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Model-based Examination of an Optimal Use of Carbon-based Energy Carriers in an Integrated Steel Mill through Integration of a Direct Reduction Plant

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Abstract

In the context of the special report of IPCC to global warming from 2018, feasibility and impact of a limitation of global warming by 1.5 °C were examined. Compared with the 2 °C target, it should have significant advantages regarding climate change. Therefore, extensive efforts have to be made not only in the energy sector, but also in the industrial sector. With a share of 8 % on global energy-related CO_2 emissions, the steel industry is one of the large emitters in the industrial sector. Facing increasing prices of CO_2 certificates, different measures to lower CO_2 emissions are considered.

One possibility is a co-feed of direct reduced iron (DRI) from a natural-gas-based direct reduction plant (DRP) and iron ore in existing integrated steel mills. For this process concept, DRI is fed to the blast furnace as a pre-reduced iron carrier. As a result the coal consumption of the blast furnace decreases. The use of DRI in integrated steel mills therefore results in a substitution of coal by natural gas. Based on the development of process models for all major process steps, a detailed process model of an integrated steel mill including a DRP was devised. The optimal material and energetic use of carbon-based energy carriers targeting a low carbon steel production was examined.

As the primary reduction agents in a DRP are hydrogen and carbon monoxide a co-feed of hydrogen into the DRP as a means of reducing CO_2 emissions has been discussed in the literature. Therefore in a further step the opportunity of a hydrogen-based direct reduction process was considered.

The investigations showed that the integration of a natural-gas-based DRP allows a mitigation of over 10 % of CO_2 emissions. Furthermore it could be shown that a hydrogen co-feed of up to 35 % of the reduction energy allows for a further reduction in CO_2 emissions by more than 3 %. With a further increase in the hydrogen fraction the potential for emission reduction is limited due to a decrease of carbon amount in the DRI.