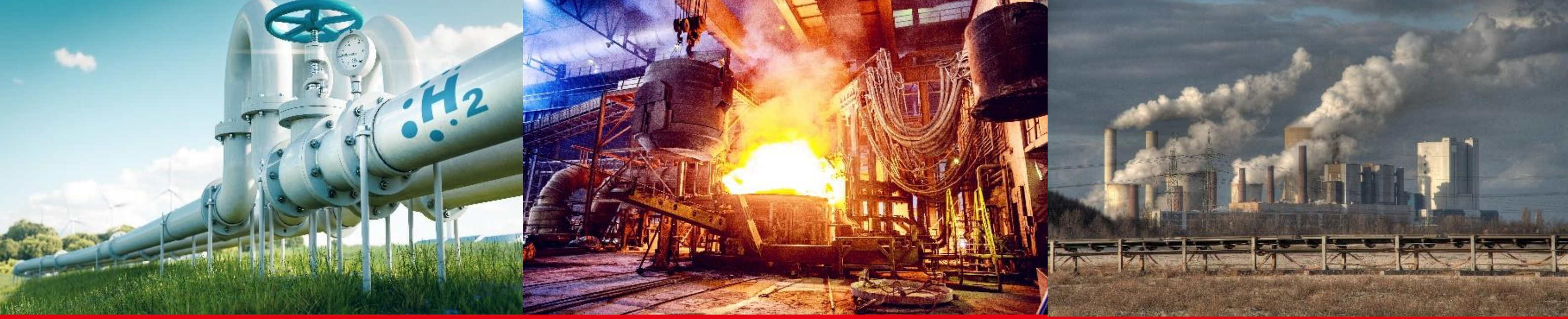

Asian Insights SparX

Steel Sector

Refer to important disclosures at the end of this report

DBS Group Research . Equity

22 Sep 2022

The road to carbon zero

- Steel is crucial to climate change as it accounts for 7.2% of global greenhouse gas emission
- Green energy, especially hydrogen, to replace coal in steel production by 2050
- Carbon tax to increase steel production cost to spur shift to zero carbon steel
- Electric Arc Furnace (EAF) based steel mills such as Hyundai Steel (BUY) to enjoy premium due to less carbon emission

Carbon neutrality, a big challenge for the steel sector. The steel sector ranks first for CO2 emissions accounting for 7.2% of global CO2 emissions in 2020. As global economies enhance carbon initiatives, the sector will face the biggest challenge since its birth. Full Implementation of EU's Carbon Border Adjustment Mechanism (CBAM) will result in charging carbon tax for imported steel in 2027.

EAF/DRI/Hydrogen to play key role for zero carbon steel. Steel production in EAF will play a key role as its carbon emission is less than a third vs. BF-BOF (Blast Furnace-Basic Oxygen Furnace) steel products. Due to limitation of steel scrap availability, the steel industry is turning towards utilising natural gas made DRI (direct reduced iron) as it reduces emission significantly at a low cost. The industry will finally move to EAF-green hydrogen-made DRI when the price of hydrogen becomes more economical.

Nucor and Hyundai Steel, less carbon emitter. Steel mill based EAF will have strong sustainability and cost competitiveness as they produce less CO2 emission. **Nucor** in the US is the lowest carbon emitting steel producer globally and **Hyundai Steel** in Korea has less carbon emission (compared to its peers). We evaluate that **Arcelor Mittal, Thyssen Krupp and Nippon Steel**'s strategy has higher possibility of realisation compared to their peers. While cumulative capital investment for decarbonisation by 2050 is estimated to be at US$1,150bn~ US$1,390bn, the production cost of near-zero emission technologies will be 10%-50% more expensive than current steel making process.

LMEX Index: 3,647

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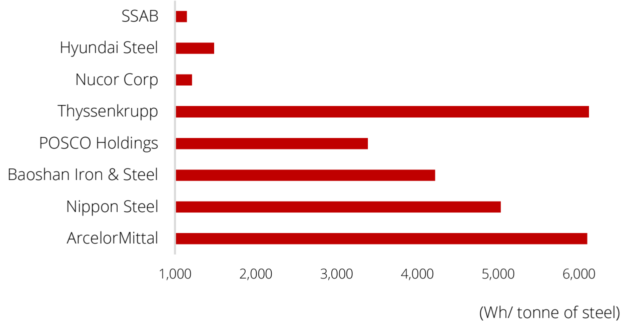
STOCKS

	Price	Mkt Cap	12-mth Target Price	Performance (%)		
	LCY	US$m	LCY	3-mth	12-mth	Rating
Angang Steel	2.24	310	2.70	(27.7)	(59.1)	SELL
Angang Steel-A	2.80	2,442	2.90	(18.6)	(50.3)	SELL
Baoshan Iron & Steel Co-A	5.38	12,567	6.50	(11.7)	(47.4)	HOLD
Hyundai Steel Company	32,600	3,079	45,000	3.4	(34.8)	BUY
Maanshan Iron & Steel	1.80	397	2.70	(39.1)	(55.3)	HOLD
Maanshan Iron & Steel-A	2.84	2,404	4.00	(25.1)	(51.6)	HOLD
POSCO	235,500	14,533	350,000	(1.9)	(34.3)	BUY

Source: DBS Bank, DBS HK, Bloomberg Finance L.P.
Closing price as of 22 Sep 2022

CO2 emission per tonne of steel in 2021 by company



Source: Bloomberg Finance L.P., WSA, DBS Bank

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Special thanks to Chloe Kyung Eun PARK for her contribution to this report

Investment summary

Why does carbon neutrality in the steel sector matter to human society? Steel is an irreplaceable material for human life as there are no cost competitive substitutes currently on the horizon. Thus, the underlying demand for steel is expected to remain robust in the future. However, steel is facing the biggest challenge since its birth, which is climate changes. Among heavy industries, the iron and steel sector ranked first when it comes to CO2 emissions, and second when it comes energy consumption. According to the WSA (World Steel Association), every tonne of steel produced led to the emission of 1.85 tonnes of CO2 into the atmosphere. The sector's direct CO2 emissions from the steel sector were 2.6G tonnes of CO2, representing 7.2% of global CO2 emissions in 2020.

Enhancing carbon neutrality initiatives, especially by the EU's CBAM. The EU is at the forefront in the carbon neutrality movement, as it introduced Emission Trading System (ETS) in 2005 which is a carbon market based on a cap-and-trade of emission allowances system for energy-intensive industries and the power generation sector. With it, the EU Council will fully implement their Carbon Border Adjustment Mechanism (CBAM) in 2027, which will cover high energy consuming sector including steel and scope emissions. This mechanism will charge the carbon tax on imported goods of high energy consuming sector, including steel. Our analysis shows that CBAM charges per tonne of EAF and BOF steel is likely to be EUR15.6/tonne and EUR60/tonne, respectively, when CBAM charges EUR25/ tonne for CO2 emission.

China's decarbonisation roadmap and US's IRA. China's low-carbon work promotion committee of the steel industry has proposed the innovation of green technology, and the development of green materials for sustaining development. It suggests a roadmap for achieving emission reduction in four phases:

i) carbon peak in 2030,
ii) deep decarbonisation from 2030 to 2040,
iii) maximum reduction from 2040 to 2050, and
iv) carbon neutral from 2050 to 2060.

The US's Inflation Reduction Act is expected to support steel decarbonisation as it is expected to reduce the US's GHG emission to c.40% by 2030 vs. 2005.

Steel products from the EAF using steel scrap, to have a key role for carbon emission. Towards the decarbonation of steel products, the steel production in EAF using 100% steel scraps will play a key role in the future. About 29% of global steel products will be produced from the electric arc furnace (EAF), which primarily uses recycled steels and direct reduced iron (DRI) or hot metal, along with electricity. According to the EU Commission, the GHG emission of a steel product from BOF process installed in 2016/2017 was 2.4 tonnes of CO2, compared to 0.63 tonnes of CO2 for steel products from the EAF, which is only 25% of GHG emissions from steel products made in BOF.

Technology roadmap towards zero carbon emission from steel sector. Due to limitation of steel scrap availability, the steel industry is turning towards utilising DRI (Direct Reduced Iron) as it reduces carbon emission significantly a low cost. The WSA and IEA expect that the industry will move from EAF-natural gas made DRI to hydrogen plasma smelting reduction (HPSR) and finally to EAF-green hydrogen made DRI when the price of hydrogen becomes more economical in the long term. This will deliver nearly-zero carbon emission and be readily available at a competitive cost.

Incremental technologies on BOF BF to partially reduce CO2 emissions in near term. However, steel plant installations have a long lifetime, with 25-year investment cycles and a 40-year average lifetime. The average age of ironmaking capacity is only c.13 years according to the WSA. Accordingly, the incremental technology to reduce carbon neutrality for the current BF-BOF based steelmaking will be introduced in the near term. This includes energy efficiency improvements, H2-BF (hydrogen blending in BF), biomass and CCUS (Carbon Capture Utilisation Storage).

Enormous capex is required to reduce carbon emission. According to the IEA, cumulative capital investment in core process equipment between 2021 and 2050 in the STEPS (Stated policies Scenario) is estimated at US$1,150bn, while in the SDS (Sustainable Development Scenario), the capex will increase by c.20% to US$1,390bn vs. STEPS. This comprises all financial costs (not just capital costs) incurred by actors both within and outside the steel sector.

Steel production cost to rise by introducing lower carbon emission technologies. The production costs of near-zero emission technologies are between 10%-50% more expensive than their commercially available process in a context with no CO2 pricing. This implies that a cost increase is expected to be higher than the current margins even if there is no price increase in the products. The speed of decarbonisation of steel will be determined by when and how much charges for CO2 emissions is implemented.

Cost competitiveness of net zero technology with hydrogen energy supply. Production cost greatly varies depending on energy prices. To achieve cost competitiveness of net zero technology, the lower energy cost from green energy sources is required. The sector expects that it is achievable with a supply of cheap hydrogen energy in the long term. Among innovative technology, smelting reduction would be one of the best options in the mid-term.

Impact to steel raw material market, scrap/iron ore/coking coal. Following the increased implementation of EAF, global steel scrap availability is likely to reach about 1bn tonnes in 2030 and 1.3 bn tonnes in 2050 from 750m tonnes in 2017, seeing more than 500m tonnes increase in the next 30 years. This growth will be mainly attributed to China, India, and ASEAN. Despite it, the obsolete steel scrap is not good enough for the market demand. Accordingly, DRI, a substitute of steel scrap in EAF, is rising as the key raw material. Currently, while India and Iran produced over half of the global DRI, the growth was mainly attributed to India from the increase in coal-based DRI, new gas-based plants in Iran. Going forward, DRI production based on low carbon emission energy such as gas and hydrogen will grow significantly, to 411m tonnes in 2050 from 108m tonnes in 2019. This will force the miner to develop resources and production technology of high-grade iron ore. While coking coal is likely to lose its dominant position as the key energy source in the steel sector, coking coal demand in 2050 will be less than a third of that in 2021.

Global major steel player's carbon strategy: DRI and EAF to be mainstream, hydrogen to be energy source. Major steel companies are considering DRI-EAF as the major technology to reduce carbon emission in the near- to mid-term. For this, they are strengthening cooperation with miners to develop iron ore for new technology. In particular, Asian major mills including BaoWu Group, Nippon Steel, and POSCO have been pursuing joint research and development, with major miners such as Vale and BHP as they have been heavily relying on their imported iron ore. Over the long term, most of the steel majors are considering hydrogen as a key energy source, replacing coking coal.

Who is producing less carbon-emitted steel products? EAF-based steel mills should have less CO2 emission. Among the key steel companies globally, Nucor is the lowest carbon-emitting steel producer globally with 0.4 tonnes of CO2/tonne of steel, as it produced all products from scrap-based EAF. The second lowest carbon emission per tonne of steel goes to SSAB, followed by Hyundai Steel. SSAB is a Nordic and US-based company focusing on high-strength steel, while Hyundai steel is the second largest steel company in Korea, producing c. half of its product from scrap-based EAF.

Regarding carbon strategy and possibility of realisation in near future, we evaluate that Arcelor Mittal, Thyssen Krupp and Nippon Steel's strategy is advanced compared to their peers.

EAF based steel mills to enjoy premium, BUY Hyundai Steel (BUY, TP KRW45,000). We recommend Hyundai steel as the key beneficiary for carbon neutrality among our coverage given that i) c 40% of its products is produced from EAF, ii) it has more advantage to transit to carbon neutral steel making process on the back of its long period technology and experience, iii) aggressive investment of KRW1tn for next 10 years to reduce GHG emission. Hyundai Steel introduced a sealed steel material processing system for the first time among all integrated steel mills in the world when it constructed its steel complex in 2006. This involves the entire process from unloading iron ore, bituminous coal, and limestone to moving, storing, and pouring into a furnace without external exposure, which proved its high standard for environment friendly management.

