilising metallurgy. Key priorities include creating a level playing field for renewable carbon, stimulating demand for low-carbon metals through public procurement and certification, ensuring sustainable biomass supply through cascading use, and supporting industrial scale-up through funding and regulatory clarity.

BIOCHAR EUROPE

European Biochar Industry Consortium e.V., Biochar Europe (BCE)
Grünhof, Augustinerplatz 2, 79098 Freiburg
www.biochareurope.eu

KEY TAKEAWAYS

- **Biochar is the first and last step on the path to a climate-neutral and competitive metallurgical industry.** As a deployable, locally produced substitute to fossil coal, biochar is the long-term solution for industries which cannot abate the use of solid/physical carbon.

- **Europe can maximize its biomass' value through poly-generative biorefineries and strategically implementing the principle of cascading-use.** Prioritizing material and energy co-production, where most effective, will maximize biomass value, climate impact and Europe's material security.

- **With appropriate regulatory support, biochar production and use can be both financially competitive and economically efficient.**

- **Industrial demand for biochar as an emissions reduction solution will support long-term supply for carbon removals.** Urgency to reduce emissions will scale the industry and prepare a sustainable biochar carbon removal service market.

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THE INDUSTRIAL CHALLENGE: RENEWABLE CARBON FOR DEFOSSILISING A COMPETITIVE METALLURGICAL SECTOR IN EUROPE

Europe's metallurgical sector underpins its modern industrial economy, supplying essential materials such as silicon, steel, and ferroalloys. In 2024, the steel sector alone generated over €177 billion in gross value added and supported more than 2.5 million jobs in Europe (Eurofer, 2025).

Beyond economics, metallurgical production anchors regional industry and strengthens Europe's strategic autonomy. However, the sector faces mounting pressure. Metallurgical producers around the world remain deeply reliant on fossil metallurgical coal, consuming around 1 billion tonnes annually and generating roughly 3 billion tonnes of CO_2 — about 8% of global emissions (IEA, 2023; World Steel Association, 2023).

Europe's climate policies are pushing producers to cut emissions while competing in a global market shaped by lower energy costs and looser standards elsewhere. At the same time, maintaining a strong and sovereign European metals industry has become more urgent amid growing geopolitical uncertainties. In response, the European Steel and Metals Action Plan (EU, 2023a) was implemented with aims to decarbonize the sector through hydrogen, electrification, and circularity. However, not all processes can eliminate their use of solid carbon.

High-temperature reduction in silicon, ferroalloys, and parts of steelmaking still require it. Moreover, Europe is a net importer of coal, leaving its sector reliant on foreign supply. Phasing out fossil coal is therefore both a climate necessity and a strategic priority, especially as coking coal remains on the EU's Critical Raw Materials List (CRMA) (EU, 2023b).

In this context, biochar is a promising but mainly overlooked alternative to fossil coal in industry, changing the climate narrative from decarbonisation to defossilisation and offering Europe a homegrown solution. However, biochar's adoption in Europe's metallurgical sector faces market pressures and policy barriers that hinder its growth as a clean industrial solution. Industry's efforts to adapt value chains will only succeed if policymakers better align relevant regulatory frameworks.

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EUROPEAN BIOCHAR PRODUCTION & POTENTIAL

2.1) Origins & Systemic Integration

Europe has a longstanding tradition in charcoal production, which was historically linked to metallurgy. However, environmental constraints and the global shift toward metallurgical coal marginalized the industry. Today, growing demand for sustainably produced charcoal and biochar, and advances in pyrolysis are driving a revival. Modern pyrolysis facilities function as advanced biorefineries producing tailorable biochar products alongside heat and electricity, supporting EU objectives for resource efficiency and cascading biomass use.

