

## Impact of Temperature and Gas Composition on the Reduction and Carburization of Industrial and Biomass-containing Iron Ore Pellets

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The transition to hydrogen-based direct reduction (H<sub>2</sub>-DR) is crucial for decarbonizing steel production. While current industrial DR plants rely on fossil fuels, challenges remain in scaling up the H<sub>2</sub>-DR process due to green hydrogen supply constraints and the absence of carbon in the reducing gas. These factors prompt the exploration of complementary renewable and sustainable solutions, with biomass emerging as a potential carbon source, heat supplier, and partial substitute for H<sub>2</sub> through biogenic gas. However, the effects of adding biomass to iron ore pellets or introducing biogenic gases into the process on pellet integrity, or product formation remain poorly documented.

This study investigates the reduction and carburization behaviors of iron ore pellets and biomass-based composite pellets using thermogravimetric analysis (TGA). Mixtures of H<sub>2</sub>, CO, and other biogenic gas compositions in the temperature range of 973 K to 1273 K are investigated. Additionally, detailed microstructural and phase analysis will assess carbon deposition, phase transformations, and mechanical property changes using techniques such as X-ray diffraction, scanning electron microscopy, and Raman spectroscopy. The results on regular iron ore pellets show that pure H<sub>2</sub> allows for the fastest reduction, reaching near-complete conversion at all temperatures, whereas CO atmosphere results in slower reduction. H<sub>2</sub>/CO mixtures initially exhibit a similar reduction behavior as pure H<sub>2</sub>, but is then followed by carburization. The presence of carbon in the direct reduction iron is beneficial for the downstream process, but excessive carbon deposition, as observed at low temperatures, can also impair reduction efficiency and compromise reactor operability. The characterization methods will aim, among others, at identifying the nature of the iron carbides and of the deposited carbon. Upon these results, investigations on biochar-mixed composite pellets will be carried out, with similar TGA experiments and characterization. The question will be answered, whether the presence of biomass favors complete reduction, especially in the pellet near center region, less accessible to reducing gases, and if pellet integrity is maintained during reduction. The combined thermogravimetric and microstructural analyses will provide deeper insights into the effects of gas composition, biomass integration and reduction kinetics, contributing to the optimization of the DR process.

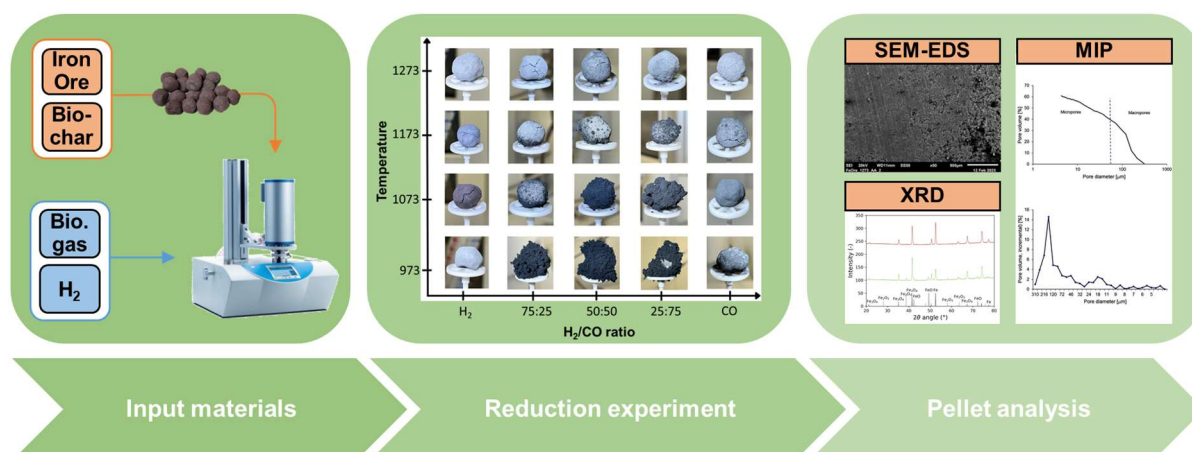


Figure 1: Graphical abstract of the present study on iron ore and biomass-based composite pellet reduction and characterization