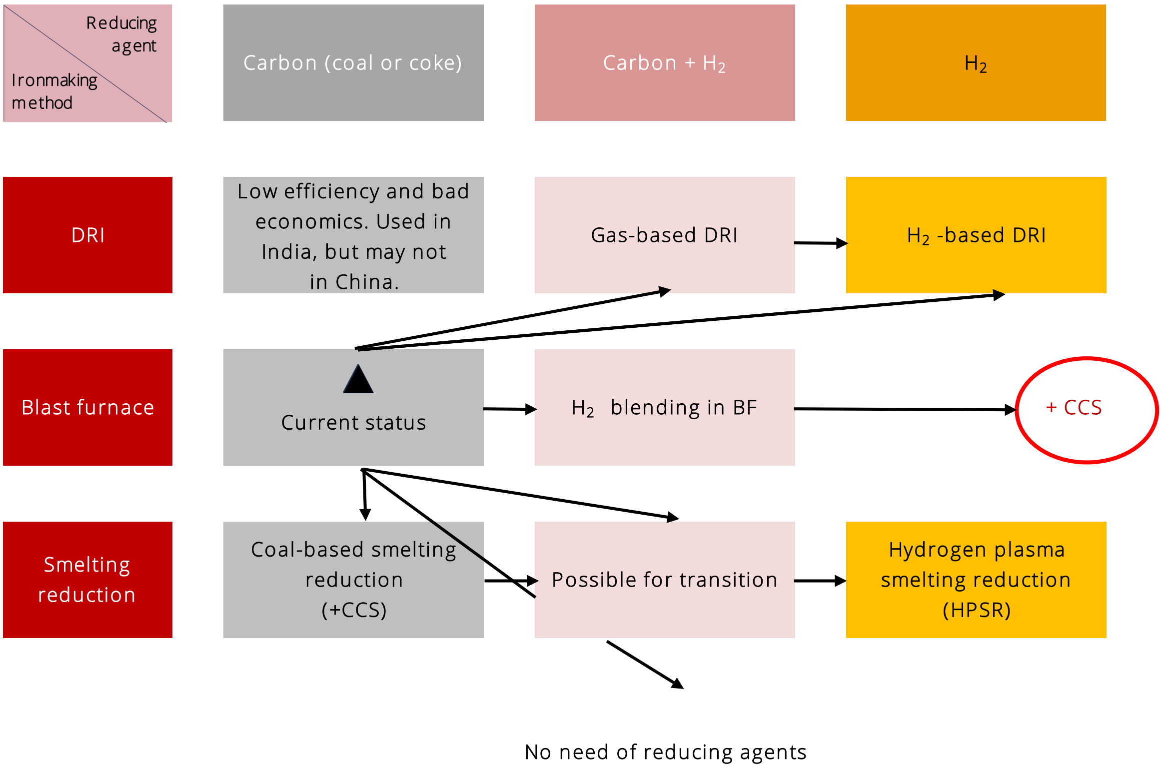
Steel peer comparison

	Market Cap (US$m)	PER			PBR			EV/EBITDA			ROE		
		FY22F	FY23F	FY24F	FY22F	FY23F	FY24F	FY22F	FY23F	FY24F	FY22F	FY23F	FY24F
Korea listed players													
POSCO	14,533	4.7	4.9	4.9	0.4	0.4	0.4	3.0	3.1	3.2	9.7	8.6	7.9
HYUNDAI STEEL CO	3,255	3.8	4.2	6.7	0.3	0.3	0.3	4.4	4.6	5.6	7.4	6.4	3.9
SEAH BESTEEL CORP	480	3.6	3.5	N/A	0.3	0.3	N/A	3.3	3.4	N/A	9.1	8.7	N/A
HK-listed players													
ANGANG STEEL CO LTD-H	3,531	3.6	4.0	4.0	0.5	0.5	0.4	2.9	3.1	3.0	15.2	12.3	11.6
MAANSHAN IRON & STEEL-H	2,819	2.7	3.1	3.1	0.6	0.6	0.5	3.8	4.3	4.2	25.6	18.1	15.2
China A-share listed players													
BAOSHAN IRON & STEEL CO-A	17,039	5.8	6.0	5.9	0.8	0.8	0.7	4.0	4.0	3.9	13.8	12.5	11.9
HESTEEL CO LTD-A	3,586	8.5	8.8	8.4	0.5	0.5	0.5	7.8	9.3	N/A	5.4	5.2	6.4
ANGANG STEEL CO LTD-A	3,531	4.1	4.6	4.2	0.6	0.6	0.5	2.9	3.1	3.0	15.7	13.1	12.0
MAANSHAN IRON & STEEL-A	2,819	4.4	4.7	4.6	1.0	0.9	0.8	3.9	4.3	4.2	23.6	18.2	16.3
Asian listed players													
CHINA STEEL CORP	14,343	9.8	10.4	12.7	1.6	1.5	1.5	6.7	6.8	7.9	18.4	17.2	12.6
TATA STEEL LTD	16,205	3.8	6.1	6.4	1.3	1.1	0.9	3.4	4.7	4.9	38.3	18.9	15.3
STEEL AUTHORITY OF INDIA	4,182	2.9	4.7	4.4	0.7	0.6	0.6	2.8	4.1	4.0	24.9	12.7	11.7
JSW STEEL LTD	20,886	6.7	8.2	7.5	2.3	1.8	1.5	5.2	5.8	5.4	36.5	24.5	22.2
JINDAL STEEL & POWER LTD	5,613	4.7	6.2	5.8	1.1	0.9	0.8	3.2	4.0	3.9	24.5	15.7	14.4
JFE HOLDINGS INC	6,290	3.7	5.7	5.9	0.5	0.5	0.5	5.1	6.4	6.3	15.3	8.7	8.4
NIPPON STEEL CORP	14,897	3.7	5.9	6.0	0.6	0.6	0.5	4.2	5.7	5.5	18.1	9.6	9.2
KOBE STEEL LTD	1,783	4.3	5.4	4.5	0.3	0.3	0.3	5.6	5.9	5.3	7.0	5.0	5.7
International listed players													
STEEL DYNAMICS INC	13,851	4.9	10.4	11.5	1.4	1.2	1.2	3.8	6.9	7.7	31.6	12.7	9.3
ARCELORMITTAL-NY REGISTERED	18,908	3.2	5.5	5.3	0.5	0.5	0.4	2.4	3.7	4.0	16.6	8.4	8.1
UNITED STATES STEEL CORP	4,823	2.6	8.5	13.3	0.6	0.5	0.5	1.8	3.7	4.0	24.0	6.7	1.4
THYSSENKRUPP AG	3,400	4.8	6.3	7.0	0.5	0.4	0.4	1.1	1.3	1.4	9.9	6.5	5.7
NUCOR CORP	29,718	6.6	17.4	18.9	1.9	1.7	1.6	4.8	9.7	10.2	28.9	10.1	7.8
SEVERSTAL PJSC	9,976	5.5	7.2	7.0	4.2	4.0	3.2	4.0	4.9	4.6	65.5	52.1	58.9
Steel pipe players													
SEAH BESTEEL CORP	480	3.6	3.5	N/A	0.3	0.3	N/A	3.3	3.4	N/A	9.1	8.7	N/A
NIPPON STEEL CORP	14,897	3.7	5.9	6.0	0.6	0.6	0.5	4.2	5.7	5.5	18.1	9.6	9.2
WELSPUN CORP LTD	895	7.2	6.8	5.5	0.9	0.8	N/A	3.5	3.1	2.5	12.8	11.8	15.0
TENARIS SA-ADR	15,866	10.2	11.3	11.3	1.2	1.2	0.9	7.0	6.9	7.1	9.4	9.6	8.9
VALLOUREC SA	2,182	N/A	14.8	11.4	1.1	1.0	0.9	5.7	4.9	4.5	1.1	7.1	9.0

As of 20 Sep 2022

Source: Bloomberg Finance L.P., DBS Bank

BF-BOF decarbonisation transitional routes



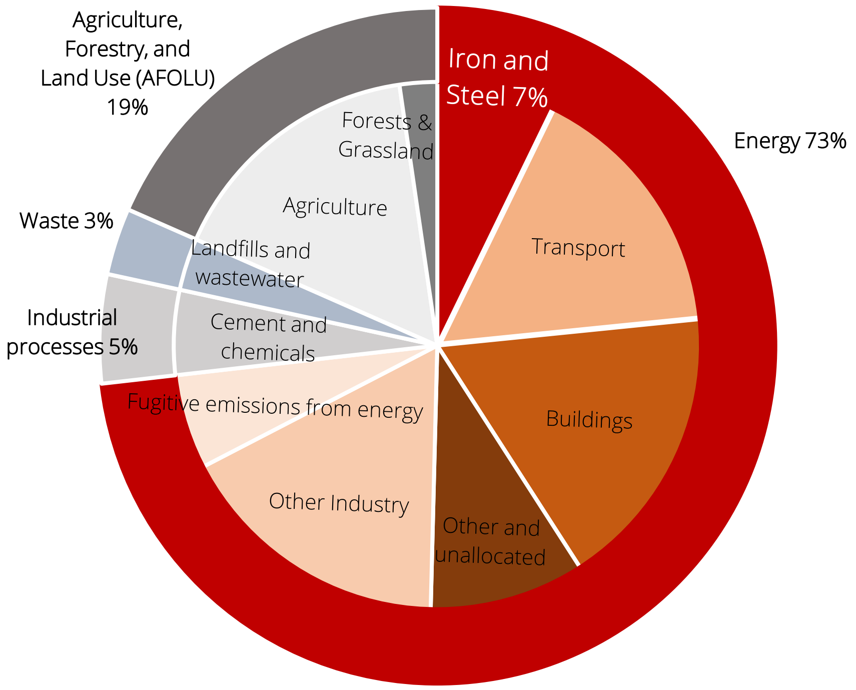
Source: RMI, DBS Bank

1. Why does carbon neutrality in the steel sector matter to human society?

Steel – an irreplaceable material facing the challenge of carbon neutrality. Steel is indispensable to our modern way of life and critical to economic growth. The intrinsic benefits of steel make it a sustainable choice in a growing number of applications. As there are no cost competitive substitutes currently on the horizon, the underlying demand for steel is expected to remain robust in the future. Accordingly, steel and steel-making materials will remain the world's biggest commodities in terms of volume of production, consumption, and transportation. However, steel is now facing the biggest challenge since its birth – climate change.

Steel sector's carbon emission contributes above 7% of global emissions. Among heavy industries, the iron and steel sector ranked first when it comes to CO2 emissions, and second when it comes to energy consumption. According to WSA (World Steel Association), every tonne of steel produced led to the emission of 1.851 tonnes of CO2 into the atmosphere in 2019. In 2020, 1,860m tonnes of steel were produced, and total direct emissions from the steel sector were of the order of 2.6 Gt CO2 tonnes, representing 7.2% of global CO2 emissions. Of note, the energy use in the industries accounts for 24.2% to total GHG (greenhouse gas) emission followed by agriculture, forestry, and land use (18.4%), energy use in transport (16.2%) and energy use in buildings (17.5%) in 2020, according to the World Resource Institute. Of note, IEA's CO2 emission accounting methodology results in a direct emission intensity of 1.4 tonnes of CO2/tonnes of steel, and a direct + indirect emission intensity of 2.0 tonnes of CO2/tonnes of steel in 2019, on average. In 2018, the net energy consumption reached c. 800m tonnes of oil equivalent and coal accounted for c 87.5% of the net energy .consumption

Global greenhouse gas (CO2) emissions



Source: Our World In Data, World Resource Institute, DBS Bank

The vast majority of the steel sector's direct emissions are CO2, as opposed to other greenhouse gases, so decarbonisation in the context of this strategy refers to CO2mitigation in the steel sector boundary unless otherwise stated. This excludes emissions associated with electricity generation, which account for a further ~1.1 Gt CO2

Heavy usage of coking coal a key reason for high CO2 emission. The reason for high CO2 emission in the steel sector is mainly due to its high usage of coal in the steelmaking process. As iron occurs only as iron oxides in the earth's crust, the ores must be converted or reduced using carbon. The primary source of this carbon is coking coal. Coke – made by carburising coking coal – is the primary reducing agent of iron ore. Coke reduces iron ore to molten iron saturated with carbon, called hot metal. C.71% of global steel is produced in the blast furnace (BF) and basic oxygen furnace (BOF), which uses raw materials including iron ore, coal, limestone, and recycled steel. On average, this route uses 1.37 tonnes of iron ore, 0.78 tonnes of metallurgical coal, 0.27 kg of limestone, and 0.125 tonne of steel scrap to produce 1 tonne of steel.

Steel products from EAF using steel scrap, to have much lesser carbon emission. The other 29% of global steel products is produced from the electric arc furnace (EAF), which uses primarily recycled steels and direct reduced iron (DRI) – or hot metal – and electricity. On average, the recycled steel-EAF route uses 710 kg of recycled steel, 586 kg of iron ore, 150 kg of coal, 88 kg of limestone, and 2.3 GJ of electricity to produce 1,000 kg of steel. According to the EU Commission, the GHG emission of a steel product from BOF process installed in 2016/2017 was 2.4 tonnes of CO2 compared to 0.63 tonnes of CO2 for steel products from EAF, which is only 25% of GHG emissions from steel products made in BOF.

Infeasible full transition to EAF in the near term. The contribution of EAF to the total steel production is higher in the developing countries such as Europe and the US than other regions because those regions have more steel scrap resources in line with longer history for steel usage. In the developing countries, India has a higher production in the EAF than in BOF due to the abundant availability of DRI (Direct reduced Iron), a substitute of steel scrap. The proportion of EAF in China is only 10.6%, which accounts for over 50% of global steel production.

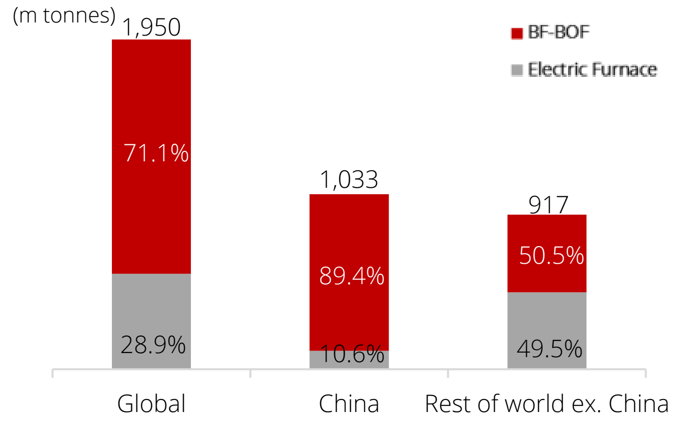
Carbon neutrality of steel, crucial but challengeable. Steel plant installations have a long lifetime, with 25-year investment cycles and 40-year average lifetime and the current average age of ironmaking capacity is only c.13 years according to WSA. Because steel making facilities based on BF in China are still young as the most steel plants were built since 2000. This means a full transition to the EAF is not feasible in near future. While a reduction in carbon emission in the steel sector is very critical as tackling climate changes is top priority for the earth's survival and steel will remain the most useful and cost competitive material for the convenient lifestyle of human society. To meet global energy and climate goals, emissions from the steel industry must fall by at least 50% by 2050, according to IEA.

GHG emission intensity

(Tonne of CO2/tonne of product produced)	Weighted average emission of all installation in 2016/2017	Benchmark for 2021-2025
Steel product from EAF	0.63	0.50
Steel product from BOF	2.40	1.94
By production process		
EAF carbon steel	0.26	0.22
EAF high alloy Steel	0.32	0.27
Iron casting	0.37	0.28
Coke	0.28	0.22
Sintering	0.25	0.16
Hot metal	1.50	1.29

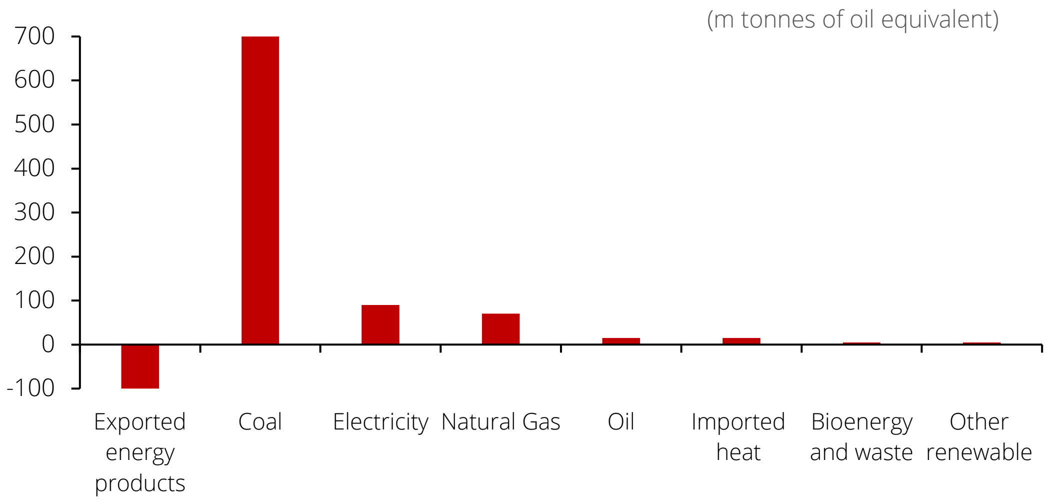
Source: European commission, DBS Bank

Steel production by process in 2021



Source: WSA, DBS Bank

Total energy consumption in 2018



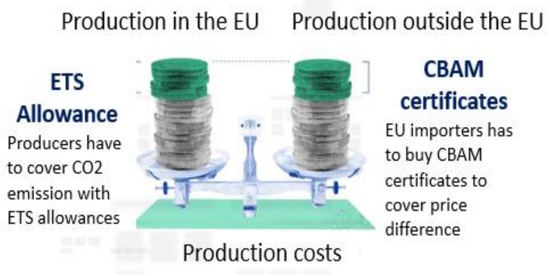
Source: IEA, WSA, DBS Bank
Note: “Exported energy products” refers to energy products that are produced but not used directly in the iron and steel sector (including coke ovens and blast furnaces). “Net energy consumption” is the sum of the gross energy inputs to the sector.

2. Carbon neutrality initiatives for steel sector

The EU – frontrunner in carbon neutrality – to charge carbon tax for steel products in 2027

European Green Deal: Fit for 55. As part of the European Green Deal, with the European Climate Law, the EU has set itself a binding target of achieving climate neutrality by 2050. This requires current greenhouse gas emission levels to drop substantially in the next few decades. As an intermediate step towards climate neutrality, the EU has raised its 2030 climate ambition, committing to cutting emissions by at least 55% by 2030 vs. the 1990s level.

How will CBAM work



Source: European Council, DBS Bank

The EU Emission Trading System (ETS) free allowances phase-out starts from 2027. The EU ETS is a carbon market based on a cap-and-trade of the emission allowances system for energy-intensive industries and the power generation sector. The Council agreed to keep the overall ambition of reducing 63% of CO2 emissions by 2030 vs.2005 levels. This will boost the linear reduction factor* to rise to 4.4%/4.5%/4.6% in 2024/2026/2029, from 2.2% at present, respectively. In addition, the carbon credits** will be reduced by 70m tonne of CO2 emission in 2024 and 50m tonnes of CO2 emission in 2026. Furthermore, free allowances will be phased out from 2027 and will end by the beginning of 2032. The reduction will follow the progressive curve pattern, i.e., free allowances will be reduced to 93% in 2027, 84% in 2028, 69% in 2029, 50% in 2030, 25% in 2031, and 0% in 2032.
**: the rate at which the cap on the number of allowances declines each year*
***: permit that allow the owner to emit CO2 gases. One credit permits one tonne of CO2 emission*

The EU Carbon Border Adjustment Mechanism (CBAM) designated for full implementation from 2027. On 15 March 2022, the EU reached an agreement on the Carbon Border Adjustment Mechanism (CBAM) regulation. Under the regulation, EU importers have to buy CBAM certificates for the production outside the EU to cover the price difference. On June 2022, European Council endorsed the proposal to end free allowances from 1 Jan 2027 progressively, until 2032. The required transition period will start in 2023, spanning until the end of 2026. While there is no need for companies to buy and submit CBAM certification, there are obliged to report the CO2 emission intensities. From the commission, the CBAM will mirror the phase-out of free allocations under the EU ETS to EU industries to provide for WTO compatibility.

CBAM to include scope 2 emission. The products of the sectors covered by CBAM extended from cement, aluminium, fertilisers, electricity energy production, iron and steel to plastic, hydrogen, ammonia, and basic organic chemicals. Furthermore, CBMA calculations will include scope 2 emissions (i.e. indirect emissions derived from the electricity used by manufacturers).

Meanwhile, the previous analysis of the EU CBAM burden assumed that the production emission intensities are oriented towards average EU emission intensities. However, in the current version of the EU CBAM, default emission intensities are calculated from actual average emissions intensities of a respective country's products plus an ominous markup that will be determined in a yet to be specified procedure. Or, alternatively, default emission is calculated from the worst 10% of similar EU producers.

Export adjustment mechanism is likely to be implemented. The EU is considering launching an export adjustment mechanism to EU manufacturers who are exporting to non-EU countries without carbon pricing mechanisms. By 31 December 2025, the European Commission will present a report with a detailed assessment of the effects of the EU ETS and CBAM on the EU's exporting manufacturers.

Analysis on CBAM charges on steel sector
Based on our analysis, CBAM charges per tonne of EAF steel is likely to be EUR15.6/tonne, EUR37.5/tonne and EUR50/tonne given that EU charges EUR25/60/80/tonne for a tonne of CO2 emission, respectively. We forecast CBAM charges per tonne of BOF steel to be EUR60/tonne, EUR144/tonne and EUR192/tonne given that EU charges EUR25/60/80/tonne for a tonne of CO2 emission, respectively. We expect CBAM's charges per tonne of BOF steel to be at quadruple that of EAF steel.

