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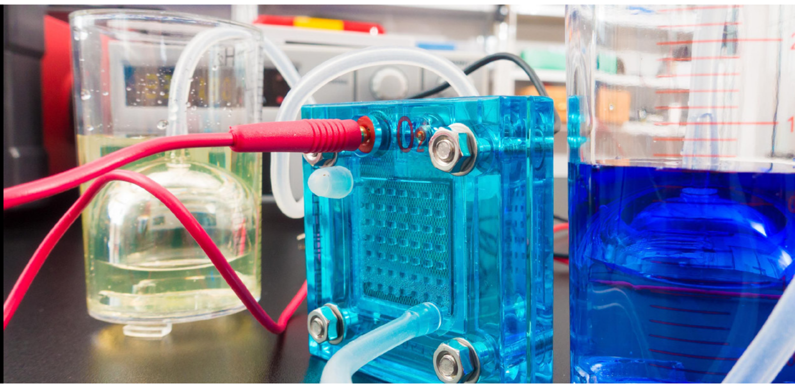


Argus White Paper:

Competing in net zero steel markets: Could green hydrogen be the silver bullet

A closer look at the potential of green hydrogen to decarbonise the hard to abate steel industry

Steel production accounts for 7pc of global carbon dioxide (CO_2) emissions at around 2.6 gigatonnes/yr and is the biggest industrial user of coal that represents 74pc of its energy input. The steel industry currently ranks among the top three contributors of CO_2. With global steel demand expected to rise to 2.5 bn t/yr by 2050, the steel industry is one of the leading candidates for decarbonisation.

Since the 2015 Paris climate change agreement, the global community has made rapid strides towards decarbonisation with over 60 countries committing to carbon neutrality by 2050. Japan and South Korea have also announced their pledges to become carbon neutral by 2050, in line with the US and EU. China, one of the largest steel producers, is pursuing carbon neutrality by 2060 with an aim to achieve peak emissions before 2030. India also promised to cut its emissions to net zero by 2070 at the UN's Cop 26.

Steel production technology landscape

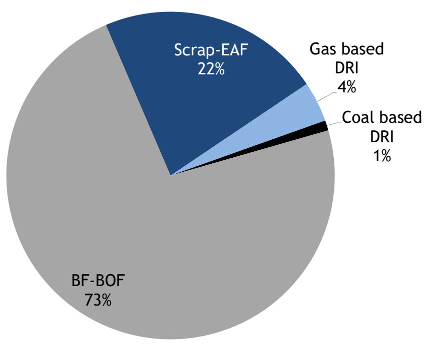
Iron and steel production traditionally consist of two major production routes. The primary route has iron ore as the main ferrous source, with reduction taking place in the blast furnace (BF) in the presence of reducing agents such as coking coal. The molten iron is then refined into steel in a basic oxygen furnace (BOF).

The secondary production route utilising electric arc furnaces (EAFs) uses steel scrap as the ferrous source and is slightly less energy intensive than the primary route. It also has lower emissions intensity in comparison with the traditional BF-BOF route.

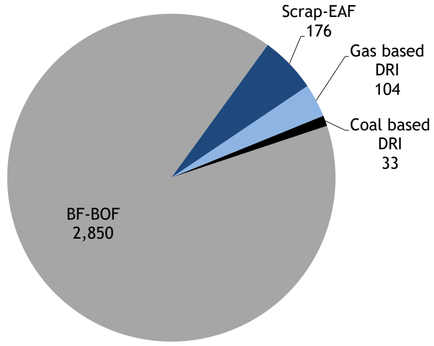
Although scrap-based steel production is a plausible pathway toward reducing CO_2 emissions, the limited availability of scrap because of availability time lag and a dependence on historical production presents a challenge to its wider application. There are other variations in the steel production process with the use of direct reduced iron (DRI) instead of 100pc scrap, with natural gas-based DRI and coal-based DRI as alternative production routes. Figure 3 gives an overview of different steel production processes and their relative reduction potential.

