Innovative technologies for steel manufacturing: extending Exiobase to analyze decarbonization paths to reduce steel carbon footprint within the European Union

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Steel is a crucial material for the manufacture of clean technologies and electrical infrastructure. However, steel production is a very energy intensive process, responsible for around 8% of global CO2 emissions. With the intensification of the net zero by 2050 target declared by the European Union, strengthened with the Fit-for-55 and REPowerEU policy plans, exploring innovative solutions to reduce the environmental impact of heavy industries is of utmost relevance. The aim of this work is to model the supply chains of new steelmaking technologies and study long-term decarbonization scenarios of the steel sector. The analysis adopts the open-source software MARIO to extend the hybrid-units Exiobase supply-use database to account for innovative steel manufacturing technologies. In particular, the technologies considered encompass the Optimized Conventional Blast Furnace-Basic Oxygen Furnace (BF-BOF) route, including hydrogen (H2) injection, charcoal injection, CCUS, and charcoal injection with CCUS, and the Direct Reduction (DR) route, exploring natural gas and hydrogen direct injections. In relation to H2-based technologies, if following BF-BOF route, they use a combination of grey (20%) and green H2 (80%); a sensitivity analyses was performed on this mix. On the other hand, natural gas-injected DR technology only uses grey H2, while hydrogen-injected DR technology is fed by green H2. The penetration of these technologies was explored according to scenarios resembling European 2030-to-2050 targets, enriched to account for the power sector decarbonization. The results show a reduction in the carbon footprint of steel across all scenarios, ranging from -9% to -24% in 2030 to -62% in 2050. However, it is worth noting that the share of emissions related to electricity production increases, so the extent of the footprint reduction is highly dependent on the share of renewable energy in the European electricity mix. The parameter has the greatest impact on green-hydrogen-based processes, particularly DR technology for which the 2022 electricity mix leads to an overall impact of 2.03 tonCO2/ton steel, while a 100% renewable or nuclear mix would lower it to 0.7.