Green carbon as reducing agent in iron and steel production via the blast furnace

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Sub-Area 2.1: Process Analysis and Simulation

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Introduction

Iron production via blast furnace utilizes coal and coke to reduce iron oxides resulting in high greenhouse gas emissions. This important issue for the iron and steel industry may be mitigated by application of biomass-based reducing agents (bioreducer).
By substituting fossil coal with bioreducer in pulverized coal injection (PCI) systems almost half of the reducing agents could stem from renewable sources. This, however, largely depends on the chemical qualities (C/O ratio) of the bioreducer and also its maximum injection amount, thus, its physical characteristics like grindability and conveyability.

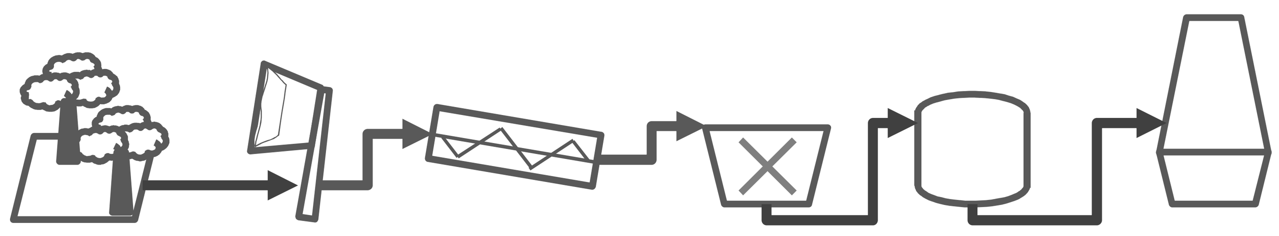

Fig. 1: The process chain of bioreducer production and usage

Research objectives

Within the last project phases a viable strategy to produce a bioreducer has been defined and concerning the pyrolysis step a reasonable temperature window was elaborated.
Figure 1 sketches the path of the bioreducer production and usage. Contrarily, Figure 2 relates the bioreducer to the blast furnace process itself, thereby indicating the current focus of the project: Evaluating the performance of possible bioreducers on a theoretical economical basis considering its implications on other mass streams (in particular the resulting coke requirement) in the blast furnace.