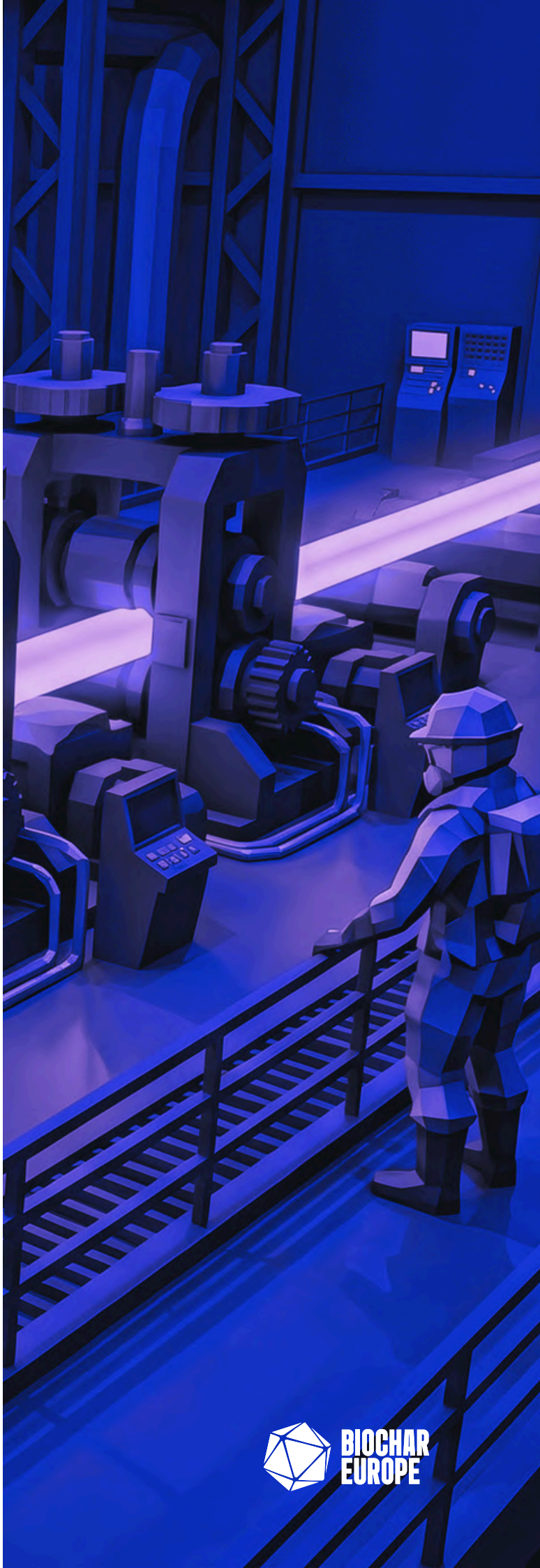
Biochar offers a regionally adaptable pathway to convert under utilized biomass, which might otherwise be burned for energy production or left to decay into a high-value industrial input. Scalable pyrolysis technologies further enable diverse and complementary business models.

In addition, biochar uses are diverse and reach into multiple industrial sectors, with an emerging global biochar carbon removal market where Europe's regulatory Carbon Removal and Carbon Farming Framework (EU CRCF) regulation is leading the way.

2.2 Production Capacity

Europe is at the forefront of biochar innovation and production technology. A growing number of European companies are now targeting the metallurgical market. Examples include Arbion Industries (30,000 t/year per installation) and Envigas (25,000 t/year per unit) are developing biochar installations in partnership with metallurgical firms. Outokumpu, Europe's only stainless-steel producer with a fully integrated production chain, has taken a vertically integrated approach. The company is investing in its own biochar production facility in Rügen, Germany (15,000 t/year), alongside a briquetting plant in Tornio, Finland to supply its ferrochrome operations (Arbion Industries, 2026; Outokumpu, 2024).

Beyond metallurgy, biochar production is expanding across multiple sectors in Europe. Installed production capacity currently stands at approximately 324,000 tonnes per year, with an additional 180,000 tonnes under development and expected online by 2026–2027 (BCE, 2025).



03

THE ROLE OF BIOCHAR IN EUROPE'S METALLURGICAL SECTOR

Biochar's climate service effectiveness as a substitute for fossil coal varies across applications. As biochar supply scales, maximizing its climate impact will depend on prioritizing applications where emissions cannot otherwise be avoided and supporting the transition to lower-carbon metal production. Biochar can play a particularly high-impact role in reducing emissions in silicon, ferroalloy, and steel production.

3.1) Silicon

Silicon production is a high-impact metallurgical application for biochar. Silicon can, in principle, be produced entirely with biochar. Unlike traditional charcoal, modern biochar can be tailored to optimal specifications for silicon production. Biochar improves furnace performance, enhances silicon purity and provides substantial climate benefit. Replacing coal with biochar can cut direct CO_2 emissions by 90%, from 4.5-5 tCO_2/tSi to as little as 0.5 tCO_2/tSi, with the remaining emissions coming primarily from electrode consumption (Hoover et al. 2024; Hoover, 2024).

