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Results from the HySteel project: integration of solid oxide electrolysis into direct reduction iron systems

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With a CO2 emission intensity of 1.9 tCO2/tcrude steel (including both direct and indirect emissions) and a primary energy consumption of 21 GJ/tcrude steel, steel production accounts for the emission of 3.74 GtCO2/y, representing approximately 10% of total manmade emissions. The production of direct reduced iron (DRI), which relies on natural gas to convert iron ore into metallic iron, results in 10.3 tons of direct CO2 emissions per ton DRI, with natural gas contributing approximately 67% of those emissions.
To further lower the direct specific CO2 emissions of this hard-to-abate sector, reducing natural gas can be displaced by introducing electrolytic hydrogen and synthetic gas (syngas) produced at pressure (up to 8 bar) and at high temperature (<800℃) exploiting the waste heat and chemical content from the ironmaking process using solid oxide electrolysis (SOE). The advantageous thermodynamics available in SOE allows converting the available CO2 and H2O from the top gas stream of DRI furnaces into a useful H2-rich stream by supplying renewable electricity at a much lower rate (35 kWh/kgH2) than non-integrated electrolyzer technologies (50-60 kWh/kgH2).
Within the HySteel project, we have demonstrated the integrated detailed design and flexible operation of SOE systems into 2 Mt/y production capacity DRI plants with emission intensities <0.03 tCO2/tcrude steel and primary energy consumption <8 GJ/tcrude steel. We report SOE stacks operating in co-electrolysis up to 8 bar to satisfy the hydrogen and syngas requirements to produce at least 1 ton per week of iron, in addition to co-producing pure oxygen. Techno-economic analyses have shown that costs as low as 270 USD/tDRI, and as high as 393 USD/tDRI are expected with 100% intermittent renewable energy inputs.

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