Figure 1: Global Production share by technology and CO_2 emissions

Global production share of crude steel 2021 %



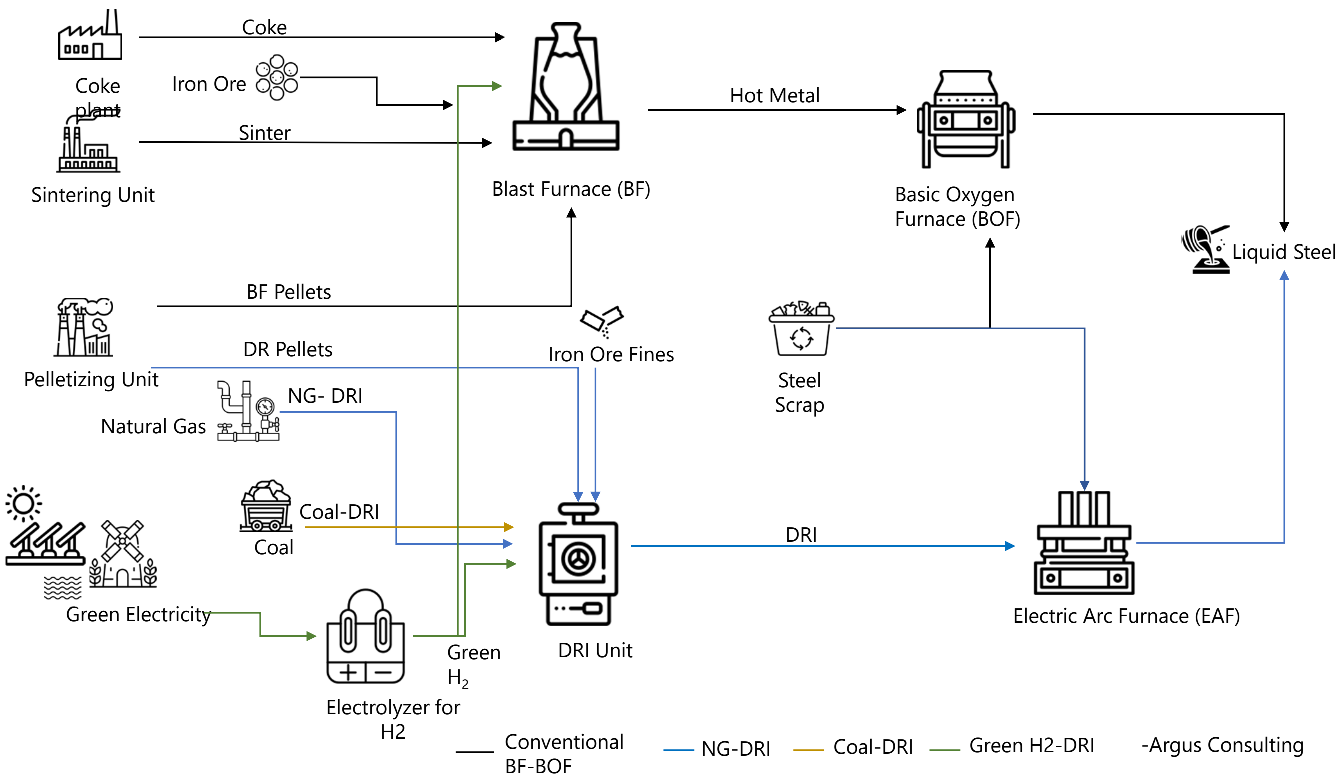
CO_2 emissions by process route in 2021 mn t



Hydrogen

illuminating the markets®

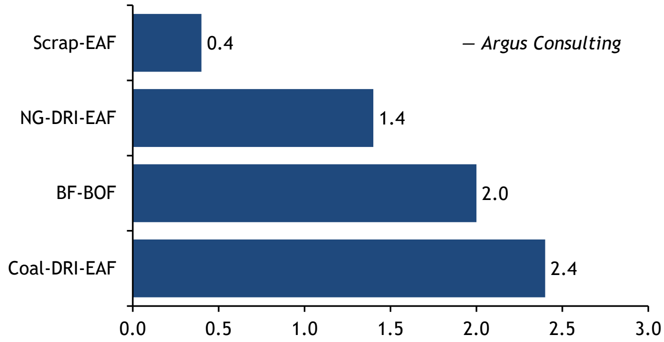
Figure 2: Major steel production pathways