3.2) Ferroalloys

All ferroalloys require carbon-based reductants in high-temperature EAF processes, making them a key target for biochar to reduce fossil emissions. Green ferroalloys are critical for low-carbon steel, as their embedded emissions affect the Product Carbon Footprint. They also support increased steel recycling and hydrogen-based steelmaking. While less GHG-intensive than the Blast Furnace Route, higher ferroalloy input is needed to achieve equivalent steel quality.

3.3) Steel

While electrification and hydrogen enable deep emission cuts, elemental carbon remains essential across all steel production routes. Biochar's use enables immediate defossilisation of steel production for today's blast furnaces and as a physical carbon in all EAF-based steel making.

3.4) Biochar Products & Metallurgical Application

To meet the stringent operational demands of metallurgical processes, biochar must achieve high fixed carbon content (>75%) and exhibit consistent quality across multiple physical and chemical parameters. Tables 1 shows the range of products, with key corresponding characteristics, suitable for the use cases previously discussed, demonstrating the abilities of pyrolysis and agglomeration technologies on the market today.

Product Category	Description	Size	FC	Use Cases
Biochar Lumps	High reactivity for Si / FeSi	10–80 mm	80–82%	Silicon/FeSi
	Medium volatiles		82–85%	Ferroalloys, EAF (semi-open)
	Closed furnaces		>85%	Ferroalloys, EAF (closed)
Biochar Fines	For injection or agglomeration	1–8 mm	>80	EAF, BF, injection
Briquettes	Roller-pressed or stamped	variable	75–85%	General processes
Pellets	Extruded with binders	<20 mm	75–85%	Engineered for process compatibility
Extruded Lumps	High-density engineered format	>20 mm	>85%	Closed furnace ferroalloys

Table 1: *General biochar product specifications for various metallurgical use cases*

Extensive research is ongoing across Europe to optimize biochar for metallurgic applications, both by industry and research institutions. Research facilities of note include SINTEF (Norway), Institute of Energy and Fuel Processing Technology (Poland), K1-MET (Austria) and the Łukasiewicz Research Network (Poland) are working with industry to drive solutions and de-risk biochar implementation in production.

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ECONOMIC CHALLENGES: WHY IS BIOCHAR NOT BEING USED?

Biochar's financial attractiveness to the metallurgical sector depends largely on the cost differential between biochar production costs and use-price for fossil-based reductants. Two major pricing components creating market uncertainty are the effects of the EU Emissions Trading System (ETS) carbon price and biomass prices.

4.1) The Dilemma Market Uncertainty and Behavior

Most industrial users are unwilling to pay a premium for biochar to protect their margins, nor are they willing to give up the flexibility of spot-market procurement. Even more critically, many companies are reluctant to sign long-term offtake agreements, which would be necessary to de-risk investments in new biochar production facilities. This reluctance is driven by two factors: (1) the belief that biochar prices may decrease as production scales and technological efficiency improve; and (2) the fact that coal markets remain liquid and familiar. The result is a classic chicken-and-egg problem: without long-term commitments, biochar producers cannot achieve the economies of scale and experiences needed to bring down costs, nor can industrial users validate and identify added value opportunities of biochar use.

4.2) Shifting Production Cost

The pricing challenge biochar faces compared with fossil coal stems from their fundamentally different cost structures. Coal is a globally traded commodity extracted from geological reserves, with prices shaped by supply, demand, and scale. Biochar, in contrast, is a manufactured product derived from biomass feedstock, produced through a yield-based conversion process that establishes an inherent cost floor. In addition to technological and logistical costs of production, biochar's price is directly influenced by the cost and availability of biomass, which is subject to fluctuation from competing biomass industries such as from energy, pulp, and other biomass markets.

This structural difference gives coal an inherent cost advantage. With established infrastructure and decades of optimization, coal typically reaches the market at lower and more volatile prices, especially in sectors benefiting from free ETS allowances. Without policy mechanisms to address carbon and other strategic externalities, biochar will struggle to compete on price alone, limiting its ability to scale.

