



THE ROLE OF BIOMASS IN THE PRODUCTION OF IRON, STEEL AND CEMENT

Over 30% of global CO₂ emissions are from industry and are increasing at 1% per year. The main drivers for the increase in emissions are population and per capita GDP growth. These are partially offset by improvements in energy efficiency and carbon-emission intensities of industrial processes. Greenhouse gas (GHG) emissions from industry need to fall by 2% per year to the end of the 2020s and then by nearly 9% per year in the 2030s to meet net zero emission (NZE) trajectories. Two of the most energy-intensive, hard-to-abate industries are the manufacturing of iron and steel (I&S), and cement. Combined they are responsible for around 12% of global CO₂ emissions. Both industries rely heavily on coal and are the second major user of coal after the power sector.

There are various ways to reduce their emissions. This report focuses on the role that sustainable biomass resources and biogenic wastes could play. This includes biomass or biomass products supplying or supplementing process heat currently provided by coal. In the manufacture of I&S, biomass products can act as a reducing agent and supplement or substitute for coal or coke.

IRON AND STEEL INDUSTRY

The I&S industry is the second-highest industrial CO₂ emitter after electricity production, producing approximately 6% (3 Gt) of global emissions in 2021. China dominates production, followed by Europe, India, Japan, and Russia. The main technologies are the integrated blast furnace – basic oxygen furnace (BF-BOF) and the direct reduced iron – electric arc furnace (DRI-EAF). The nature and age of the fleet in each region impacts the timeline and strategy for decarbonisation. One of the various ways to reduce CO₂ emissions is fuel switching to biomass-derived alternatives. This approach can be implemented rapidly, but is dependent on a secure, sustainable, economic supply chain; Brazil, India, USA and China already have significant charcoal supply chains which could deliver a fraction of their I&S industries' fuel needs.

Current developments in research methods enable modelling on a region or even plant-by-plant basis. This can synthesise and model data including age and technology of the fleet, local supply chains, and local economic factors, to help inform decision-making by predicting carbon savings and cost.

The main sources of carbon are coke and coal (pulverised coal injection, PCI) in the BF, coke breeze in the sinter plant, added or injected coal and coke in the EAF, and coal gasification in DRI. There is a fundamental difference in the carbon science of coke compared to biomass-derived chars, such as charcoal, which affects the suitability of biomass-derived chars for I&S operations. Biomass, particularly charcoal, can contribute at different levels in each type of plant. For example, blending with coal in coke production (limited to 2–10%), substituting for coke breeze in the sinter plant (up to 40%), injecting in pulverised form in the tuyeres of the BF (up to 100% in theory, but less in practice), and displacing some coal or coke in the EAF (up to 60%). The estimated levels of substitution and the associated Technology Readiness Levels (TRLs) are depicted in Figure 1. A key R&D challenge is understanding the fundamental changes in

chemistry and physics of coal/coke substitution by biomass products, such that blending can be used to optimise substitution rates while maintaining satisfactory performance.

