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Techno-Economic Assessment of H_2-DRI and NG-DRI-CCS Processes for Low-Emission Iron Production

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The transition of the iron and steel industry to low-emission systems is mandatory for meeting the global targets of greenhouse gas emission reduction. As the sector still heavily relies on fossil fuels, the shift is particularly challenging. Hydrogen-based direct reduced iron (H2-DRI) has gained increasing attention, and it is currently considered one of the most promising option for zero-emission iron production. Alternatively, natural gas-based DRI plants equipped with carbon capture and storage (NG-DRI-CCS) could play a relevant role, in presence of a CO2 infrastructure and/or in absence of substantial and low-cost availability of renewable energy sources (RES). This may be the case in Europe, where full-scale CCS projects are advancing in the cement, lime, petrochemical and waste-to-energy sectors, offering the opportunity of CCS clusters.

This work aims to provide a consistent techno-economic comparison of H_2-DRI and NG-DRI-CCS systems, by evaluating their material (feedstock, products and CO2), energy and economic balances. The two processes are simulated using Aspen Plus® for a representative plant size of 2 MtDRI/y, designing configurations that include electrification wherever possible to minimize residual emissions and improve efficiency. The integration with RES, electrolysis and storage units is investigated via mixed-integer linear programming (MILP) optimization, to properly account for the cost of renewable electricity in different locations. For the CO2 balances, the analysis considers direct and indirect contributions, adopting a life-cycle approach (e.g., solar panel manufacturing and natural gas supply chain leakages).

Preliminary calculations indicate a cost of CO2 avoidance of 50-100 €/tCO2 in case of NG-DRI-CCS, while values for H2-DRI results in 150-300 €/tCO2 with short-term technology costs and between 0 (i.e., cost parity) and 100 €/tCO2 with long-term cost projections. The outcomes of this study contribute to a deeper understanding of the feasibility of H_2-DRI and NG-DRI-CCS systems for different locations, and under different technology development scenarios.

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