How steel producers are adapting to decarbonisation options: A closer look

The BF-BOF based production technology is currently the dominant production route across the world with around 73pc of the market share. Countries are adopting measures to bring technological changes in this technology, with Japan taking early strides with its COURSE50 project. The project aims to offset 30pc CO2 in comparison with the traditional BF-BOF production route. There are other efficiency improvement programmes that use coke oven gas as an energy source in BF and increasing use of pulverised coal injection to reduce CO2 emissions.

Figure 4: Carbon emissions intensity of production routes



Natural gas-based direct reduction of iron (NG-DRI) allows for roughly 30pc reduction in direct CO2 emissions relative to coal-based BF-BOF. The production of DRI requires high-grade iron-ore pellets and confirmed supplies of affordable natural gas. It explains why most of the NG-DRI plants are situated in the Middle East, which accounts for nearly 40pc of the global total DRI plant capacity.

Scrap-based EAF steel production is a mature technology for producing steel. Most of the end-of-life scrap takes years to

Figure 3: Emissions reduction potential of steel production routes

Process	Reducing agent	Furnace type	Products	Operating temperature (°C)	CO2 reduction potential
BF-BOF	Coke, Pulverised coal	Shaft furnace	Pig iron from BF Crude steel from BOF	1,400-1,500°C (To produce molten iron)	Up to 21pc (if hydrogen used in blending)
NG-DRI-EAF	Natural gas	Shaft furnace for DRI	Sponge iron from DRI Crude steel from EAF	900-1,000°C (for DRI) 1,800°C (for crude steel)	Up to 30pc (100pc if natural gas is completely replaced by hydrogen)
Coal-DRI-EAF	Coal	Rotary kiln for DRI	Crude steel	1,000-1,100°C (for DRI) 1,800°C (for crude steel)	Up to 65pc (if coupled with CCUS)
Scrap-EAF	None	Electric arc furnace	Crude steel	1,800°C	70-80pc (Up to 100pc if the electricity used is green)

enter back into the recycling value chain, so limited availability of scrap is a cause of concern for scrap-EAF steel producers. Japan's largest steel producer by capacity Nippon Steel is working towards the development of larger EAFs capable of producing high-grade steel using scrap.

The utilisation of biomass-based reductants can partially replace coal in blast furnaces, although it cannot entirely replace coke consumption because of the multiple roles played by coke in the blast furnace. Coke serves as a reducing agent and as fuel to provide heat for melting slag and metal. The availability of biomass on a large scale for steel production is another area limiting its potential.

Figure 5: Benefits/limits of using hydrogen in steelmaking process

Benefits	Limits
Hydrogen has high density and reactivity with iron ore that is suitable for energy-intensive steel output	Preheating of hydrogen gas is required before injecting it into DRI
H_2-DRI using green hydrogen and EAF with renewable electricity has zero on-site CO_2 emissions	Additional carbon sources are required for ferrous oxide (FeO) reduction as low carbon steel is associated with high FeO slag
Hydrogen can be used to substitute 30pc of the natural gas in the existing gas-based DRI and can be adapted to use 100pc hydrogen gas with a minor retrofit	Constraints with availability of green hydrogen both in terms of required volumes, as well as at a competitive price

Green hydrogen-based steel gathers momentum

Green hydrogen is creating an opportunity for steel producers to meet their emissions targets in this hard to abate sector. Hydrogen as a reducing agent finds its use in steel production along three major pathways. One of them is the direct injection of hydrogen into existing BFs along with coke. The second method is direct reduction of solid iron ore using hydrogen in shaft furnaces or fluidised bed reactors. Natural gas is used for reduction, with the potential of replacing around 30pc of natural gas with hydrogen already tested. The third technology, which is still in an emerging phase, is hydrogen plasma reduction where iron ore melting and reduction occurs simultaneously.

