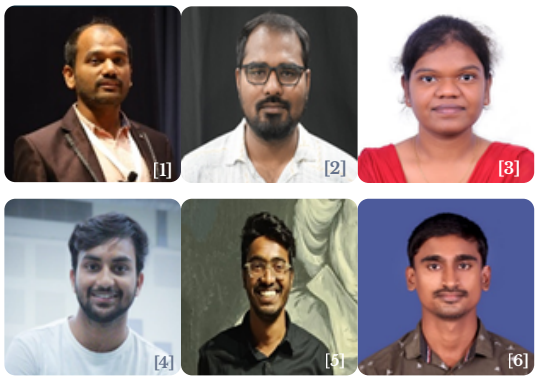
Green Steel: Building a cleaner future



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Steel is the backbone of modern infrastructure—used in everything from buildings/bridges to cars and household appliances. However, traditional steelmaking processes depend heavily on fossil fuels, making the steel industry one of the largest sources of carbon dioxide (CO_2) emissions worldwide. These emissions contribute to global warming by trapping heat in the Earth's atmosphere. Over the last 150 years, human activities—especially burning fossil fuels—have raised CO_2 levels significantly. Today, the iron and steel industry accounts for over 8% of global CO_2 emissions. At present, most of the steel is produced through the Blast Furnace-Basic Oxygen Furnace (BF-BOF) route, which uses coal and emits 2.5 to 2.7 tons of CO_2 per ton of crude steel. Each year, around 2.6 billion tons of iron ore are converted into crude steel, with 70% produced by the BF-BOF route. In contrast, the Electric Arc Furnace (EAF) and Induction Furnace (IF) routes contribute 30% of global production and are generally cleaner.

India produces about 140 million tons (MT) of crude steel per year, with plans to reach 300 MT by 2030. Currently, about 92% of India's steel is made using fossil fuels, contributing to around 11-12% of the country's total greenhouse gas emissions. India's coal-based Direct Reduced Iron (DRI) process, which supplies raw materials for the EAF/IF route, emits even more CO_2 than the BF-BOF route.

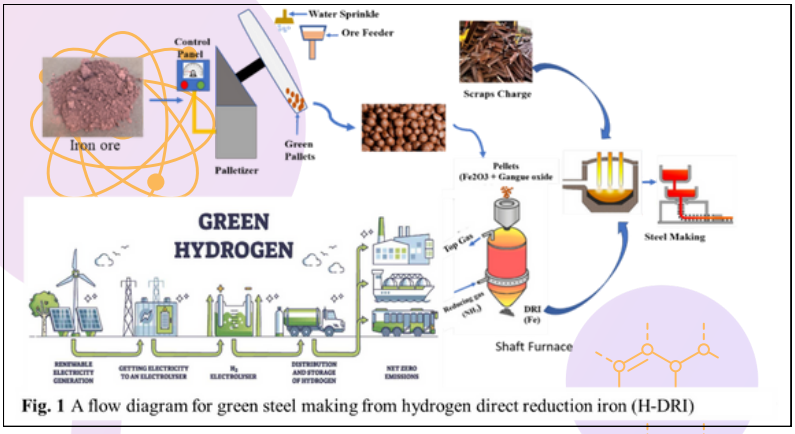

Fig. 1 A flow diagram for green steel making from hydrogen direct reduction iron (H-DRI)

To reduce emissions, the world is now focusing on green steel—steel made using cleaner energy sources like hydrogen, ammonia, biomass, and hydrogen plasma. Recycling scrap steel is another effective method, as it uses far less energy. Therefore, green steel plays a vital role in fighting climate change. As countries aim for net-zero targets, green steel will be key to a sustainable and cleaner future. At the forefront of India's transition to sustainable steelmaking, our Sustainable Metallurgy and Industrial Technologies (SMITH) Research Lab at the Department of Materials Science and Metallurgical Engineering, IIT Hyderabad, is playing a pivotal role in advancing green steel technologies.

Our research group focuses on developing technologies for the reduction of various grades of iron ore using clean reducing agents like hydrogen, ammonia, and biomass/biochar for the green steel production. Through experimental studies and kinetic investigations, we aim to understand and optimize reduction behaviour under controlled atmospheres, exploring process parameters windows for temperature, gas composition, exposure time, etc, for efficient reaction rates.

Our SMITH Lab is currently working on several organization-funded research projects toward green steelmaking, including one supported by the Ministry of Steel on iron ore reduction using ammonia and hydrogen, another in collaboration with CSIRO Australia focusing on CCUS assessment for iron and steelmaking, and a third project funded by TATA Steel on the induration behavior of high-alumina iron ore Notably, our recent study focused on the reduction of blue dust iron ore using ammonia gas at temperatures ranging from 600°C to 1100°C, with different exposure times.

The results were compared with similar reduction experiments using hydrogen and cracked ammonia (a mixture of hydrogen and nitrogen produced by decomposing ammonia). Encouraging results from the experimental campaigns allow us to establish a green steel complex at IIT Hyderabad with the following state-of-the-art national facilities,

- 10 kg vertical shaft gas-solid reactor.
- 10 kg rotary kiln gas-solid reactor.
- 10 kg induction melting unit

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