Scenario Analysis: CBAM Charges per tonne of steel

			CBAM Charges	
		(EUR25/ton of CO2)	(EUR60/ton of CO2)	(EUR80/ton of CO2)
		25	60	80
EAF steel	Carbon emission per ton of steel (tonnes of CO2e)	0.50	0.50	0.50
	CBAM Charges per tonne of steel (EUR)	15.6	37.5	50.0
BOF steel	Carbon emission per ton of steel (tonnes of CO2e)	1.94	1.94	1.94
	CBAM Charges per tonne of steel (EUR)	60	144	192

Carbon emission intensity

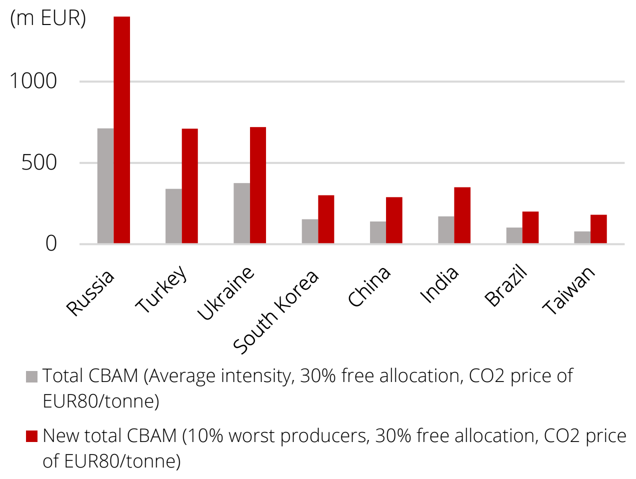
(tonne of CO2e/tonne of product produced)

	Weighted average emission of all installation in 2016/2017	Benchmark for 2021-2025
EAF carbon steel	0.26	0.22
EAF high alloy Steel	0.32	0.27
Iron casting	0.37	0.28
Coke	0.28	0.22
Sintering	0.25	0.16
Hot metal	1.50	1.29

Source: "Update of benchmark values for the years 2021-2025 of phase 4 of the EU ETS", European Commission, DBS Bank

CBAM could lead to higher burden for steel importers, especially from Russia, Turkey, and Ukraine. The following tables and charts give updated estimates for the range of the burdens to be expected for the most affected countries. The calculations from the 2021 SWP study "A CO2 border adjustment for the EU Green Deal" by Susanne Dröge serve as a benchmark for the previously expected burden based on average EU emission intensities, while the red column of a column pair indicates the adjustments according to the new 10% worst emitters benchmark in EU CBAM. Calculations are based on EU's average 2019/2020 trading volumes. For each importing country, the tariff is calculated by multiplying carbon emission after free allowance for imported volume with the difference between in house CO2 charges and EU CBAM. We expect CBAM tariffs and surcharges to double across these countries under the new mechanism.

Estimated EU CBAM tariffs and surcharges for imported steel products by countries



EU CBAM tariffs and surcharges for imported steel products: % to total imported amount

Source: Zimmer's "EU CBAM: Well intended is not necessarily well done" (2021), DBS Bank

EU's top 10 import countries for steel products and potential CBAM charges

	Import quantities (m tonnes)	CO2 content of imported quantities (m tonnes)	Average import for 2019/2020 (m EUR)	Total CBAM charges (m EUR) *			% Proportion of CBAM surcharges to steel import**
				EUR25/tonne of CO2	EUR60/tonne of CO2	EUR80/tonne of CO2	
Russia	9.9	12.8	3,886	154.9	379.3	507.6	9.8 %
Turkey	4.7	6.1	2,590	74.0	181.2	242.4	7.0 %
Ukraine	5.2	6.8	2,418	81.1	200.1	268.0	8.3 %
South	2.7	3.5	2,136	13.9	74.6	109.3	3.5 %
China	1.9	2.5	1,722	30.5	74.7	100.0	4.3 %
India	2.4	3.1	1,623	37.3	91.4	122.2	5.6 %
Brazil	1.4	1.8	1,148	22.2	54.3	72.6	4.7 %
Taiwan	1.1	1.4	869	17.0	41.7	55.8	4.8 %

**Premised 50% free allowance*

*** Premised EUR60/tonne of CO2*

Source: Susanne Dröge's "A CO2 border adjustment for the EU Green Deal" (2021), DBS Bank

China's policy for carbon neutrality of steel sector

About the energy transition. About a month ago, China's Low-Carbon Work Promotion Committee of the steel industry brought forward a proposal to insist the innovation of green technology and the development of green materials for sustaining development. In the latest industry roadmap, it emphasises the importance of energy efficiency, resource utilisation, smelting process, and product upgrade, achieving emission reduction in four phases: i) Carbon peak in 2030, ii) deep decarbonisation from 2030 to 2040, iii) maximum reduction from 2040 to 2050, and iv) carbon neutral from 2050 to 2060.

Policy supportive of short-process development. In the same month, the Ministry of Industry and Information Technology, the National Development and Reform Commission, and the Ministry of Ecology and Environment's Implementation Plan for 'Carbon Peak in the Industrial Field' highlighted the priority development of advanced short process steel electric furnaces to account for 15% of the national capacity by 2025 and 20% by 2030. Although, compared to the previous guidelines, the timeline of reaching 20% has been postponed from 2025, it has reaffirmed the development of EAF to be on the agenda.

Scrap-based electric arc furnace is an option. In 2021, the State Council mentioned in the Carbon Peak Action Plan (2030) that the steel industry carbon peak pathway must optimise the steel industry capacity and energy structure, as well as develop scrap-based electric arc furnace, reflecting the electric arc furnace to be an important tool for the decarbonisation in China.

Green energy scrap based EAF the better choice. Since then, the overall industry policy became more supportive of replacing steelmaking capacity towards the short-process method along with the electricity price reform in terms of electricity tariff. Contrary to the power restriction for blast furnace, electricity arc furnace can produce at off-peak hours, being more flexible. In Oct-21, the reform of market-oriented coal-power generation electricity prices widened the up/down limit of the electricity transaction price, charging > 20% for energy intensive industrial users at peak hours. Lastly, electric arc furnaces can choose renewable energy sources supplied from grid companies.

The US – Speed up with Inflation Reduction Act

The US's Inflation Reduction Act to support steel decarbonisation. On 16 Aug, Biden signed the Inflation Reduction Act (IRA) into law to increase the potential of curbing the country's greenhouse gas emissions (GHG) significantly over the next few years. US$369bn is earmarked for clean energy and climate change mitigation initiatives. It is expected that the Act will reduce US GHG emissions to approximately 40%, compared to 2005-levels, by 2030 vs. 26% reduction without IRA. The IRA's credits – aimed at driving down the cost of clean hydrogen, carbon capture, and electricity – will help the US steel industry produce green steel and continue its decarbonisation efforts.

IRA likely to make the US one of the cheapest regions in the world for clean hydrogen production. Under the new section 45V, hydrogen producers will be entitled to receive a credit of up to US$3/kg of clean hydrogen by the government. According to Platts estimates, this could drive the effective cost of producing green hydrogen to US$0.7-US$3.5/kg of H2 for ~~its~~ unsubsidised production.

Clean electricity incentives to support production via EAF. The IRA created a US$5.8bn programme, running until Sep 2026, to invest in project in industries, either energy-intensive or which produce hard to abate emissions such as steel. The act, through several clean energy credits, will further drive down the cost of clean electricity and make it more widely available. By driving down the cost of electricity, it may further increase the production of green steel via EAF route.

The IRA makes key changes to 45Q, an existing tax credit for CCUS. Under the IRA's revised 45Q, the credit amount per tonne of CO2 permanently stored increased to US$85 from US$50 for carbon captured and to US$50 from US$35 for carbon used. While it is unclear whether the IRA's modifications to 45Q will be enough to make retrofitting steel production facilities with CCUS equipment economical in all cases, nevertheless, the IRA has provided US steel producers with another potentially attractive approach for decarbonising steel.

3. Technology roadmap towards a zero-carbon steel sector

Towards the decarbonation of steel products, steel production in EAF using 100% steel scrap will play a key role in the future. However, secondary steel production has encountered challenges for industrial-scale production due to limited steel scrap availability. Instead, the steel industry is turning towards utilising DRI (Direct Reduced Iron) as it reduces carbon emission significantly a lower cost than other carbon reduction technologies. The WSA and IEA both state that the industry will move from EAF-natural gas made DRI to hydrogen plasma smelting reduction (HPSR) and finally to EAF-green hydrogen made DRI when the price of hydrogen becomes more economical. This will deliver nearly-zero carbon emission and be readily available at a competitive cost

Incremental technologies on primary steel production to partially reduce CO2 emissions.

As the average age of ironmaking capacity is only c.13 years according to the WSA, primary steelmaking will still be a big share of overall steel making. There are several incremental technologies that could reduce carbon emissions of BF-BOF steel making. This includes energy efficiency improvements, H2-BF (hydrogen blending in BFs), biomass, and CCUS.

Energy efficiency improvements

China's steel industry has worked on energy efficiency improvements for more than 15 years and has made great progress developing and implementing advanced energy-saving technologies. However, the mitigation potential of the energy efficient improvement is becoming insignificant (10-20% mitigation of CO2 emission) with the cost of emission reduction becoming elevated.

Energy efficiency technology in use

Process	Technology	Details
Sintering	Microwave sintering Sintering gas recycling	Reduce carbon intensity per tonne of steel by 10%
Coking	Gas recycling from ascension pipes in coke ovens Cove oven gas reuse	Recycle the CO and H2 as products or for methanol production
Blast furnace	Increasing pellet share High-coal-low-coke ratio iron making BF equalising gas recovery	The energy intensity of pelleting process can be 50% lower than sintering process Save coke consumption
Casting and rolling	Heat-free rolling	ESP (Endless Strip Production) technology, MIDA technology, etc, which could reduce the casting process energy consumption by 50%
Digitalisation	Smart process digitalisation	Increase over all energy efficiency by 10%-15%

Source: RMI, DBS Bank

Blast furnace efficiency (BOF)

The most feasible option in the near term. It can improve efficiency and reduce CO2 emission in BF/BOF operations via 1) optimised BOF with higher inputs of DRI and scrap and 2) increased fuel injection of hydrogen rich blast furnace (H2-BF) or PCI. While H2 injection in BFs cannot be zero carbon process, however, it has a potential to mitigate carbon emission by 10-20%. Despite its limitations on hydrogen blending ratio, it can be applied to any BFs with less renovation cost. Therefore, this technology it is more economical to other technologies using hydrogen. Baowu is testing the hydrogen-rich BF project in Xinjiang, China, which aims to reduce carbon emissions by over 30%, together with carbon recycling and other techniques. This process is also piloted by COURSE50 and ThyssenKrupp.

Biomass

A promising short-term option is to replace fossil fuel, especially charcoal. Partially injecting renewable biomass products into BF and utilising thermally treated biomass in place of fossil fuels as a heating source, which is likely to reduce 30% of CO2 emissions. Charcoal is currently used commercially to substitute for a proportion of the coal in iron making process, primarily in Brazil. For instance, Brazil currently produces about 10m tonnes of pig iron using charcoal. However, the undesired physio-chemical properties and higher costs of biomass remain as major obstacles for its commercial implementation. Moreover, it is difficult for some countries, including China and the EU, to build in the industrial scale due to lack of biomass availability.

Further R&D on other types of biomass. In Belgium, the ArcelorMittal plant in Gent is testing the use of bio-coal (torrefied waste wood) to substitute coal partially. In the early stages, the facility will be able to convert 60k tonnes of waste wood into around 40k tonnes of biocoal p.a. capa. Reactors 1 and 2 are expected to be operational by the end of 2022 and 2024, respectively. In addition, Rio Tinto has developed a process over the past few decades that combines lignocellulosic biomass with microwave technology to convert iron ore to metallic iron during the steelmaking process. The process is in the R&D process in a small-scale pilot plant in Germany. Nippon Steel is also considering incorporating biomass like eucalyptus and sugarcane to process Vale's iron ore and produce moulded pig irons.

Carbon capture and usage

Technological and economic hurdles to limit its potential. Installing carbon capture, usage, and storage technologies (CCUS) in integrated steelworks would require less change of existing facilities as it would allow existing BFs to keep running. New CCS-based technologies have been developed, some being able to achieve emission reduction of up to 63% through carbon oxide conversion. However, the process sees a limited potential in BFs as the carbon capture at the coking or iron ore sintering stage has been less explored in research. Moreover, there are considerable technological knowledge gaps and economic limitation of integrated CCUS projects in the iron and steel sector.

New CCUS projects are under construction, and R&D. ArcelorMittal's STEELANOL project, partnered with LanzaTech, is under construction in Ghent, Belgium. Once complete, the plant is expected to produce 80m litres of sustainable ethanol p.a. by 2022. In addition, the company's "3D" project on amine-based carbon capture for BFs at its Dunkirk Site commenced operations on Mar 22 with 4.4k tonnes of CO2 p.a. The project aims to reach the industrial scale of 1m tonnes of CO2 p.a. by 2025. Furthermore, Carbon2Chem was CCUS technology developed by Thyssenkrupp and the UMSCICHT Fraunhofer Institute. At the earliest, industrial use for plant retrofitting in the BF route will be possible in 2025. The project is still being piloted and the industrial version of the process is in the R&D stage, with construction expected to be commenced by 2025.

Few commercial facilities for steel CCS projects. While there are now 65 commercial CCS facilities to reduce carbon emissions globally, there are only two commercial facilities for steel CCS projects – an ultra-low CO2 steelmaking blast furnace project in France and a steel CCS facility called Abu Dhabi Cluster in the UAE. There are four facilities under advanced development (ie. North Dakota Carbonsafe, Net Zero Teesside, Zero Carbon Humber, and Athos). There are an additional four facilities under early development (Dartagnan, CarbonConnect Delta, Aramis, and Louisiana Hub) for the iron and steel sector.

Many CCUS demonstration projects but unclear outlook for expansion in China. Full-chain CCUS-related demonstration projects have yet to be carried out in the Chinese steel industry. In China, 17 CCUS demonstration projects have verified CCUS system integration technology, gained operational experience, and promoted rapid technological advancement. Meanwhile, Hebei Iron and Steel Group announced its plan to build CCS demonstration projects at its steel plant by 2030. However, CO2 capture technologies in the steel industry mainly comprise post-combustion capture and oxygen-enriched ironmaking technologies, which are both in R&D stages. The experts expect there will be limitations for CCUS to spread out in China.

Smelting Reduction

It is a group of upcoming ironmaking processes which aim at overcoming certain fundamental problems of the existing blast furnace route. Smelting reductions – such as HIsarna or HIsmelt technology – may cut the iron sintering and coal coking process to have coal directly react with liquid iron. It could reduce coal consumption for steelmaking, thus producing less CO2 than conventional blast furnaces. Currently, China's Jianlong Steel and the Baowu Group are running this route. However, the route still requires further technological improvements.

Innovative SR BOF CCUS

It is the combination of smelting reduction and CCUS. The method is used since smelting reduction is more compatible with carbon capture, increasing the CCS capture ratio to 80%. Tata Steel's HIsarna plant is expected to produce steel with CCUS. It is not implemented yet, however, a 0.5m tonnes p.a. demonstration plant (TRL8) is expected to commercialise by 2027 in India and a 1.5m tonnes p.a. industrial-scale plant with CCUS (TRL 9) is targeted for the Netherlands between 2027-2033. In addition, Primetals is currently conducting the initial testing of amine-based CO2 scrubbing in FINEX plant.

Hydrogen plasma smelting reduction (HPSR)

Hydrogen plasma smelting reduction (HPSR) is a direct transformation from iron oxides into liquid steel with ionized H2 (hydrogen plasma). The plasma generated by passing an electric current through a gas, which acts as a reducing agent and generates the required energy to melt metallic iron. While the method is still under development, it will be deployed in the Susteel project of Voestalpine and Jianlong steel in China. For instance, Jianlong Steel's hydrogen-based smelting project (0.3m tonnes p.a. capa) succeeded in inner Mongolia, China in April 2021. The technology has an advantage with no specific location requirement for steel production, but the TRL of this technology (TRL1-3) is still lower than H2-DRI (TRL6-8). As a result, the technology requires CCUS for full decarbonisation.