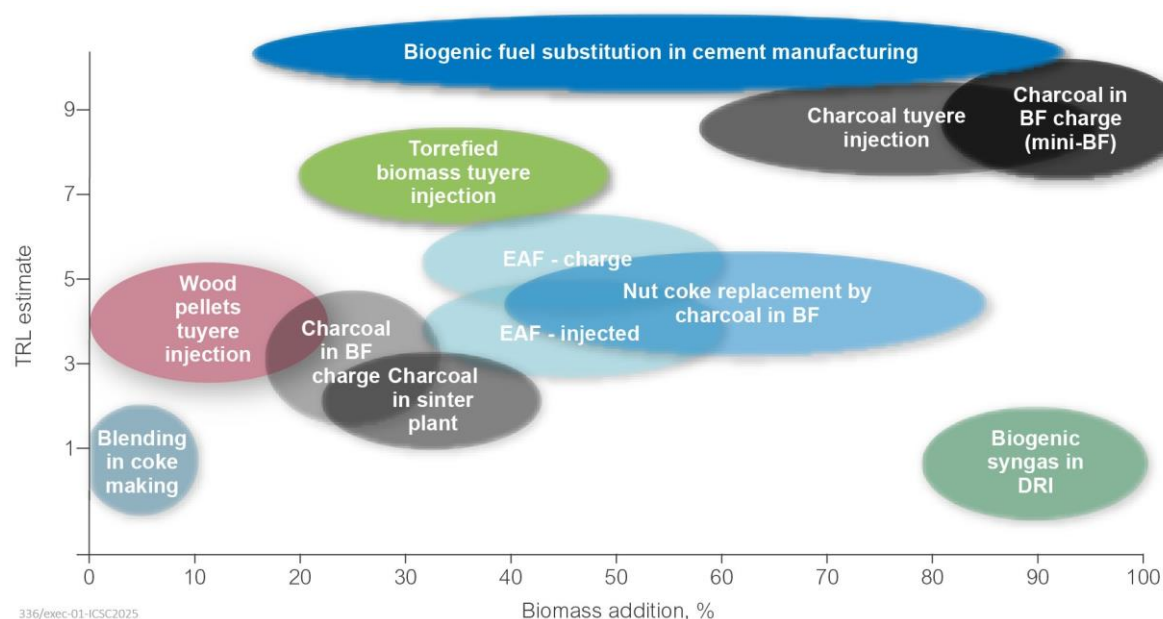


Figure 1 Estimated TRLs of different strategies for biomass addition in I&S manufacturing, and approximate substitution rates achieved (authors' work)

The industry has been slow to implement biomass products as there is a perception that they are expensive, with unreliable supply chains and, generally, do not match coke in performance. Certainly, charcoal cannot meet coke for its mechanical strength and low reactivity which means substitution in very large BFs is limited. However, in Brazil, which has smaller BFs, charcoal has displaced coke. Some of the key issues in utilising biomass and charcoal in I&S manufacturing include economics versus sustainability credentials. Local sourcing of well-managed forest supplies or waste residues helps to mitigate some of the concerns. Carbon taxes and regulatory standards will be required as effective incentives for wider adoption.

CEMENT PRODUCTION

Cement production is the third largest CO₂ emitting industry globally and is responsible for 5–8% of CO₂ emissions. The two main sources of direct CO₂ emissions in cement manufacture are CO₂ from calcining, which is inherent in the process and produces 55% of total CO₂ emissions from the sector, and CO₂ from fuel combustion to produce the necessary process heat, responsible for 38% of the total CO₂ emissions. Various carbon emission reduction measures have been used, including the use of alternative fuels with lower life-cycle CO₂ emissions. Partial substitution of fossil fuels with a variety of waste fuels or biomass reached 53% in the EU in 2021, and a global average of 23% in 2022. In theory, a 100% substitution rate is possible with modern dry kilns. An example is Schwenk's Allmendingen cement plant in Germany, where more than 94% of coal input has been substituted by alternative fuels, including a 75–85% biogenic share. Thus, the displacement of coal by alternative biogenic feedstocks in the cement sector is commercial and practiced worldwide, at different substitution levels (*see* Figure 1). The GCCA roadmap anticipates the global average substitution rate of alternative fuels to reach 43% by 2050 through utilising biogenic feedstocks. R&D priorities include understanding and minimising the impact of impurities from biogenic fuels on cement, the role of thermal pretreatment of biogenic sources, and optimising firing strategies in different parts of the plant to maximise fuel substitution rates. The effectiveness and uptake of alternative fuel use is influenced by regional factors, such as availability, economics, and policies and regulations that

support effective management of waste streams. Policy measures or incentives that promote the use of alternative fuels over fossil fuels would support this decarbonisation lever.

CONCLUSIONS

Early retrofitting of all carbon-reducing measures in energy-intensive industries is key to achieving maximum emissions reduction but both I&S and cement sectors will require significant initial investment to achieve this goal. Any improvement in efficiency will result in financial savings for the industry, but decarbonisation projects require large, upfront capital costs. Carbon taxes and regulatory standards can be an effective incentive, and border adjustment mechanisms can reduce the risks of leakage. There are wider environmental and societal co-benefits from improved efficiency and decarbonisation measures which can include improvement in air quality, reduction in water use, minimisation of waste, extending plant lifetime and maintaining and expanding workforce employment opportunities.

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Each executive summary is based on a detailed study which is available separately from: www.sustainable-carbon.org. This is a summary of the report: The role of biomass in the production of iron, steel and cement by Prof Jenny Jones, Dr Leilani Darvell, Dr Bijal Gudka, ICSC/3365, ISBN 978-92-9029-659-1, 117 pp, February 2025.

