[Clean Technology for Heavy Industry] : Converting a Steel Mill to Climate-Neutral Steel Production

Steel production causes significant emissions of carbon dioxide. To decarbonize steel production and its high CO_2 emissions, Fraunhofer researchers and partners are working on converting an existing steel mill to climate-neutral production methods. The aim is to produce steel by the direct reduction of iron ore with hydrogen, which would completely replace harmful coke as a reducing agent. The hydrogen required for this method is produced using electrolysis processes with electricity generated from renewable energy sources. Overall, this could reduce carbon dioxide emissions by up to 97 percent. The decarbonization of the steel industry would therefore contribute significantly to protecting the climate.

Steel has many useful qualities and is found in virtually all products where strength, malleability and stability are key properties. Whether in buildings, vehicles, machines or household appliances, steel is an indispensable component - but according to the Competence Centre on Climate Change Mitigation in Energy-Intensive Industries (KEI), around 55 million tons of CO_2 are emitted every year from steel production in Germany alone. The steel industry is therefore responsible for around 28 percent of the total CO_2 emissions generated by German industry. This is primarily due to the use of coke, which is required in blast furnaces to remove oxygen from the iron ore and to extract the pig iron.

Work has been underway to develop new technologies to decarbonize production for years. The Fraunhofer Institute for Ceramic Technologies and Systems IKTS, the partner institutes Fraunhofer Institute for Systems and Innovation Research ISI and Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT are focusing on hydrogen-based direct reduction. During direct reduction in a reactor, the iron ore reacts with hydrogen at a high temperature. This hydrogen acts as a reducing agent and removes the iron oxide from the iron ore. What remains is the raw pig iron. "By using electricity from renewable energy sources, the production of hydrogen is completely free of CO_2 emissions. This means that by implementing green hydrogen in crude steel production, we can save up to 97 percent of harmful carbon dioxide" [Ceramic Technologies for the Reduction of Industrial CO_2 Emissions]

Direct reduction plant on a laboratory scale for reaction kinetic investigations and shaft furnace modeling

µDRAL plant — first direct reduction plant flexibly operated with hydrogen and natural gas in an integrated mill.

Green Hydrogen from High-Temperature Electrolysis : In principle, green hydrogen is produced using electrolysis, where an electrical voltage is applied to split steam into hydrogen and oxygen. In particular, high-temperature electrolysis based on solid oxide electrolysis cells (SOEC) has had a long history at Fraunhofer IKTS. Given that the waste heat from high-temperature processes can be used to increase the electrical efficiency, this offers considerable advantages compared to other electrolysis processes — especially in steel production. Fraunhofer IKTS researchers have developed in-house electrolysis cells and stacks and used their own operating data for the techno-economic assessment of the process concept. Furthermore, the consortium has demonstrated the feasibility of the new process in both the MACOR study and BeWise follow-up project.

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Thanks and Regards,

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