Technology roadmap for decarbonisation of steel sector

CO2 reduction → Full decarbonisation

	Blast furnace efficiency (BOF)	Biomass reductants	Carbon capture and usage (CCUS)	Electric arc furnace (EAF)	DRI plus EAF using natural gas	Hydrogen plasma smelting reduction (HPSR)	DRI plus EAF using H2
TRL*	6-8	1-3	6-8	6-8	6-8	1-3	1-3
Strategy	Make efficiency improvements and reduce CO2 emission in BF/BOF operations	Use biomass as an alternative reductant or fuel	Capture fossil fuels and emissions and create new products	Maximise secondary flows and recycling by melting more scrap in EAF	Increase usage of DRI in the EAF	Use electric current as a reducing agent to produce ionised H2 (hydrogen plasma)	Replace fossil fuels in DRI process with renewable energy or H2
Actions	Optimised BOF with higher inputs of DRI and scrap. Increased fuel injection of hydrogen rich blast furnace (H2-BF)/PCI	Charcoal, Torrefied waste wood, Lignocellulosic biomass, Eucalyptus, and sugarcane	Bioethanol production from CO2 emissions	EAF-usage to melt scrap	Current DRI plus EAF plants using natural gas (NG)	Utilising H2-SRI (Hydrogen-based smelting reduced iron) plus EAF plants	MIDREX DRI process running on H2 HYL DRI process running on H2
Current outlook	Technology readily available at competitive cost	Lack of biomass supply except in South America and Russia. Technical limitations and high costs of biomass.	Not available on an industrial scale due to technological and economic problems.	Technology readily available at competitive cost.	Technology readily available	In the R&D process. Due to its low TRL (1-3), it requires CCUS for full decarbonisation.	Technology available at high cost

DRI = Direct Reduced Iron, EAF = Electric Arc Furnace, TRL= Technology Readiness Level

**: It is a method for estimating the maturity of technologies during the acquisition phase of a program. It is based on a scale from 1 to 9 with 9 being the most mature technology.*

Source: McKinsey & Company, RMI, DBS Bank

Key resource usage for technologies

(Per tonne of steel)	BF-BOF (current best available)	100% DRI-fed EAF+DRI plant fuelled by natural gas	100% DRI fed EAF+DRI plant fuelled by "blue" hydrogen	100% DRI fed EAF+DRI plant fuelled by "green" hydrogen
GHG Intensity (tonnes of CO2 emission)	1.64	0.55 (-67%)	0.11 (-93%)	0.05 (-97%)
Iron ore (tonnes)	1.55	1.66	1.67	1.66
Coal (tonnes)	0.54	0.02	0.02	0.02
Natural gas (m3 at stp)	0	301	316	0*
Electricity (MWh)	0	0.68**	0.77	4.06

**Full electrification assumption, although today's common practice is to use some natural gas in EAFs in order to reduce electricity use*

***Assumption that furnaces use cold HBF, which need preheating: 0.60 for EAFs and 0.08 for DRI*

Source: European commissions (BF-BOF GHG intensity, H2 Future's "Report on exploitation of the result for the steel industry in EU28" (BF-BOF resource use), CE Delft (blue hydrogen), Sandbag (hydrogen production), Danieli, Tenova, Tenova/Danieli (DRI and EAF best available technologies)

The table above outlines key resource usage for technologies. According to European Commissions, BF-BOF emits 1.64 tonnes of CO2 per tonne of steel. For 100% DRI made by natural gas/blue hydrogen/green hydrogen with EAF, three methods can reduce GHG emission intensity by 67% and 93% and 97% compared to BF-BOF, producing 0.55/0.11/0.05 tonnes of CO2/tonnes of steel with significant lower usage of coal.

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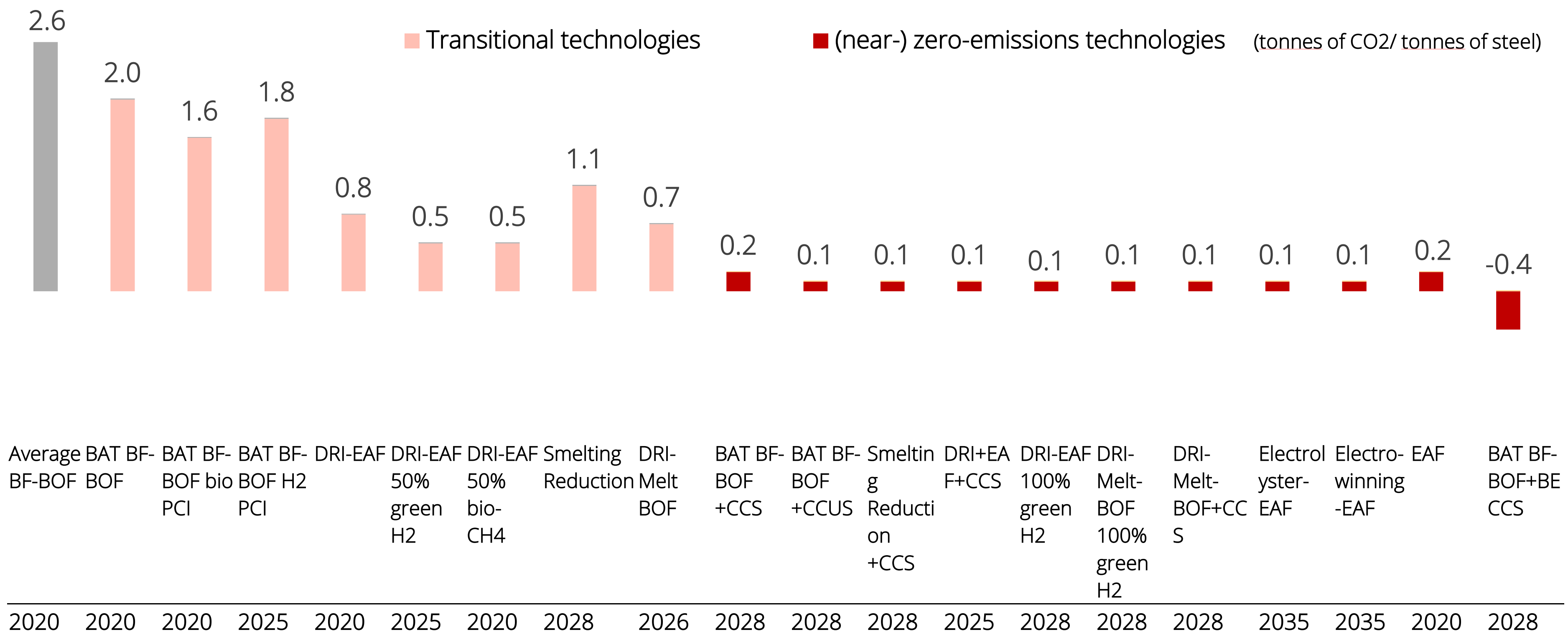
Emission intensities in 2050 and expected commercial availability by routes



**The year above indicates the expected commercial availability by routes.*

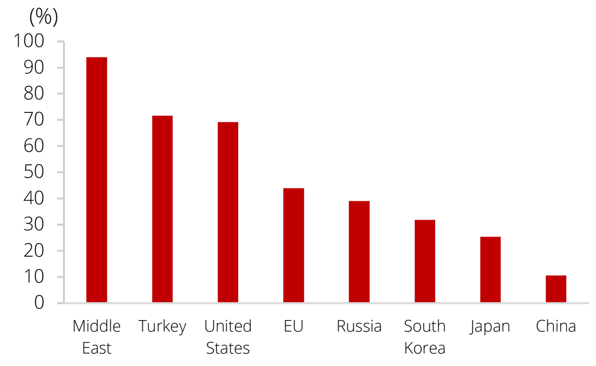
Source: MPP, DBS Bank. Note: BAT: Best available technology. BECCUS: Bio-Energy CCUS

The table above outlines the emission intensities in 2050 and expected commercial availability by each steelmaking routes.
While currently commercially available technologies such as BF-BOF and DRI-EAF and EAF are likely to produce 2.6, 0.5 and 0.2 tonnes of CO2/ tonne of steel, respectively, in 2050, future technologies such as smelting reduction with CCUS and Green H2-DRI-EAF are expected to be commercially available by 2028 with emission intensity of 0.1 tonnes of CO2/tonnes of steel in 2050.

Secondary Steel Production: EAF with steel scrap

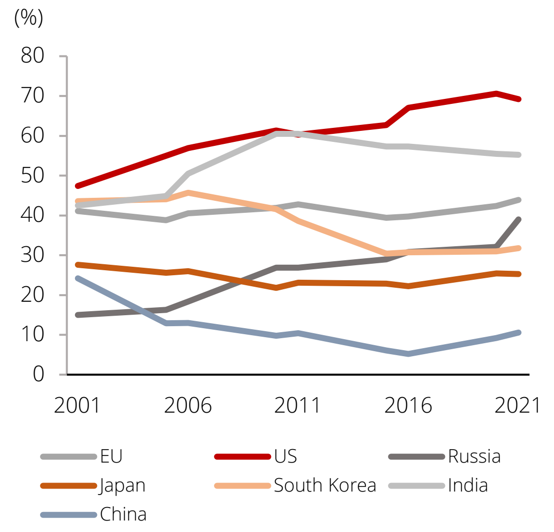
Electric Arc Furnace (EAF) with steel scrap is the most feasible decarbonisation strategy in the near term. The EAF route, accounting for 29% of global production, uses electricity to melt scrap steel. Therefore, steel scrap as a main source of the EAF will play an increasingly important role in decarbonising the sector. Emissions are highly dependent on the carbon intensity of the electricity supply with an average of 0.6 tonnes of CO2 emissions tonnes of steel. The benefits of the EAF route are: 1) It has a lower reliance on diminishing quality iron ore sources (i.e., predominantly scrap-based), 2) it has a current global recycling rate of 80-90%, and 3) it uses only 1/8th of the energy compared to conventional integrated mills.

Proportion of EAF steelmaking by countries in 2021



Source: WSA, DBS Bank

Proportion of EAF steelmaking from 2001-2021



Source: WSA, DBS Bank

Limited scrap supply to prevent the growth in the proportion of EAF. There are obvious bottlenecks to continuously increase the proportion of EAF steelmaking in major steel-producing countries. While the US and India have a higher proportion of EAF (more than 50%), the rest of the major countries fall into the range of 20%–40% (except China). For example, the proportion of EAF steelmaking in Russia, South Korea, and Japan is 39%, 31.8%, and 25.3%, respectively. Due to the large export of scrap, the tight supply of electricity, and the relatively mature primary steelmaking, Japanese steelmakers lack the motivation to develop EAF steelmaking.

New capacity and plants under construction. On Aug 2022, India's Tata steel announced that the company signed an agreement with Punjab’s government to set its first 0.75m tonnes p.a. capa EAF facility and plans to bring similar plants in west and south India. This EAF facility will be supported by the company's 500k tonnes p.a. capa steel recycling plant at Rohtak, which was commissioned last year. In addition, POSCO will begin construction of two new EAFs in Pohang and Gwangyang from 2023 and has planned to launch them by 2025 and 2027, respectively. The combined steel capacity will be 2.5m tonnes p.a.

EAF with Direct Reduced Iron (DRI)

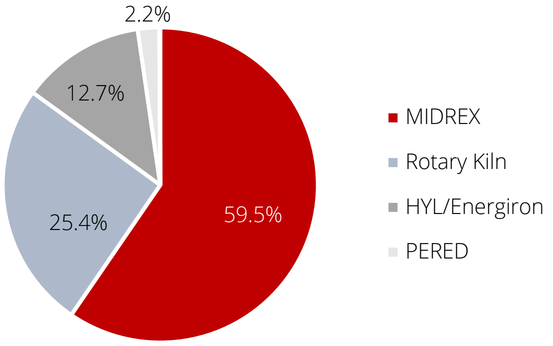
DRI, an alternative of steel scrap. DRI is necessary to guarantee specific qualities if the scrap availability is limited. Gas-based production process will remain as the go-to option among manufacturers – especially in North America and the Middle East – due to lower natural gas prices.

EAF with natural gas made DRI. Steelmakers plan to switch to DRI-EAF with DRI’s own production capacity that they will rely on natural gas until they are able to secure a sufficient green hydrogen supply. This approach could be readily introduced and is estimated to decrease CO2 emissions by 35% vs. the BF-BOF route. The operating gas mixture could be gradually enriched with hydrogen, but its share is limited by hydrogen availability, costs, and process requirements.

Full decarbonisation way of ironmaking by H2-DRI process. Hydrogen-based DRI directly reduces solid iron ore with the hydrogen-based reducing reaction by releasing water. As a result, it offers a fully decarbonised way of ironmaking with a TRL of 6-8. In addition, the process uses cheap renewables to produce hydrogen and has the potential to greatly reduce future costs. This route relies on iron ore pellets for key ingredient. As pelleting plants are currently not available in most integrated plants and the method requires higher quality of iron ore, it may face some challenges for its application.
Although H2-DRI may face challenges of costs and replacing existing assets, it is a very promising technology for steel decarbonisation and is piloted by global steelmakers, including China.

New capacity and plants under construction. In Europe, Thyssenkrupp expects the construction of its 1.2m tonnes p.a. capa H2-DRI plant to be completed by 2025 and produce 400k tonnes of green steel. The company is targeting to produce 3m tonnes of green steel by 2030. In China, Sinosteel, a subsidiary of Baowu Group, contracted Tenova for the design and supply of a hydrogen-based 1m tonne p.a. capa ENERGIRON plant, which will be installed at Baosteel's plant in Guangdong. The plant is likely to be in commission by early 2024, which will become the second H2-DRI plant in China, followed by HBIS' 0.6m tonnes p.a. capa ENERGIRON plant completed in 2020 (powered by hydrogen-enriched gas with 70% hydrogen concentration). According to SP global, China is likely to have at least 8.2m tonnes p.a. of low-or zero-carbon DRI capacity coming on stream with Baosteel and HBIS.

Global DRI production by process in 2021



Source: Midrex Technologies, Inc, DBS Bank
Note: Rotary kiln: convert iron ore directly into metallic iron without the melting of the materials and requirement of coking coal.
Other technologies use reduction gases from natural gas or coke oven gas as the reduction agents of iron ore.

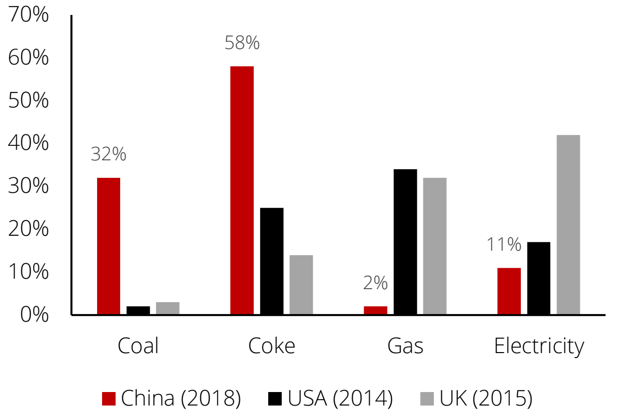
EAF with "green" hydrogen made DRI. Green hydrogen DRI is often depicted as the ultimate GHG emission reduction solution, able to drive steelmaking close to carbon neutrality. Each tonne of steel would require 3,500-3,800kWh of electricity consumption in total. Ansteel has begun its construction of China's first green H2-DRI plant. The 10k tonnes p.a. pilot plant is likely to be commissioned in 2023 and scale up to 500k tonnes. In Europe, ArcelorMittal is building a green H2 DRI-EAF facility in Hamburg, Germany. The plant will become operational before the end of 2025, initially producing an annual volume of 100k tonnes of DRI. In Jul 2021, the company also invested US$1.2bn in building a 2.3m tonne p.a. capa green hydrogen direct reduced iron (DRI) unit, complemented by a 1.1m tonne p.a. hybrid electric arc furnace (EAF) at its Spanish plant in Gijón. The new DRI unit and EAF are estimated to be operational before the end of 2025. In Feb 22, the company announced a US$1.9bn investment in constructing a 2.5m tonne p.a. DRI furnace, two electric furnaces at ArcelorMittal Dunkirk, and a scrap-based electric furnace at ArcelorMittal Fos-sur-Mer. The new installations are expected to be operational in 2027.

4. China/India to play key role in zero carbon steel

China's policy implementation on the steel sector for carbon neutrality

Coal is the dominant fuel for steelmaking. China's coal and coke consumption accounts for a much higher proportion of energy use in steelmaking compared to developed countries such as EU and the US (which uses natural gas). For the same calorific value, coal combustion produces more than twice of CO2 emission compared to other energy sources. China has abundant coal resources, making coal the dominant fuel for steelmaking. And thus, decarbonisation of the Chinese steel industry is a greater challenge.

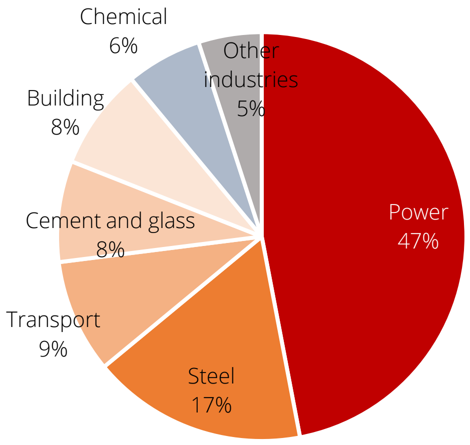
Comparison of steelmaking energy consumption by fuel type in China, the US, and the UK



Source: China Metallurgical Planning and Research Institute, China Statistic Book, Global Efficiency Intelligence (2017), Statista, Bloomberg Finance L.P., DBS HK

Steel – China second contributor of CO_2. China is the world's largest producer of steel. Even with the impact of the global pandemic in 2020, China's steel production reached a new high, producing more than 1 bn tonnes of steel and accounting for 56.4% of the world's total. China's steel sector emitted more than 1.5bn tonnes of CO2 in 2017. This accounted for 17% of the national total, making it the second largest emitter after the power sector. Reducing emissions in the steel industry is crucial to achieving China's goal of carbon neutrality.

China's carbon emissions by sectors in 2019



Source: Internet, DBS HK

Improved energy efficiency in steel production. China's steel industry has the experience and ability to promote innovation along with the scale-up and industrialisation of new technologies. China's steel industry has gone from purchasing foreign second-hand metallurgical equipment to manufacturing, integrating, and reinventing the equipment. China's steel smelting equipment manufacturing ability and technology reached an advanced level on a global scale with an independent supply rate of 95%. These advances have improved production efficiency and energy efficiency as well. Since 2000, China's comprehensive energy consumption per tonne of steel has dropped by nearly 40%, and the energy consumption level and waste emissions level of many processes have reached the international advanced level.

