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Design of a sustainable iron ore smelting system using biochar-based direct reduction and CO_2 sequestration to lower steel's carbon footprint in Marcegaglia site at Ravenna port

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Steel production is a major contributor to global CO_2 emissions, primarily due to the reliance on coking coal in conventional iron ore reduction processes. This study proposes an innovative system for the direct reduction of iron ore through a smelting process utilizing biochar as a renewable reducing agent, coupled with efficient CO_2 capture to minimize the carbon footprint of steelmaking.
Biochar, produced via biomass pyrolysis, offers a carbon-neutral or even carbon-negative reduction pathway. In the proposed system, iron ore is smelted in a high-temperature reactor where biochar acts as both a reductant and a source of renewable carbon. The process leverages the high reactivity and low impurities of biochar to facilitate efficient iron oxide reduction while minimizing slag formation. The resulting CO_2 emissions are then captured using post-combustion sequestration techniques, such as amine scrubbing or mineral carbonation, ensuring near-zero emissions.
Preliminary assessments indicate that this approach could reduce CO_2 emissions by up to 80% compared to traditional blast furnace methods. Additionally, the integration of biochar—derived from agricultural or forestry waste—enhances circular economy principles by valorizing biomass residues. The reactor design, biochar properties, and CO_2 sequestration efficiency will be faced to enable the industrial scalability. This system presents a viable transitional pathway toward greener steel production, aligning with global decarbonization goals while maintaining cost-effectiveness and material performance.

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