4.3 The importance of ETS Carbon Price

To provide further depth to the discussion, Figure 1 from Hauser & Lerchenmüller (2025) illustrates the biochar equivalence price for different applications—i.e., the break-even biochar price above which fossil alternatives remain cheaper. It integrates fossil reference prices, biochar substitution ratios, and carbon intensity per tonne.

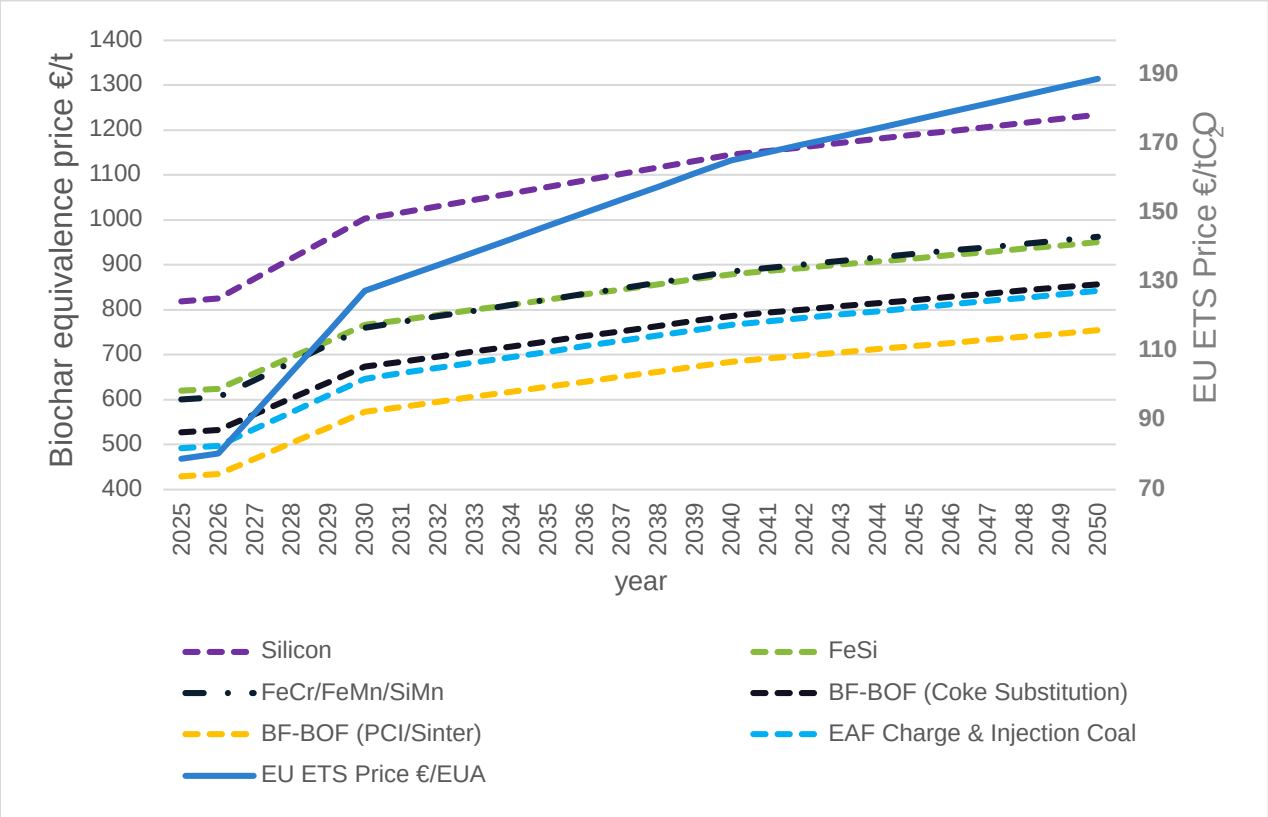

Figure 1: *Equivalence Price for Biochar versus projected fossil reference cost as function of EU ETS Carbon Price*

The figure shows the biochar equivalence price varies significantly across its use in different metallurgical processes. It demonstrates how a rising and stable EU ETS price trajectory, alongside improved biochar supply economics and targeted regulatory adjustments, make biochar competitively priced climate alternative for key European metal industries. However, climate service pricing alone may not be enough to enable markets, meaning further policy support is key to catalyzing both supply and demand.