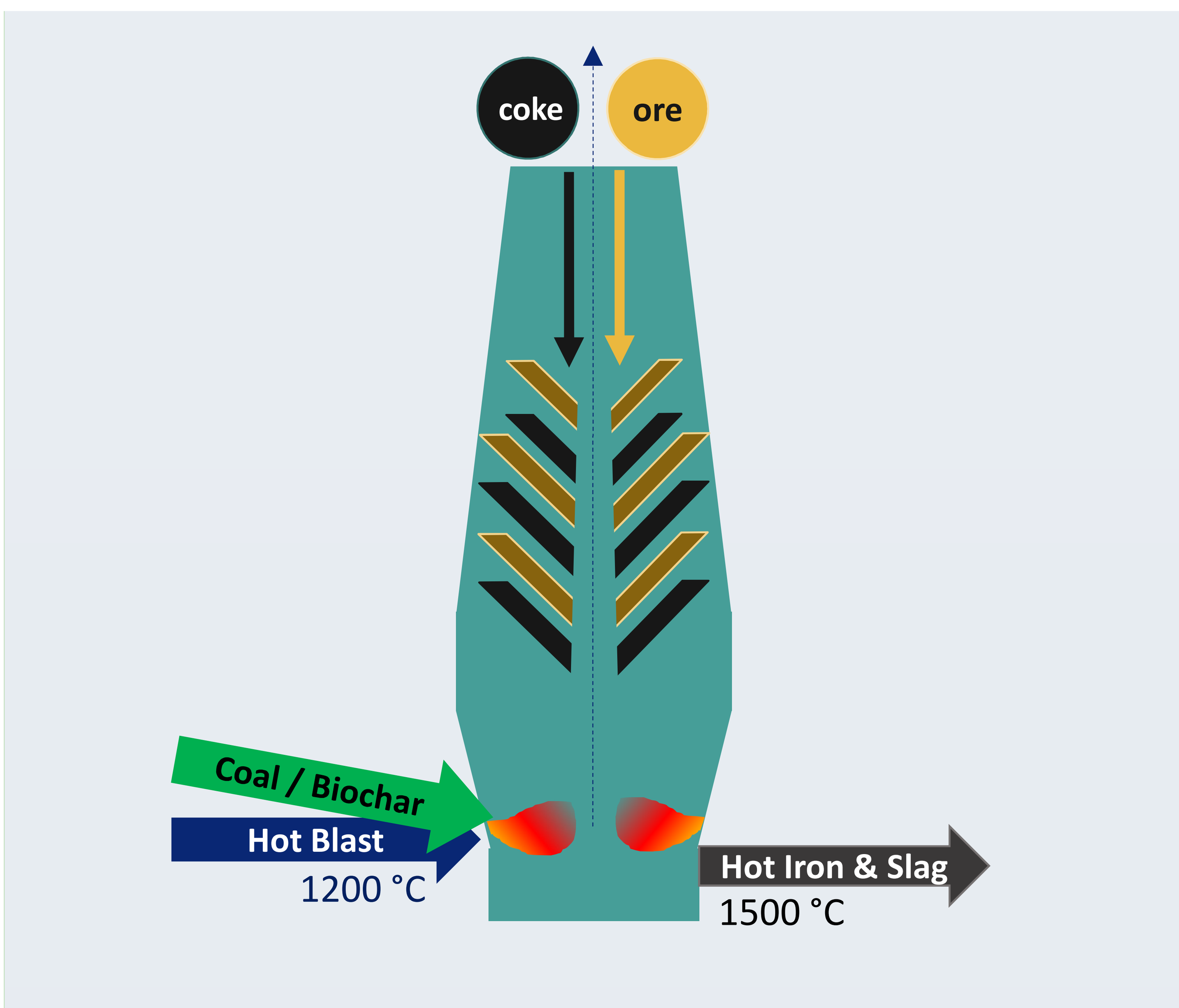

Fig. 2: Blast Furnace process with pulverized coal/char injection in the raceway (yellow/red zone)

Important bioreducer criteria:

- High possible **injection rate**:
  - Spherical particles after grinding
  - Narrow particle size distribution
  - High density
  - Proportionally low conveying gas rates
- High **coke replacement** ratio:
  - High reduction potential (high carbon and hydrogen ratio)
  - Appropriate proportion of volatiles
- **Economical viability**:
  - Taking into account the costs of all affected fuel / reductant streams
  - Evaluating strategies to optimize the production costs

Challenge

Higher pyrolysis temperatures result in a better coke replacement ratio (thus decrease the costs for fossil fuel) but also in a lower bioreducer yield (thus increase the costs for wood). As a result the optimum pyrolysis temperature also depends on the relative costs of all involved fuel streams. Figure 3 indicates that depending on this relation the most favorable pyrolysis temperature is varying – there even are cases, where intermediate temperatures have a slightly better economic performance.
Furthermore, various characteristics of the bioreducer cannot be modified independently from another. E.g. while high C-content is beneficial to the overall process, it cannot be limitlessly increased without decreasing the bioreducer's volatile matter content to an extent, which is unfavorable for the burnout in the raceway. Possible tradeoffs must be evaluated.

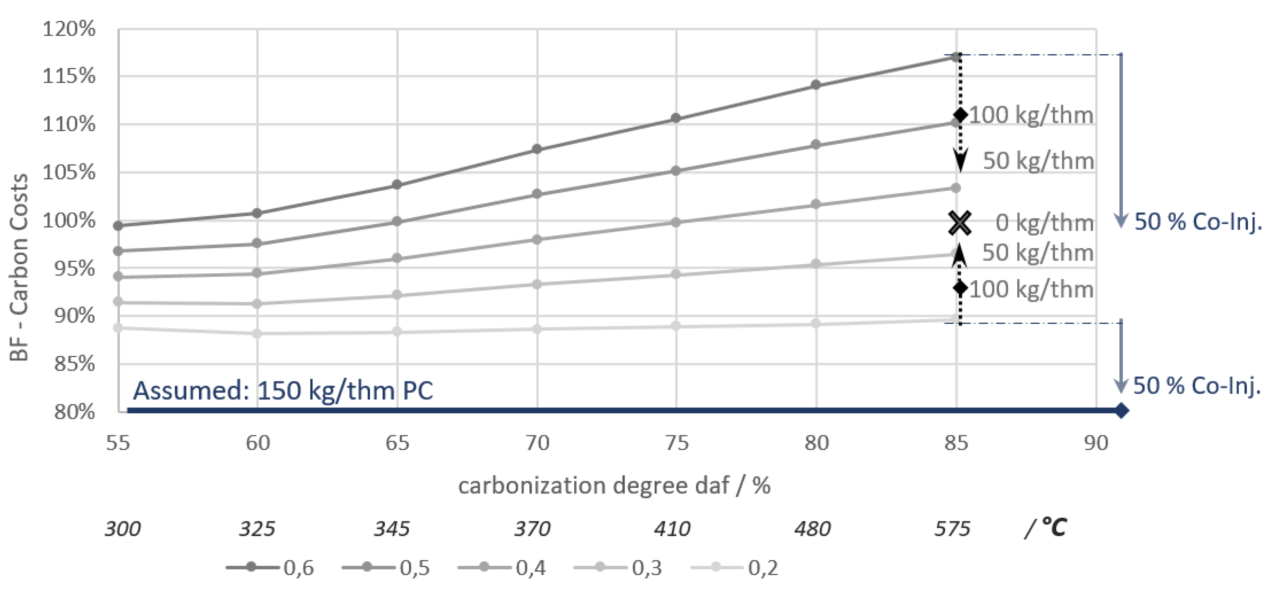

Fig. 3: Blast furnace carbon costs in dependence of carbonization degree and relative prices of wood to fossil expenditures (0,6 to 0,2 … e.g. €/€)

Approach

By feeding analytical bioreducer data regarding various pyrolysis temperatures (yield, CHN) into a blast furnace model and computing the resulting mass streams, various cost scenarios can be evaluated. Different optimization strategies (such as the potential to valorize the pyrolysis gas stream) shall be evaluated as well.

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