New technology developing for decarbonisation. Facing the new carbon-neutrality target, Chinese steel companies have started planning on new technologies. Baowu, HBIS, Jiuquan Iron and Steel, Jianlong Steel, and other companies have begun to cooperate with domestic and foreign technology partners in areas such as hydrogen steelmaking and smelting reduction. China's steel industry can make full use of its strong innovation capability to play a key role in the rapid industrialisation and scale-up of new technologies and contribute to the decarbonisation of both China and the global steel industry.

SOE mills to play a key role for carbon neutrality by consolidation. In 2020, the top 10 steelmakers in China accounted for 39% of output. There is still a gap between the industry concentration and the 60% target proposed by the Ministry of Industry and Information Technology. However, the development trend and policy direction show that future production capacity will be concentrated in the head enterprises, and the mergers and acquisitions toward SOEs will be stronger. In general, SOEs have a stronger and more stable implementation of national policies and a leading role for the whole industry. For example, after China announced its carbon-neutrality target, SOEs such as Baowu Group, HBIS Group, and Ansteel Group announced their carbon-peaking and carbon-neutrality plans as well.

China top 10 steel companies' production and state-owned enterprise (SOE) ratio in 2020

	Corporate	Production (m tonnes)	Type
1	Baowu Steel	115.29	Central SOE
2	HBIS	43.76	Regional SOE
3	Shagang	41.59	Private
4	Angang	38.19	Central SOE
5	Jianlong	36.47	Private
6	Shougang	34	Regional SOE
7	Shangang	31.11	Regional SOE
8	Delong	28.26	Private
9	Valin	26.78	Private
10	Fangda	19.6	Private
	Total	415.05	
	State-owned enterprise (SOE) total	262.35	
	State-owned enterprise (SOE) ratio	63%	

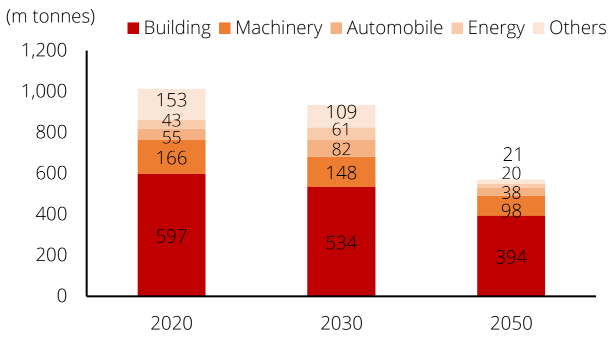
Source: World Steel Association, DBS HK

Carbon neutrality's impact to China steel demand

China's steel demand to contract. China's steel consumption has reached more than 700kg per person, higher than the peak level in Europe and the US. Its infrastructure construction is gradually slowing down amid the maturing industrialisation and urbanisation. The domestic consumption is expected to peak in the short term and then continuously decline. By 2030, when China peaks its carbon emission, the overall domestic demand for steel will drop by 9.2% to 934m tonnes vs. 1,014m tonnes in 2020. By 2050, under the zero-carbon scenario, the total demand for steel will drop 38.9% to 571m tonnes vs. 2030.

Changing consumption pattern. (1) Building (-ve): Nearly 60% of China's steel consumption came from the building industry in 2020. But the sector's share is set to gradually decrease in the medium run due to the application of non-steel materials due to their new enhanced law and the benefit of extended lifespan. (2) Machinery (-ve): Intelligent manufacturing and high-performance equipment will increase demand for premium and special steel. (3) Automobiles(+ve): Improved technology, lightweight steel production, and material innovations like carbon fibre as substitutes. (4) Energy (+ve): Electrification to drive expansion of power grids and high voltage direct current transmission amid the new infrastructure development. Also, increase of generation capacity and efficiency per unit of wind turbines and solar panels to be supportive for steel demand.

Demand of major steel-consumption sectors and their CAGRs in China (2020, 2030, and 2050)



Source: Various, RMI, DBS HK

Carbon neutrality's Impact to China steel production

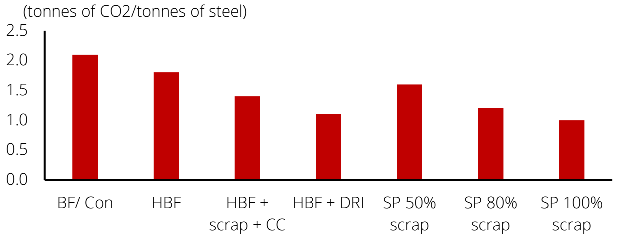
China's steel production to decline. In the medium to long term, China's steel production will continue to decline, with total production dropping to 621m tonnes by 2050 in the zero-carbon scenario, about 58% of the 2020 level. This is consistent with the IEA's projection in its Sustainable Development Scenario (SDS) in Energy Technology Perspectives. Under the more ambitious scenario, total production of steel will be further reduced to 475m tonnes by 2050, if net steel export remains at the current level. The results are lower than most projections conducted by domestic experts. It provides a glimpse of the reduction potential of China's steel production to achieve zero carbon by 2050.

Steel industrial structure adjustment required. Under this trend, downstream industries are incorporating volume reduction and resource utilisation, leading to an extended lifespan of products. In addition, the need to develop a circular economy will force the steel industry to adjust its industrial structure, improve the utilisation rate of scrap steel and output of EAF steel, and reduce the need for primary steel, which requires raw materials – including iron ore and coke.

EAF and steel scrap in China – the first step of steelmaking toward carbon neutrality

China's steel production predominantly by BF-BOF: Higher carbon emission intensity than EAF. The BF-BOF route accounts for 90% of China's steel production, while EAF-based secondary steelmaking accounts for only 10%. In contrast, the global average share of the BF-BOF route is 73%, and only about 30% in the US, far lower than China. The comprehensive energy consumption per tonne of steel is about 550 kg of coal equivalent (kgce), emitting about two tonnes of CO_2. EAF-based steelmaking – with electricity as its main energy source – consumes about 500 kWh of electricity and emits about 0.6 tonnes of CO2/tonnes of steel (calculated based on average grid carbon intensity).

China: CO2 per tonne of steel by different processes



Source: Various
Keynote: BF: blast furnace, Con: convertor, CC: carbon cycling, HBF: hydrogen-based BF, DRI: direct reduced iron, SP: short process

The increasing supply of scrap and development of secondary steel in China. In 2020, China's measurable scrap supply was c 270m tonnes. The supply of scrap resources in China is far from reaching a level that can support a high proportion of EAF steelmaking. Early used steel products gradually reach the end of their useful life, releasing more available scrap resources, which enables the accelerating development of secondary steelmaking with scrap as raw material. If China's scrap steel supply can increase and preferential policies of capacity replacement, electricity price, environmental production, and land use are in place, scrap based EAF steelmaking in China can grow swiftly.

Scrap-based EAF steelmaking: Expectable solution. According to the China metallurgical Industry Planning and Research Institute, the estimated total scrap supply in China will reach 350m tonnes in 2025 and 420m tonnes in 2030. By 2050, the steel industry is expected to supply 500m tonnes of scrap, which is sufficient to support EAF steelmaking – which accounts for up to 60% of the total steel production of 621m tonnes. We believe scrap based EAF to be an expectable solution for China carbon reduction.

Anecdotal evidence of EAF and the next 5-10 years

A low start from the ground check. China has an electric arc furnace capacity of 10.7% of national total capacity in 2021. Among the listed companies we have covered, Maanshan Iron has the most advanced progress for operating two electric furnaces of total 2.2m tonnes p.a. (c.10% of total capacity) and two electric furnace in construction scheduled to operate in 2023 and 2024 (estimated to reach 26%) accordingly, leading its major listing peer Baoshan Iron's 2m tonnes p.a. electric furnace (2% of total capacity) and 800k tonne hydrogen-based furnace scheduled to commence 2024 (estimated to reach 5%).

Robust room for electric arc furnace expansion. At present, about 6% of China's steel capacity has met the national standard in energy conservation and emission reduction. According to industry estimate, about 87% of China's steel capacity belongs to blast-furnace production process by year-end. Since long process generates about 1.8-2.2 tonnes CO_2, three times higher than scrap based EAF process at about 0.5-0.9 tonnes of CO2/tonnes of steel. Certain downstream industries (such as automobile) are forcing steel suppliers to develop green products. Ministries, commissions and local governments have pursed electric furnace development.

Scarp supply bottleneck expected to ease. According to SCI data, total scrap supply in China was 270m tonnes in 2021, mostly used for steelmaking from converters. Assuming a 3% steel net capacity reduction towards 2025 and all from blast furnace, it will bring China's total capacity to 800m tonnes by 2030. Based on the target of 20% for EAF's contribution and assumption of 700kg scrap usage per tonne of steel, it is estimated the short process would require about 110m tonnes of scrap. That would be satisfied by an expected local scrap supply for reaching 380m tonnes (up 110m tonnes) by 2030, before adding scrap import supply.

Challenges in EAF. The advantage of blast furnace method in China is maturely developed and operated at good economic of scale, assets life expectancy could last for two more decades. Comparatively, there is concern that product quality is inferior in making silicon steel, high-end auto sheet and home appliance sheet through the EAF method. Further, although almost 90% of the equipment of the electric arc furnace has been localised, the development of energy efficiency, i.e., higher 300kWh per tonne of steel produced, is constraining the adoption of EAF process in China.

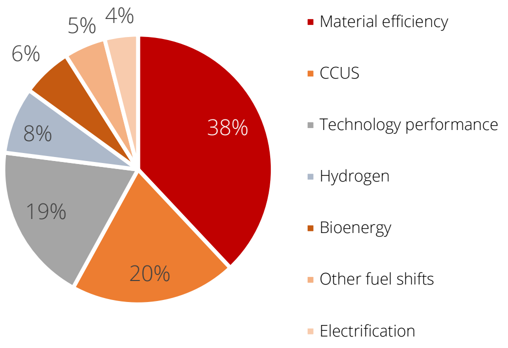
India

India's heavy reliance on coal based DRI production. India is currently the second-largest steel-producing country in the world – producing 118.2 tonnes in 2021 with the electric furnace production, accounting for 55.2% of its output. At the same time, it is the largest DRI producer in the world, producing 39.1m tonnes in 2021. Due to its low investment costs, scarcity, and high cost of quality steel scrap, many plants in India operate with low quality coal based DRI. Such iron is mainly used for producing induction furnace steel, accounting for approx. half shares of its total electric furnace output. Thus, the industry is more energy-and emission-intensive than many other countries, due to the i) presence of many small production facilities, ii) the heavy reliance on coal for DRI furnaces, and iii) the low proportion of scrap in total metallic input (India's 23% compared to the global average of 32%).

India's steel strategy by 2050: Increase in steel production vs lower GHG emission. As many BFs in India are only 10 years old, India's production from conventional ironmaking processes is expected to peak around 2040. Under IEA's Stated Policies Scenario (STEPS), India's steel production is likely to continue to grow to 190m tonnes in 2030 and 350m tonnes in 2050 from 111m tonnes in 2019. The limited availability of scrap in conjunction with rising levels of output mean that India builds large amounts of primary steelmaking capacity. Under India's decarbonisation strategies, the CO2 emission intensity of the steel production is likely to fall over 60% to 0.9 tonnes of CO2/tonnes of steel in 2050 from 2.3 tonnes CO2/tonnes of steel.

Technology pathways towards zero emissions in India. India is likely to see a diversified portfolio of decarbonised routes by early 2030: 1) material efficiency and existing technology performance improvement 2) good access to low-cost renewable energy resources (particularly solar PV and wind) and an openness to development of CCUS. For instance, Tata Steel has commissioned India's first CCU facility (five tonnes/day) in Sep 2021 at its Jamshedpur Works with the use of amine-based technology, making the captured carbon available for on-site use. H2-DRI route and the integration of CCUS in various production pathways will account for substantial shares of emission reductions by 2050. India is projected to have access large supply of cheaper renewable electricity in the future, making the 100% H2 DRI-EAF route an attractive decarbonisation option for new-build plants once it is commercially available in the early-mid 2030s.

Cumulative direct emission reduction between 2020-2050



Source: IEA, DBS Bank

5. Steel production cost and capex with carbon neutrality

Enormous capex required to reduce carbon emission

STEPS (Stated Policies Scenario) and SDS (Sustainable Development Scenario) towards zero carbon steel. WSA launched the "step-up" programme in 2020 to accelerate the industry's progress in operational and environmental performance, which aims for the industry to adopt operational best practices and efficiency improvements where possible. A voluntary programme, it uses lean techniques to incrementally improve on the four parameters that most influence the CO2 emissions of commercially available primary steelmaking processes: 1) raw material quality, 2) process yield, 3) energy intensity, and 4) process reliability. In line with this programme, STEPS (Stated Policies Scenario) was constructed by projecting forward its current trajectory, shaped by existing and announced policies. In STEPS, the direct CO2 emissions must fall by more than 50% by 2050 relative to today. While IEA set a more ambitious pathway to net-zero emissions for the energy system by 2070, SDS (Sustainable Development Scenario) requires a 58% reduction in the direct emission intensity of steel by 2050.

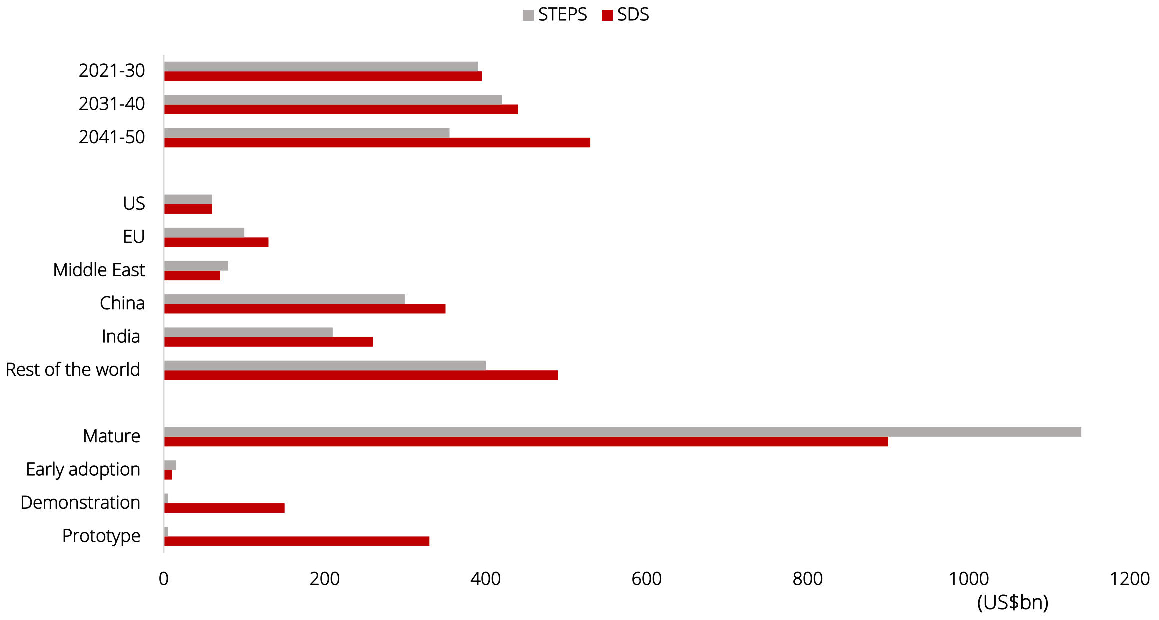
SDS to introduce innovative steel making process vs. STEP's usage of mature commercial technologies. In STEPS, most investments would go into mature commercial technologies – about 40% goes to the DRI-EAF route, 25% to the BF-BOF route, 25% to scrap-based EAFs and inductions furnaces, and much of the remainder to finishing processes spread across the different routes in 2050. In the SDS, on the other hand, just under half of cumulative investment to 2050 goes into mature commercial technologies, of which about 15% is for the BF-BOF route and conventional BOFs using iron from innovative routes, 35% for conventional DRI-EAF technologies, 30% for scrap-based EAFs, and the remainder for finishing processes. A further 12% of cumulative investment is for innovative smelting reduction, which is at the demonstration stage currently. Additionally, around 30% of investment is for the hydrogen-based DRI-EAF route and 4% is for innovative blast furnaces, both of which are at the prototype stage today. Carbon capture technologies applied to various routes account for 6% of cumulative investment.

Both of scenarios require huge capital investment. According to the IEA, cumulative capital investment in core process equipment between 2021 and 2050 in STEPS is estimated at US$1,150bn. While in the SDS, the capex will increase by c.20% to US$1,390bn vs. STEPS. This comprises all financial costs (not just capital costs) incurred by actors both within and outside the steel sector. For SDS, the investment in 2041~2050 is much higher than the period of previous decades and STEPS.

China and India to require more investment. The regional spread of investment is closely tied to the contribution of steel production across regions. China sees the largest cumulative investment – at about 26% of the total – in both scenarios, and India is the second – with c.18% of investment in both scenarios. Less investments in the US and the Middle East are largely driven by a higher share of scrap-based production as secondary production is considerably less capital-intensive, avoiding expenditure on furnaces for producing hot metal or DRI, as well as on coke ovens, pelletisers and sinter plants for iron ore, and coke processing.