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POLICY ACTION FOR CLIMATE IMPACT

Several policy hurdles exist which are disadvantageous for biochar in metallurgy. Aligning policies will create the opportunity for biochar and industry unlike any other market intervention. The following are key steps to encourage biochar's integration into European metal production:

5.1) Create a Level Playing Field for Renewable Carbon

Fossil inputs like coke continue to benefit from structural advantages, including free ETS allowances, long-established regulatory recognition, and exclusion from the Carbon Border Adjustment Mechanism. While the Activity Level Change Regulation extended allowances to some fossil coal uses, revisions to the Free Allocation Rules are needed to ensure certainty beyond 2030 and formally recognize biochar as a functional and strategic substitute for metallurgical coal under ETS guidance.

The EU's strategic autonomy policies, in this case the CRMA, must also be adjusted as coking coal is listed as a critical raw material. Although its role is essential, this designation is counter-intuitive to both Europe's climate and autonomy goals, and signals continued dependency on status-quo fossil fuel consumption.

Biomass subsidy schemes should also ensure biochar production has equal access to biomass residues and support for plant development alongside other established markets, such as bioenergy and other material applications. To advance Europe's objectives of resource efficiency and cascading use, funding and subsidy programs should be reviewed and aligned to prioritize biomass deployment in markets that deliver high value with significant climate and environmental impact.

5.2) Stimulate Demand for Green Materials

As green metal production in Europe remains more costly than fossil-based imports, demand-side measures are essential. In line with its objectives, the Clean Industry Deal (EU, 2026) must support the use of lead market mechanisms, demand aggregation tools, and robust certification systems to promote green steel, silicon, and ferroalloys produced with renewable carbon inputs. Public procurement is a particularly effective tool, creating predictable demand that encourages private investment and signals long-term political commitment to low-carbon industrial materials.

Carbon leakage protection must also extend across the entire value chain, and harmonized EU-level carbon footprint accounting, including emissions from charcoal and biochar production, is necessary to ensure transparency and fair competition.

5.3) Secure Sustainable Biomass Through Cascading Use

Reliable and sustainable biomass supply is fundamental. Regulatory guardrails under the European Regulation on Deforestation-free products(EUDR) (EU, 2023c) , and Renewable Energy Directive (EU, 2023d) already promote responsible sourcing and prioritization of residues. Biochar in metallurgy should be explicitly recognized as a cascading-compliant, high-value material use converting lower-value residues and wastes into stable carbon for essential industrial processes before energy recovery is considered.

As the sector scales, biochar deployment must prioritize metallurgical applications with the greatest climate mitigation and resource-security impact. At the same time, policy frameworks must support the full valorization of pyrolysis co-products, ensuring energy and other outputs are integrated into regional industrial and energy systems to maximize overall system and resource efficiency.

5.4) Enable Scale-Up and Industrial Integration

Accelerating commercialization requires both regulatory clarity and targeted funding. Biochar and poly-generative biorefineries should be clearly recognized within EU and Member State legislation, with alignment across biomass strategies, industrial policy, and permitting frameworks to reduce investment risk and enable facility deployment and integration.

An important start in biorefinery recognition was the inclusion in the EU Bioeconomy Strategy's Strategic Framework for a Competitive and Sustainable Bioeconomy (EU, 2025). The file is an important enabling policy framework to link bio-resources to fossil substitution. However, to effectively support biochar, this framework must be closely aligned with the key policies outlined above.

In particular, it must facilitate the integration of biomass into new industrial-scale application opportunities, while reinforcing the effectiveness of EU climate policies to encourage industry toward lowering emissions through biomass-based solutions.

Dedicated financial support including through Horizon Europe, Innovation Fund, RePowerEU and Research Fund for Coal and Steel should prioritize demonstration projects, production scale-up, industrial co-location, and carbon removal integration. In the medium term, rising carbon prices will improve competitiveness; in the short term, coordinated investment is necessary to bridge the gap and reduce financial risks.

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CONCLUSION

Sustainably produced biochar offers a renewable alternative to fossil carbon in essential European metallurgical processes that cannot be decarbonized due to their technical necessity of using elemental carbon as a feedstock. Biochar production and use is not just a technological solution, but a gateway to replacing linear fossil-based value chains with a decentralized, nature-based circular economy.

While biochar has the potential to contribute to Europe's competitiveness and prosperity in the medium to long run, it will only grow if its potential and holistic contributions are recognized, obstacles are removed, and investments in further technological development, product validation, and growth are supported by Europe and its Member States.

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