Hydrogen has high density and reactivity with iron ore, which makes it suitable for use in the energy-intensive steel production process. The reduction of iron ore yields water vapour instead of CO_2, a common by-product of carbon-based reductants. There are near zero on-site CO_2 emissions in hydrogen-based H_2-DRI process, which are much lower than the 2t CO_2/t crude steel from the traditional steel producing BF-BOF process.

German steel producer Salzgitter is planning to use green hydrogen from domestic utility Uniper, converting green ammonia into green hydrogen and also through an electrolysis unit connected to an offshore wind farm for producing green hydrogen. Salzgitter plans to fully move to hydrogen and renewable energy-based DRI-EAF steel production by 2033. BP and Germany's ThyssenKrupp Steel are exploring the development of low-carbon hydrogen and renewable power supplies to accelerate the decarbonisation of steel production in Europe.

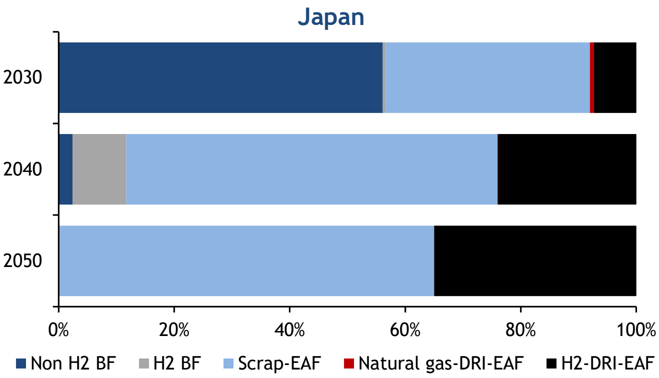
German utility RWE and European steel producerArcelorMittal have shown intentions to work together to develop, build and operate offshore wind farms and hydrogen facilities that will supply power and green hydrogen to ArcelorMittal's steel mills in Germany.

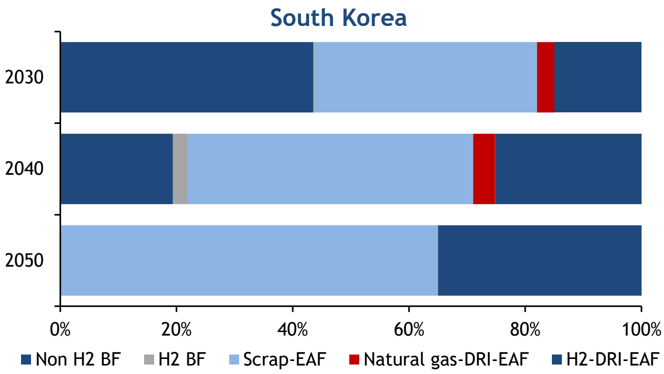
The tentative production mix of some of the prominent steel-producing countries in Asia will change in the coming years (see figure 6). Argus Consulting scenario modelling has EAF and DRI gaining prominence to create opportunities for green hydrogen. This will depend on the willingness of the steel industry to adopt reduced emissions targets in line with the country targets, cheap and abundantly available renewable electricity, phasing out of blast furnaces and availability of scrap at competitive prices.

The era of disruption awaits steel production

The steel industry is on the verge of shifting its emissions landscape and steel producers will play a key role to compete in changing market conditions. Regulatory conditions need

Figure 6: Technology mix of major steel-producing countries





to be carefully examined by manufacturers for cross-border trade of steel in the era of rising interest in green steel. The value proposition needs to be carefully understood for early adopters of green steel, both at production and end use levels. The investment decisions that steel companies make today will help them prepare for the era of disruption that awaits on the other side for steel.

Author Abhijeet Singh, Research Manager, *Argus* Consulting

Argus Consulting

Argus' consulting team is well placed to research and advise on the possibility of extending hydrogen use. Argus Consulting has done a feasibility study on hydrogen imports and downstream applications for a southeast Asian country.

Click **here** to contact us to find out more details or how this trend will affect your company.

For more information:

singapore@argusmedia.com +65 6496 9966 www.argusmedia.com @argusmedia