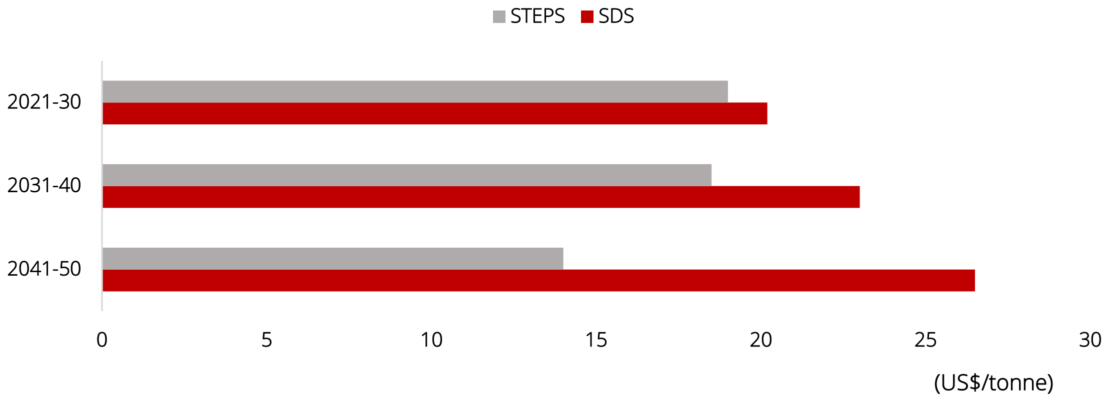
Carbon reduction capex per tonne of steel to be US$50~70/tonne. While almost all investment in the STEPS is for technologies that are already mature at present, in the SDS, c.35% of cumulative investment is in technologies that are currently in the demonstration or prototype phases. The investment for innovative stage technologies will be full scale in 2041~2050 once they have become commercially available. The capex per tonne of steel for the transition to low carbon production will be c. US$50/tonne for STEPS and c. US$70/tonne for SDS, 40% higher vs. STEPS.

Cumulative capital investment in process equipment in steel by scenario



Source: IEA and WSA, DBS Bank

Capex per tonne by scenario



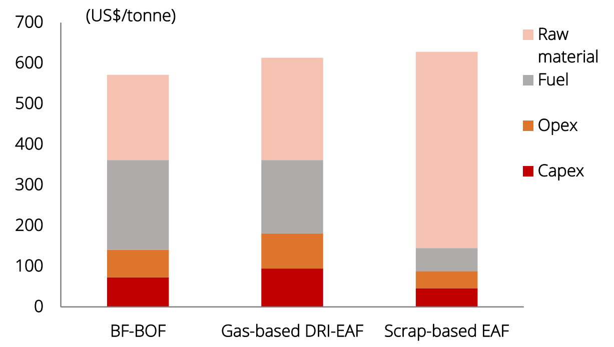
Source: IEA and WSA, DBS Bank

Steel production cost to rise by introducing lower carbon emission technologies

BF-BOF's production cost is competitive vs. EAF based production now. The simplified levelised cost per metric tonne of steel production, based on average raw material prices in 2021, shows that these raw material and energy inputs account for 66-86% of the total. This is higher than the typical contribution of 60%~80% due to surges in raw material prices. Currently, the production cost of steel from BF-BOF is lower than that from scrap. However, the cost competitiveness of BF-BOF is expected to weaken when carbon tax such as CBAM are implemented, as the CO2 emission of BF-BOF is over three times that of EAF.

Primary production pathways, higher sensitivity to energy prices than secondary production. The primary production pathways (BF-BOF and DRI-EAF) consume around eight times as much final energy as the secondary route, so are much more sensitive to energy prices. While the primary production routes consume large amounts of coal and natural gas (and electricity and heat generated from their off-gases), the scrap-based EAF pathway mainly uses electricity imported from the grid. Electricity and natural gas prices are subject to much wider regional variation, hence the contribution of energy to overall cost sensitivity would be larger in the DRI-EAF and scrap-based EAF routes.

Simplified levelized cost of steel production cost by process



Based on average raw material prices inf 2021. (Iron ore: US$140/tonne, Coking coal: US$220/tonne, Steel scrap:US$460/tonne, Natural gas:US$10/M BTU, Electricity:US$140/Mwh, coking coal factored as fuel cost)

Source: IEA and WSA, DBS Bank

Near zero steel making process to have much higher cost now. According to IEA's analysis, production costs of near-zero emission technologies are between 10% and 50% more expensive than their commercially available process in a context with no CO2 pricing. This implies that cost increase is expected to be higher than current margins if there is no price increase in the products. According to RMI in China, the cost of steel from the conventional BF-BOF route is c.US$400/tonne in 2020. With a US$6/kg hydrogen price in 2020, the cost of steel from a hydrogen-DRI is estimated to be 80% higher. Meanwhile, the CCUS route would also have a 40% cost premium based on an US$80/MWh electricity price.

Cost competitiveness of net zero technology to be achieved with lower energy cost from hydrogen in the long term.

Production cost highly varies depending on energy prices. There is uncertainty for gauging production cost because of the regional variation in energy prices which can have a significant impact on the production cost of steel. The economics of the gas-based DRI and electrolytic hydrogen-based DRI processes are particularly sensitive to the cost of gas and electricity, respectively. In the absence of a reliable global CO2 abatement mechanism for the sector, switching to low-carbon hydrogen production in the DRI-EAF route would not be competitive with conventional gas-based DRI-EAF and BF-BOF routes given its higher production costs, except where electricity prices are very low.

To compete with its natural gas-based counterpart equipped with CCUS, the electrolysis-based hydrogen DRI would need reliable low-carbon electricity prices below US$35/MWh (US$10/GJ) and a gas price of US$6/MBtu (US$6/GJ) based on current estimates of capital and operating costs at commercial scale according to the IEA. This implies that an innovative steel making process is not able to compete with current commercialised steel producing technologies in near to mid-term.

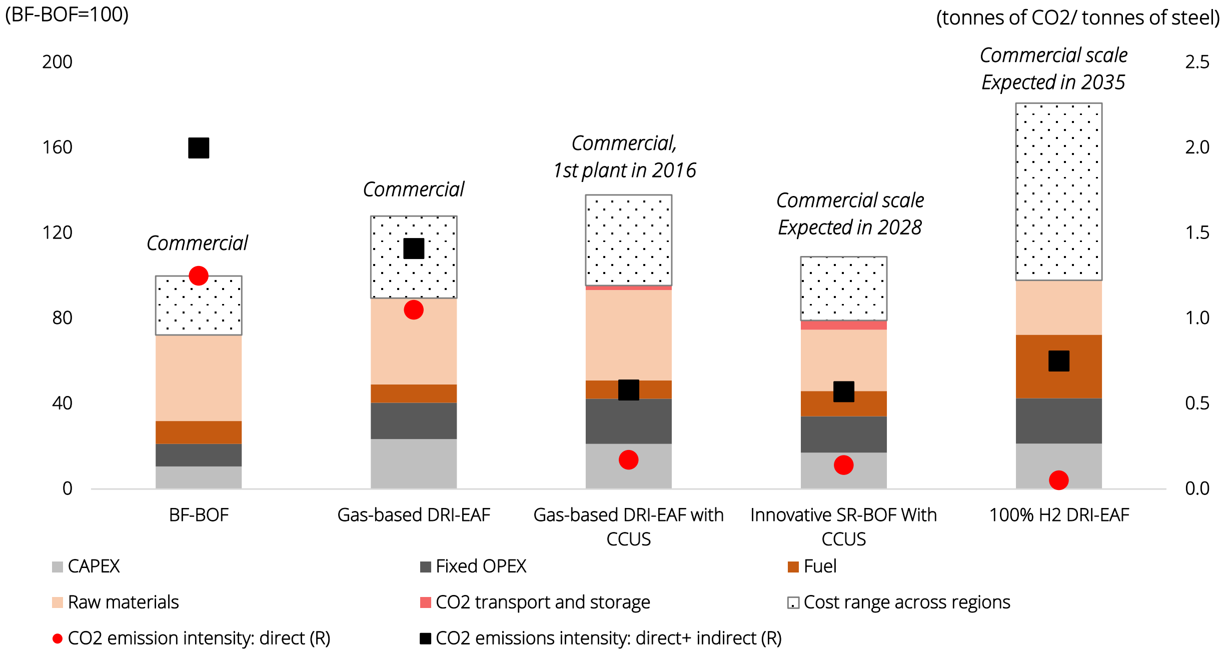
Smelting reduction to be one of the best options in mid-term. Smelting reduction route could reduce coal consumption and thus produce less CO2 than conventional blast furnaces with fitting into existing facilities (brownfield construction projects). This should have a merit of reducing capex. Furthermore, smelting reduction is more compatible with carbon capture. In China, Jianlong Steel and Bayi Steel under the Baowu Group are running this route. The Xinggang relocation project plans to take the "smelting reduction + EAF" route as well. While IEA and WSA suggest that the innovative SR (Smelting Reduction)-BOF route has the lowest overall production cost in most regions at current energy prices and estimated capital and operating costs among the near-zero emission technologies. This is developed by the ULCOS consortium, Hisarna pilot plant currently operating at a Tata Steel plant in Ijmuiden, Netherlands (60k tonnes of steel produced, CCS not yet implemented). A demonstration-scale (0.5m tonnes p.a.) plant is expected in 2023-27 in India and an industrial-scale (1.5m tonnes p.a.) plant with CCS is targeted in the Netherlands for 2027-33. Overall, it's expected to be commercialised around 2028.

Other factors may determine a choice of innovative technology. Despite innovative SR-BOF with CCUS route being of a lower cost than others, this wouldn't always be the best option. Other factors may have a considerable impact on costs or could lead to technology choices not based solely on costs. For example, electrolytic hydrogen DRI may still be chosen over innovative SR-BOF with CCUS in some locations without suitable access to CCUS infrastructure. The natural gas DRI with CCUS route could be opted for in regions where local availability of natural gas is preferred over imports of coal. The low electricity prices required to make electrolytic hydrogen DRI competitive may be achievable in certain regions with ample low-cost renewable resources.

Cost competitiveness of zero carbon steel with lower hydrogen prices in the long term. In the long term, the economic competitiveness of zero-carbon steel would be greatly improved with technology development, economies of scale, and power system development. Following analysis of RMI, the capex for CCUS equipment would decline by 10%–20% in the next three decades and the cost for electrolysers will fall from its current US$300/kW to US$100/kW in China. Also, the energy efficiency of water electrolysis could be improved. Backed by the massive renewable capacity growth in China, the electricity price is expected to drop significantly to US$50/MWh in 2030 and US$30/MWh in 2050. The electricity price drop will also result in the massive cost reduction of green hydrogen. Many countries – including Germany and the US –have set targets to bring the cost of hydrogen down to US$2/kg by 2030 and US$1/kg by 2050. This would significantly improve the cost-competitiveness of hydrogen-based steelmaking routes.

The critical difference of CO2 emission by pathway. Comparing CO2 intensity per tonne of steel by production route, we acknowledged that there is huge gap between them. The CO2 intensity of BF-BOF is over 2 tonnes of CO2/tonne of steel, including direct and indirect emissions. And, gas-based DRI-EAF has an intensity of 1.5tonnes of CO2/tonne of steel. The intensity of the Innovative SR-BOF with CCUS's is only estimated to be 0.6 tonnes of CO2/tonne of steel, a similar level to the secondary steel from EAF based scrap. Accordingly, CO2 pricing will be determined the speed of introduction of decarbonization technologies for steelmaking.

Simplified levelised cost of steel production for production routes



Source: IEA and WSA, DBS Bank

Notes: This is cost comparison when production cost of BF-BOT = 100. SR: Smelting reduction, CCUS: Carbon Capture Utilisation Storage.

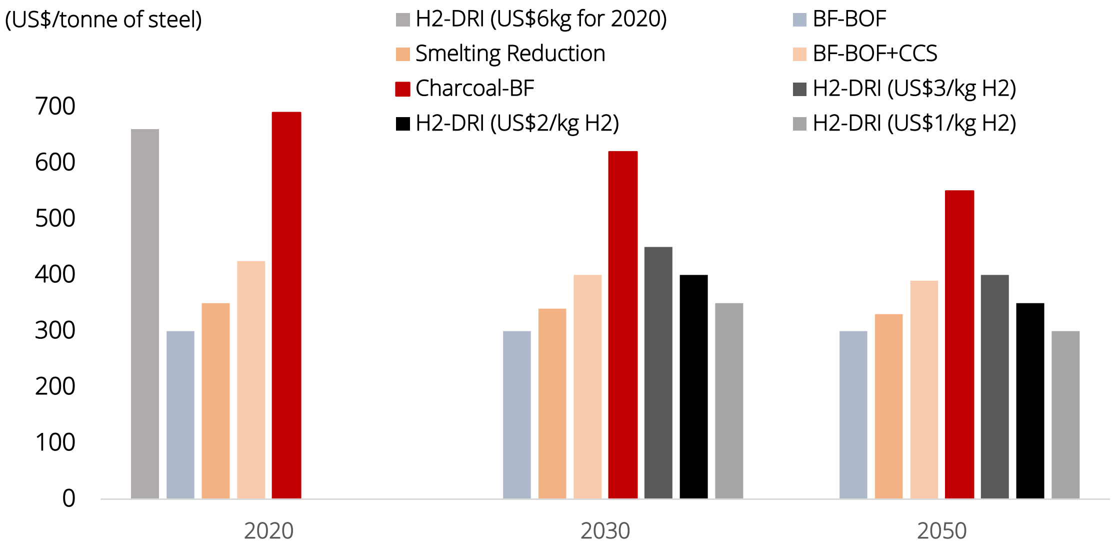
Presented costs account for regional variation. kWe = kilowatt electrical; MBtu = million British thermal units;

tce = tonne of coal equivalent. Energy costs: Natural gas = US$2-10/MBtu (USD 2-9/GJ), thermal coal = US$35-80/tce(US$1-3/GJ), coking coal = US$75-155/tce (US$3-5/GJ) and electricity = US$30-90/MWh (US$8-25/GJ). Scrap = US$200-300/tonne. Iron ore = US$60-100/tonne. CO2 transport and storage = US$20/tonne of CO2 captured. CO2 streams are captured with a 90% capture rate.

For BF-BOF, direct CO2 emissions do not include indirect emissions resulting from blast furnace gas and coke oven gas used for power generation. Indirect emissions include emissions resulting from imported heat and power generation provided either from excess blast furnace gas and coke oven gas or electricity from the grid.

While CO2 intensity of electricity considered for H2 DRI-EAF = 144 gCO2/kWh, which is the global average CO2 intensity of power generation in the Sustainable Development Scenario in 2035. CAPEX comprises process equipment costs (including air separation units, carbon capture equipment and electrolysers where applicable) plus engineering, procurement and construction costs. Electrolyser CAPEX = US$452/kWe and OPEX = US$7/kWe. 8% discount rate, 25-year lifetime and a 90% capacity factor are used for all equipment. 90% capture rate assumed for all CCS routes. Comparison is made assuming no price on CO2 (price of CO2 = US$0/t CO2).

Steelmaking cost by production routes in China



Assumptions	2020	2030	2050
Electrolyser CAPEX (US$/kW)	300	200	100
Electricity price (US$/MWh)	80	50	30
Coking coal price (US$/tonne)	200	200	200
Iron ore price (US$/tonne)	90	90	90

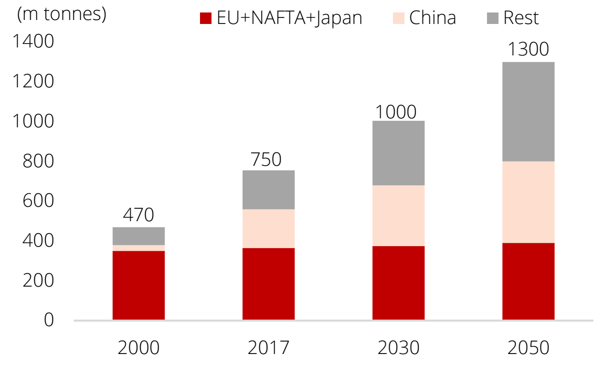
Source: RMI, DBS Bank

6. Implication to steel raw material market

Steel Scrap

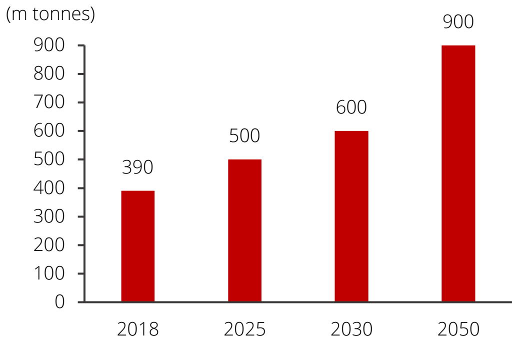
Increasing scrap availability to meet EAF capacity in the near term. The market expects higher growth in future scrap consumption from EAF capacity expansions and the push to decarbonise and utilise more scrap in BOF. Global ferrous scrap availability was at 750m tonnes in 2017, with 630m tonnes being recycled by the global steel and foundry cast industries. It is likely to reach about 1bn tonnes in 2030 and 1.3 bn tonnes in 2050, seeing more than 500m tonnes increase in the next 30 years. This growth will be mainly attributed to China and strong growth in steel production from India and ASEAN. India and the ASEAN region are expected to see their scrap availability double in the next 15 years. According to WSA, global supply of the obsolete scrap is likely to increase to 600m tonnes and 900m tonnes in 2030 and 2050, respectively from 390m tonnes in 2018.

Global total scrap availability forecast by 2050



Source: WSA, DBS Bank

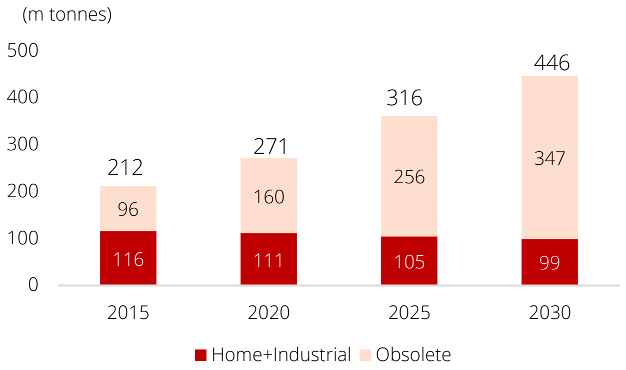
Global obsolete scrap availability forecast by 2050



Source: WSA, DBS Bank

Stronger obsolete scrap availability in China. China's scrap will increasingly take the form of steel recovered from old products, buildings, infrastructure and machinery, while amount of scrap from home and manufacturing industries including steel will decline. According to McKinsey Analysis, the obsolete scrap will drive the growth of available scrap in China as its share is estimated to reach 77.8% by 2030, from only 45.3% in 2015 to total scrap supply. The growth in obsolete scrap is sufficient to offset the decline in availability of home and industrial scrap, driving the overall domestic scrap availability to 446m tonnes by 2030 from 212m tonnes in 2015.

China's scrap availability by 2030

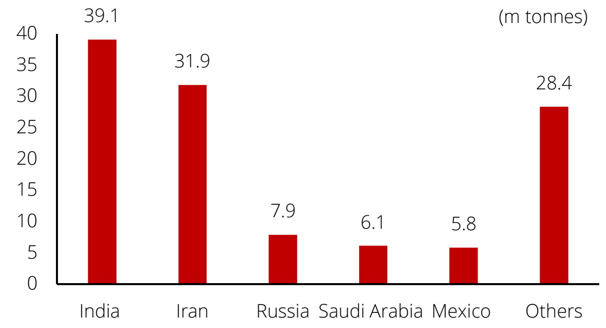


Source: McKinsey analysis, DBS Bank

Directed iron ore (DRI)

Increased DRI production driven by India. The global DRI production in 2021 increased by 13.7% y-o-y to 119m tonnes, mainly driven by India (32.8%) and Iran (26.8%). The growth was mainly attributed to India from the increase in coal-based DRI, along with new gas-based plants in Iran, and the ramp-up of new gas-based capacity in Algeria, Egypt, the US, and Russia.

Global DRI production by country in 2021



Source: Midrex Technologies, Inc, DBS Bank

Growth of global DRI market in the near term. The IIMA (International Iron Metallic Association) expects iron ore-based metallics including DRI to be vital components in the pathway to carbon-neutral steel making until the scrap sees the improved availability. Steel manufacturers are aggressively expanding their DRI production capacities in response to the growing steel demand within region.

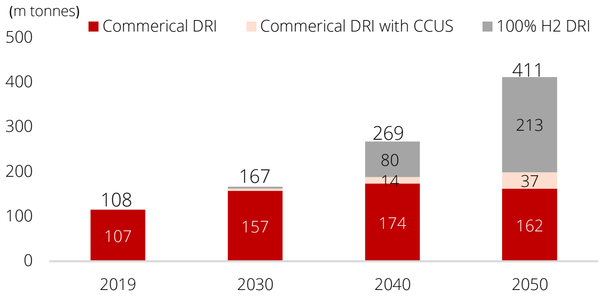
Higher requirements on iron ore to produce DRI. The BF-BOF method currently uses 70-75% of fine iron ore with 58-62% Fe content, 20-25% of lump iron ore with 65% Fe content, and 5-10% of iron ore pellet. However, the transition towards DRI-EAF method requires higher quality requirement on iron ore because 1) the sponge iron (DRI) is basically made from using lump ore with 65% or higher Fe content, 2) it should have better handling properties, preferably +85% tumbler index, 3) it should be calibrated to size with less fines (preferably 6-16mm with less than 3% fines), and 4) Hematite ores are preferred as they have high reducibility. Hence, from this transition, we expect a huge discount in fine ore due to fall in its demand and an increase in premium for lump ore and pellets.

DRI production growth to require iron ore resource development. DRI production growth will require iron ore resource development and new technology due to insufficient supply of iron ore concentrate to produce high quality DR-grade pellets. In particular, it is important to develop low carbon emission method to produce DRI with the use of fine ore. While BHP is currently producing sufficient high quality iron ore, Vale is looking into producing low-emissions iron products, diversifying from pellet. Recently, Rio Tinto and Salzgitter AG have signed an agreement to optimize iron ore pellets, lumps, and fines for use in H2-DRI steelmaking and target carbon-free steel production, starting in 2025. Furthermore, steel companies such as Cleveland-Cliffs and ArcelorMittal are already fully integrated, producing DRI/HBI*, and Russian companies are investigating DRI projects to improve production process and pellet plant capacity.

**HBI (Hot Briquetted Iron) is premium form of DRI, which has been developed to overcome the problems associated with shipping and handling of DRI. HBI is less porous and reactive than DRI and does not suffer from the risk of self-heating associated with DRI.*

Expect ample production growth until 2050. According to IEA's SDS assumption, global DRI production is likely to grow from 108m tonnes in 2019 to 411m tonnes by 2050. It expects that the production of commercial DRI will maintain growth – from 107m tonnes in 2019 to 174m tonnes by 2040. However, commercial DRI is likely to be stagnant after 2040 due to the growth of H2-DRI and conventional DRI coupled with CCUS. The production of commercial DRI with CCUS and 100 H2% DRI is forecasted to increase to 37m tonnes and 213m tonnes by 2050, respectively.

DRI production forecast by technology

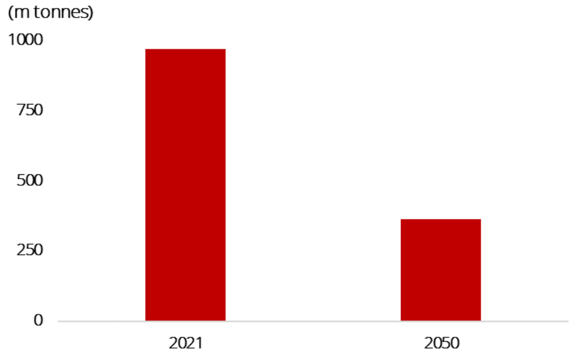


Source: IEA, MIDREX, DBS Bank. Based on IEA's SDS assumption

Coking coal

Weaker coking coal demand due to plummet in BF proportion in steelmaking. There is an expectation that green hydrogen will be increasingly used to decarbonise steel production, now a priority goal for many steelmakers in developed markets. Whilst the green hydrogen industry is still relatively nascent and industrial scale production systems are difficult to come online very soon, the stronger growth in scrap and DRI market in the near term will deteriorate coking coal demand outlook in steel production. According to our analysis, with IEA's SDS assumption, coking coal demand will plummet from 970m tonnes in 2021 to c.364m tonnes in 2050 due to lower BOF proportion of steelmaking process (from 71% to 25%).

Global coking coal demand forecast



Source: IEA, DBS Bank. Based on IEA's SDS assumption

7. Carbon strategy of key players

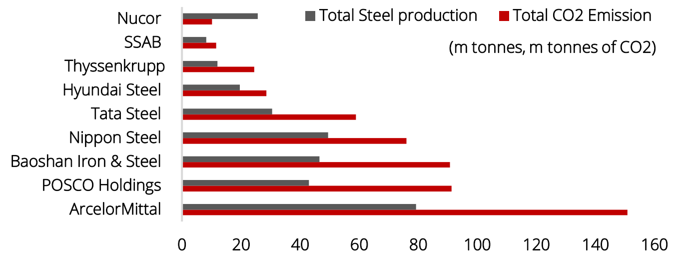
Steel companies based on EAF have far less GHG emission than others

Production volume, energy consumption, and carbon emission. In general, energy consumption and carbon emission have strong correlation with energy intensity as the higher consumption of energy used to lead higher CO2 emission. As the total energy consumption is in line with the steel production volume, the largest steel mill – Arcelor Mittal – registered the largest energy consumer in the sector. While in terms of energy intensity per tonne of steel, Thyssenkrupp in Germany has registered as the largest energy consumer followed by Arcelor Mittal. The steel mills based on EAF such as Nucor, SSAB Hyundai Steel has far lower energy intensity per tonne of steel product.

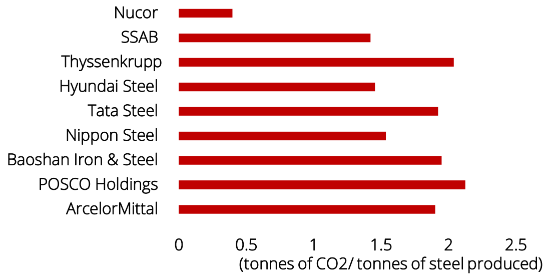
Who is producing less carbon emitted steel products? We can intuitively see which steel companies emit more GHG even before taking account the data. The steel mills based on EAF should have less CO2 emission. Among key steel companies globally, Nucor is the lowest carbon emitting steel producer globally with 0.4 tonnes of CO2/tonne of steel as it produced all products from scrap based EAF. The second lowest carbon emission per tonne of steel goes to SSAB followed by Hyundai Steel. SSAB is a Nordic and US-based company focusing on high strength steel, while Hyundai steel is the second largest steel company in Korea producing c.half of its product from scrap based EAF. While the integrated steel mills based on BF-BOF posted high carbon emission, POSCO in Korea has registered the biggest GHG emitter per tonne of steel followed by Thyssenkrupp in Germany.

The carbon emission is correlated to energy intensity. For the key steel companies, the energy intensity per tonne of steel products generally in line with GHG emission. This implies higher energy intensity is resulted in higher emission in GHG. Despite Nippon steel producing steel based on blast furnace and higher energy intensity, its carbon emission is lower than others due to its effort to reduce CO2 emission such as replacing energy source to reduce coal consumption. Accordingly, steel companies are required to make progress for enhancing energy efficiency with introduction of innovative technology with less carbon emission.

Total CO2 emission and steel production in 2021



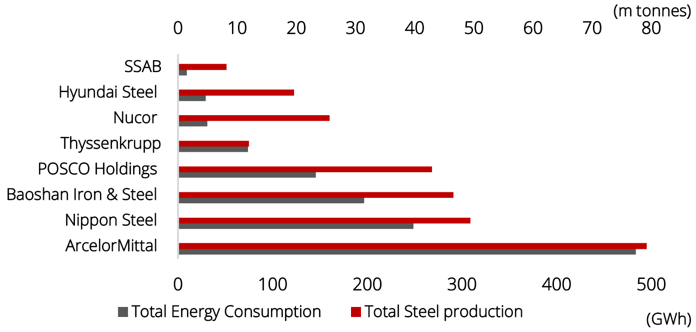
CO2 emission per tonne of steel in 2021



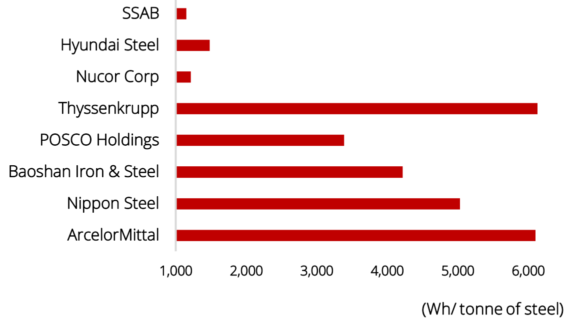
Source: Bloomberg Finance L.P., DBS Bank, WSA

**The data on total CO2 emission for 2021 is equivalent to that of 2020 for listed companies: ArcelorMittal, Nippon Steel, Hyundai Steel, POSCO Holdings, and Tata Steel*

Total energy consumption and steel in 2021



Energy consumption per tonne of steel in 2021



Source: Bloomberg Finance L.P., DBS Bank

Source: Bloomberg Finance L.P., WSA, DBS Bank

**The data on total energy consumption for 2021 is equivalent to that of 2020 for listed companies; ArcelorMittal, Nippon Steel, Hyundai Steel and POSCO Holdings.*

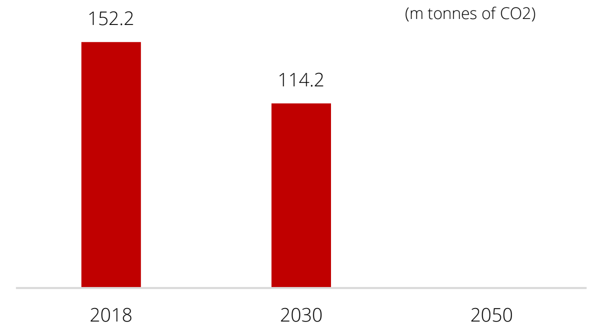
Zero carbon strategy of global major steel mills

DRI and EAF to be mainstream, hydrogen to be energy source. Major steel companies are considering DRI-EAF as the major technology to reduce carbon emission in near to mid-term. For this, they are strengthening cooperation with miners to develop iron ore for new technology. In particular, Asian major mills including BaoWu Group, Nippon Steel, and POSCO have been pursuing joint research and development of it with major miners such as Vale and BHP as they have been heavily relying on imported iron ore from them. Over the long term, most of the steel majors are considering hydrogen as a key energy source replacing coking coal.

ArcelorMittal as a frontrunner in decarbonisation technologies.

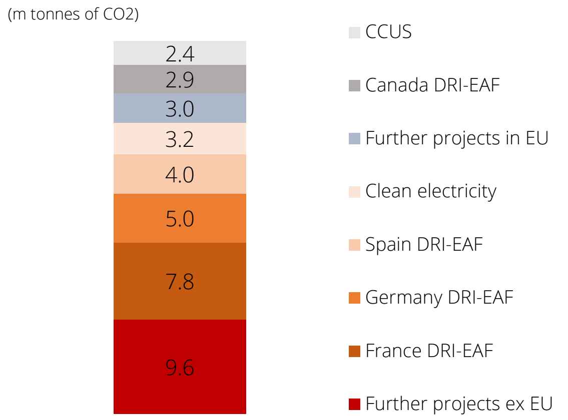
ArcelorMittal's path to carbon neutrality. ArcelorMittal aims to achieve 25% absolute reduction by 2030 vs.2018 and be carbon neutral by 2050, globally. For Europe, it aims to achieve absolute 35% absolute reduction by 2030 vs. 2018. The company is currently building 100k tonnes of green H2-DRI demonstration plant in Hamburg, Germany and is expected to likely operational before the end of 2025, initially producing an annual volume of 100k tonnes of DRI. While hydrogen holds the key to delivering the 2050 target, due to high transition cost, it is unlikely to be commercial at scale by 2030. As a result, the company is focusing on two main approaches: DRI-EAF facilities, which uses green hydrogen instead of fossil fuels and smart CCUS technology.

ArcelorMittal's decarbonisation plan



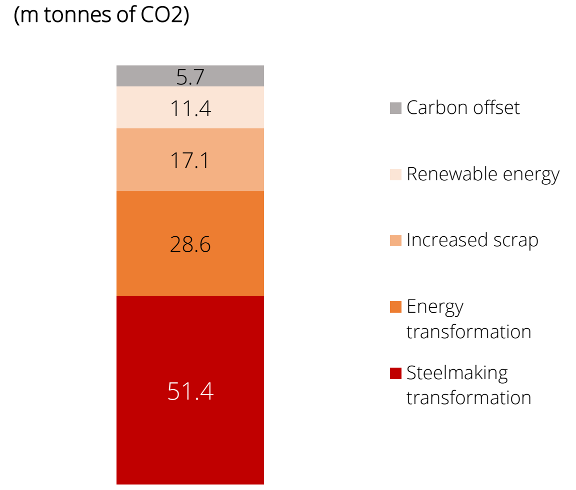
Source: The company, Bloomberg Finance L.P., DBS Bank

CO2 emission abatement by 2030



Source: The company, Bloomberg Finance L.P., DBS Bank

Additional CO2 emission abatement from 2030 to 2050



Source: The company, Bloomberg Finance L.P., DBS Bank

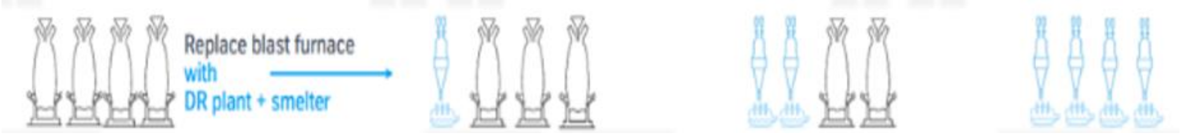
Expansion in CCUS project. A "3D" project on amine-based carbon capture for BF at ArcelorMittal's Dunkirk Site has begun operations from Mar 22 with 4.4k tonnes of CO2 p.a. capa. The project aims to reach an industrial scale of 1m tonnes of CO2 p.a. by 2025. The company partnered with LanzaTech to develop Steelanol project with investment of EUR165m capex. The plant is currently under construction in Ghent, Belgium, and expected to produce 80m litres of sustainable ethanol p.a. by 2022.

Ample investments on H2-DRI projects. ArcerlorMittal has currently expanded DRI-EAF projects in Germany, France, and Canada. From these projects, we estimate the company's production capacity of DRI and EAF to rise from zero to 5.8m tonnes p.a. and 3.5m tonnes p.a. by 2030, respectively. Through these projects, the company aims to reduce 15.7m tonnes of CO2 emission by 2030, I) In Jul 2021, the company decided to invest CAD$1.8bn on constructing new DRI facility (2.5m tonnes p.a. capa) and EAF facility (2.4m tonnes of high-quality steel p.a capa) at ArcelorMittal Dofasco in Hamilton. This project is expected to start production by the end of 2028 and aims to reduce the annual CO2 emission of Hamilton plant by 60%, within the next seven years. ii) The company invested US$1.2bn for building a 2.3m tonne p.a. green H2-DRI unit, complemented by a 1.1m tonnes p.a. hybrid EAF in Gijón, since Jul 2021. The new DRI unit with EAF are estimated to be operational before the end of 2025. iii)In Feb 2022, the company announced a US1.9bn investment in construction of a 2.5m tonnes p.a. DRI furnace and two electric furnaces at ArcelorMittal Dunkirk, and a scrap based electric furnace at ArcelorMittal Fos-sur-Mer. The new installations are expected to be operational in 2027. Once this transition is complete by 2030, ArcelorMittal France's CO2 emissions would reduce by almost 40% vs. 2018.

Thyssenkrupp to pilot diverse projects to achieve net zero by 2050.

The company aims to reduce 30% absolute emissions reduction by 2030 vs. 2018 and be carbon neutral by 2050 where the company estimates EUR7bn of cumulative capital expenditure. The company has been testing the use of hydrogen in a BFs in Germany, replacing a proportion of injected coal since 2019. The company also explored CCUS through Carbon2Chem pilot plant in 2018, which produced ammonia and methanol from steel off-gases. It aims to commercialise industrial-scale plant by 2025. Furthermore, the construction of 1.2m tonnes p.a. H2- DRI plant is expected to be completed by 2025 at Duisburg site in Germany and produce 400k tonnes of green steel. The company's target is increase green steel output to 3m and 11.5m tonnes p.a. by 2030 and 2045, respectively, from 50k-500k tonnes p.a. in 2024.

Thyssenkrupp's action towards decarbonisation



	Up to 2024	2025-2029	Up to 2030	Up to 2045
Cumulative Capex required:				~EUR 7bn
CO2 saving:	-2%	-8%	-30%	-100%
Green steel Output:	50-500k tonnes p.a.	~1m tonnes p.a.	~3m tonnes p.a.	~11.5m tonnes p.a.

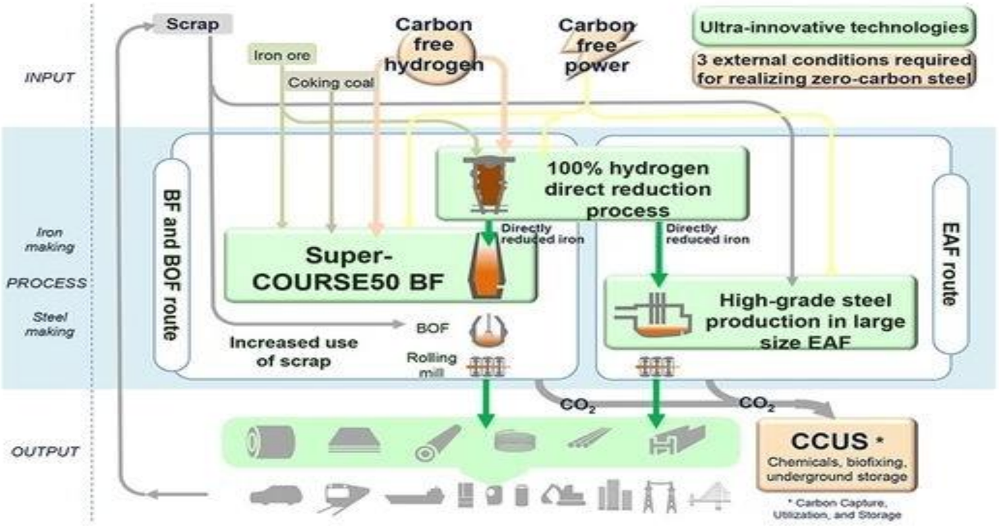
Source: The Company, DBS Bank

Nippon Steel to focus on Japan's COURSE50

Adoption of hydrogen-reduction steelmaking – together with mass production of high-grade steel in large size electric furnaces – could help the company reduce CO2 emissions by 30% in 2030 after hitting the peak in 2022 and achieve carbon neutrality in 2050. The company is currently working on the implementation of Japan's COURSE 50* in the existing BF-BOF process where the company estimates JPY4tn (US$28bn) of capital expenditure. The company will engage in joint research with Vale regarding the utilisation of green moulded pig iron**, green briquettes*** and other carbon neutral steelmaking processes. Nippon Steel is also considering incorporating biomass – such as eucalyptus and sugarcane – to process Vale's iron ore and produce moulded pig irons.

**: Under the "COURSE 50" initiative, Japanese blast furnaces should lower blast furnace CO2 by 30%: -10% via partial modification of BF to enable the usage of modified coke oven gas (hydrogen amplification), and the remaining 20% via CO2 separation, collection, and storage.*
***: Pig iron in which molten iron produced using carbon neutral carbon materials is cooled and solidified.*
****: Raw materials in which iron ore fines are moulded using pressure, without the use of heat.*

Nippon Steel’s Carbon neutral steelmaking process



Source: The Company, DBS Bank

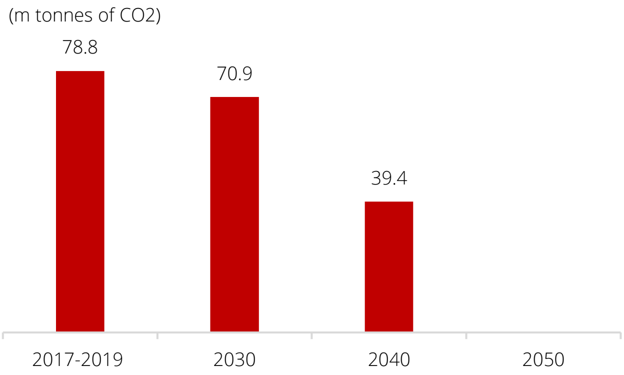
POSCO-Carbon neutrality in 2050 with key technology, HyRex

HyRex-green hydrogen-based iron making technology. According to the company’s announcement, POSCO is trying to reduce 10% and 50% in CO2 emission by 2030 and 2040, vs. 2017-2019 average levels. It aims to achieve carbon-neutrality by 2050. POSCO and Primetals will jointly design a demonstration plant with HyRex (green hydrogen-based ironmaking technology) at POSCO’s Pohang Site. They will continue with their R&D on direct hydrogen reduction by gradually increasing the ratio of hydrogen on two fluidized reduction furnaces – 1.5m and 2m tonnes p.a. capacity, respectively. The company is aiming to produce steel with combination of HyRex technology and increased use of scrap through renewable energy-based electric furnaces and hopes to operate the plant by 2030.

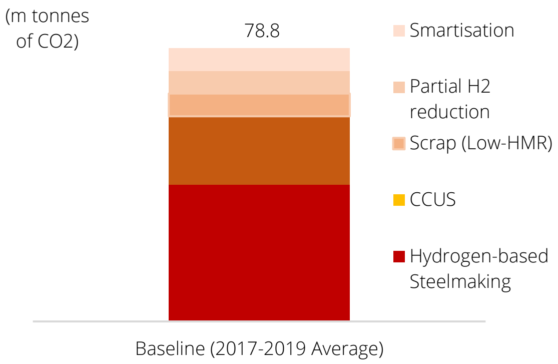
Form JV with BHP to explore steel decarbonisation. In Oct 21, POSCO and BHP decided to promote joint R&D with US$10m investment for the next five years in manufacturing high-strength cokes and utilising biomass. This includes improving the reporting systems for estimating GHG emissions in the entire supply chain (Scope 3) and developing CCUS technologies.

Hydrogen aid to POSCO’s carbon neutral goal. POSCO will building 2m tonnes of hydrogen-based production capacity by 2040, expanding to 5m tonnes by 2050. Hydrogen-based steelmaking is expected to account for c.50% % of the overall emission reduction by 2050.

POSCO’s decarbonisation plan



CO2 abatement strategy by 2050



Source: The Company, DBS Bank

**The average emission for 3 years (2017-2019) based on the Emission Trading Scheme Phase 3 (2021-2025)*

Hyundai steel to deploy electric furnace as a low-carbon strategy

Hyundai Steel is committed to be carbon neutral by 2050 with interim targets of 20% cut in CO2 emission by 2030. The company steel decided to make an investment of KRW 890bn from 2021 to 2025 to reduce CO2 emission. The company plans to install a coke dry quenching system* (CDQ) by 2025. With this investment, we expect to reduce GHG emissions by more than 500k tonnes p.a. Furthermore, the company is planning to improve the energy efficiency of its steel mills by using heat exchangers and recovering waste heat. This investment decision brings the total amount of the investment in the environment to KRW1tn, including KRW510bn invested from 2016 to 2020. Moreover, the company will build Hy-Cube, a carbon neutral steel production system based on its own electric furnace and convert to a hydrogen-based steel production system by 2030. Such a process also emits about 25% less carbon compared to steelmaking with a blast furnace. In addition, Hyundai Steel signed agreement on Nov 2021 with Vale to promote joint research on the application of new material, iron ore briquette**.

**: waste heat is recovered from the coke cooling process and recycled into steam and electricity*
***: Iron ore briquettes are low-carbon steel material produced at a low temperature and was developed to replace shaft furnace's sintering, lump, pellet processes.*

Baowu Group to build the largest H2-DRI facility in China

Target to carbon neutral by 2050. Baowu Group, the largest global steelmaker, producing 120m tonnes of steel in 2021, aims to reduce 30% of absolute emissions by 2025 after reaching peak emission in 2023, and achieve carbon neutrality by 2050. Its subsidiary Baosteel, aims to possess 30% of carbon reduction technology capability in 2030, reduce emission 50% in 2042, and be carbon neutral in 2050. Baowu is testing the H2-BF project in Xinjiang, China, to reduce carbon emissions by over 30% together with carbon recycling and other techniques. According to SP Global, Baowu is also planning to build an EAF steel mills together with its own solar plant in Xinjiang.

Investments from iron ore companies such as BHP and Vale to further develop technologies through biomass and CCUS. BHP signed an agreement with Baowu in Nov 2020 to invest US$35m within five years to carry out projects on smart carbon use (SCU), carbon-free iron making and CCUS. Vale has invested RMB60-70m into Baowu's biochar pilot plant, In Nov 2021, where the project uses biochar for BF production.

Transit towards H2-DRI-EAF steelmaking process. Baosteel has ordered 1m tonnes p.a. H2-DRI plant with ENERGIRON technology from Tenova and Danieli to generate green steel through the combination of EAF at its Zhanjiang Iron & Steel base in Guangdong. The facility is scheduled to be completed by the end of 2023 and will reduce carbon dioxide emissions by more than 500k tonnes p.a.

Decarbonisation goals by key global companies

Steelmaker	Percentage of 2020 global primary steel production	Interim goal	Long-term net zero goal
Baowu Group	6.14%*	30% absolute emissions reduction by 2025 (from 2023 peak)	Carbon-neutral by 2050
ArcerlorMittal	4.18%	Global: 25% absolute reduction by 2030 Europe: 35% absolute reduction by 2030 (2018 baseline)	Global: Carbon-neutral by 2050
HBIS Group	2.33%	30% absolute emissions reduction by 2030 (from 2022 peak)	Carbon-neutral by 2050
Nippon Steel	2.21%	30% absolute emissions reduction by 2030 (from 2022 peak)	Carbon-neutral by 2050
POSCO	2.16%	Absolute emission by 10% and 50% by 2030 and 2040, respectively (with the average CO2 emission for 3 years from 2017 to 2019 as a baseline)	Carbon-neutral by 2050
Hyundai Steel	1.06%	20% absolute emission reduction by 2030	Carbon-neutral by 2050
U.S. Steel	0.62%	20% emission intensity reduction by 2030 (2018 baseline)	Carbon-neutral by 2050
Thyssenkrupp Steel	0.57%	30% absolute emissions reduction by 2030 (2018 baseline)	Carbon-neutral by 2050
Tata Steel	0.54%	30% to 40% absolute emissions reduction by 2030 (2018 levels)	Carbon-neutral by 2050
Voestalpine	0.38%	N/A	8.0% to 95% absolute emissions reduction by 2050
Liberty Steel	0.37%	N/A	Carbon-neutral by 2030
SSAB	0.23%	Sweden: 25% absolute emissions reduction by 2025	Global: Fossil-free by 2045
Salzglitter	0.21%	N/A	95% absolute emissions reduction by 2050 without offsets
BlueScope	0.15%	12% reduction in GHG emissions intensity by 2030 (2018 baseline)	Net-zero GHG emissions by 2050

**excludes ongoing Shandong Steel acquisition*
Source: MPP, The Company, DBS Bank

Decarbonisation strategies by Chinese steelmakers

Chinese Steelmaker	Action Plan
AnSteel	Carbon peak before 2025, cut carbon 30% in 2035, to be the first batch of large steel enterprise achieve carbon neutral.
Nanjing Iron and Steel	Plan to adopt hydrogen energy metallurgy and carbon capture and utilisation for steel production during the 14th FYP.
Baosteel	Achieve carbon peak in 2023, possessing 30% of carbon reduction technology capability in 2030, cut emission 50% in 2042 and carbon neutral in 2050.
Luan Iron and Steel	Signed strategic cooperation agreement with Metallurgical Industry Planning Research Institute, becoming the first steel company in the Yangtze River Delta region to commit the carbon work.
Jinding Steel	Held strategic cooperation with Metallurgical Industry Planning Research Institute, be the first steel company in Hebei to launch decarbonisation work.
Delong Steel and New Tianjin Steel	Target to reduce carbon emissions starting from 2022. According to media report, Jianlong will invest RMB1.09bn CISP Inner Mongolia a hydrogen based with DRI with annual capacity of 300,000 tons high-purity pig iron.
China South Steel	Strive to achieve carbon peak in 2023, possessing 30% of carbon reduction technology capabilities in 2035, carbon neutrality in 2050.
Taigang	Set a vision of “13460” one low-carbon centre, three low-carbon development stages, four low-carbon implementation steps, six low-carbon development paths, zero carbon target.

Source: The company; DBS Bank

Appendix. Scenarios for CO2 taxation on imports under EU CBAM for steel

Scenarios for CO2 taxation on imports under EU CBAM for the iron and steel sector

		EUR25/tonne of CO2		EUR60/tonne of CO2		EUR80/tonne of CO2	
Import countries	Free allowance (%)	Total CBAM surcharges (m EUR)	% Proportion of CBAM surcharges to steel imports	Total CBAM surcharges (m EUR)	% Proportion of CBAM surcharges to steel imports	Total CBAM surcharges (m EUR)	% Proportion of CBAM surcharges to steel imports
Russia	80 %	58.7	1.5 %	148.4	3.8 %	199.8	5.1 %
	50 %	154.9	4.0 %	379.3	9.8 %	507.6	13.1 %
	30 %	219.0	5.6 %	533.2	13.7 %	712.8	18.3 %
Turkey	80 %	28.0	1.1 %	70.9	2.7 %	95.4	3.7 %
	50 %	74.0	2.9 %	181.2	7.0 %	242.4	9.4 %
	30 %	104.6	4.0 %	254.7	9.8 %	340.4	13.2 %
Ukraine	80 %	30.7	1.3 %	78.3	3.2 %	105.5	4.4 %
	50 %	81.1	3.4 %	200.1	8.3 %	268.0	11.1 %
	30 %	114.7	4.7 %	281.2	11.6 %	376.4	15.6 %
S.Korea	80 %	4.7	0.2 %	29.0	1.4 %	42.8	2.0 %
	50 %	13.9	0.7 %	74.6	3.5 %	109.3	5.1 %
	30 %	20.0	0.9 %	105.0	4.9 %	153.6	7.2 %
China	80 %	11.6	0.7 %	29.3	1.7 %	39.4	2.3 %
	50 %	30.5	1.8 %	74.7	4.3 %	100.0	5.8 %
	30 %	43.1	2.5 %	105.1	6.1 %	140.4	8.2 %
India	80 %	14.1	0.9 %	35.8	2.2 %	48.1	3.0 %
	50 %	37.3	2.3 %	91.4	5.6 %	122.2	7.5 %
	30 %	52.7	3.3 %	128.4	7.9 %	171.7	10.6 %
Brazil	80 %	8.4	0.7 %	21.2	1.9 %	28.6	2.5 %
	50 %	22.2	1.9 %	54.3	4.7 %	72.6	6.3 %
	30 %	31.3	2.7 %	76.3	6.6 %	102.0	8.9 %
Taiwan	80 %	6.5	0.7 %	16.3	1.9 %	22.0	2.5 %
	50 %	17.0	2.0 %	41.7	4.8 %	55.8	6.4 %
	30 %	24.1	2.8 %	58.6	6.7 %	78.3	9.0 %

Source: Susanne Dröge's "A CO2 border adjustment for the EU Green Deal" (2021), DBS Bank

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STRONG BUY (>20% total return over the next 3 months, with identifiable share price catalysts within this time frame)
BUY (>15% total return over the next 12 months for small caps, >10% for large caps)
HOLD (-10% to +15% total return over the next 12 months for small caps, -10% to +10% for large caps)
FULLY VALUED (negative total return, i.e., > -10% over the next 12 months)
SELL (negative total return of > -20% over the next 3 months, with identifiable share price catalysts within this time frame)

**Share price appreciation + dividends*

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