STEELING A MARCH

Assessing the outlook for global steel companies

Summary report

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Image: Hot Briquetted Iron (HBI)

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Benchmarking steel transition

This report uncovers how the world's largest steel producing companies perform against net zero. We assess 30 companies representing a combined 40% of global steel production. Our analysis provides a detailed account of the risks and opportunities presented by a "post-carbon" economy and what companies are doing, or not doing, to address them.

The steel sector is at a crossroads. For centuries it has used coal to convert iron ore into steel. It cannot easily transition because coal is required, not just for energy, but for specific chemical and physical properties that are crucial to the blast furnace steelmaking process.

However, huge technological tipping points are approaching, such as hydrogen direct reduction (HDR) and iron ore electrolysis (IOE), with the potential to disrupt the status quo. With the race for "Green Steel" accelerating, companies risk falling behind competitors and finding themselves locked-in to carbon-intensive assets intended for 40 years of continuous operation.

Nowhere is the transition risk or physical risk greater than in India. While China enters a phase of consolidation and decline, the Indian Government has established a bold strategy to double steel production capacity by 2030. This has provoked a scramble among national and international producers for a slice of the pie. The problem is that steel companies are opting for blast furnace technology when they should be leapfrogging to direct reduction. Simultaneously, India is most at risk of heat and water stress, which could trigger significant future costs.

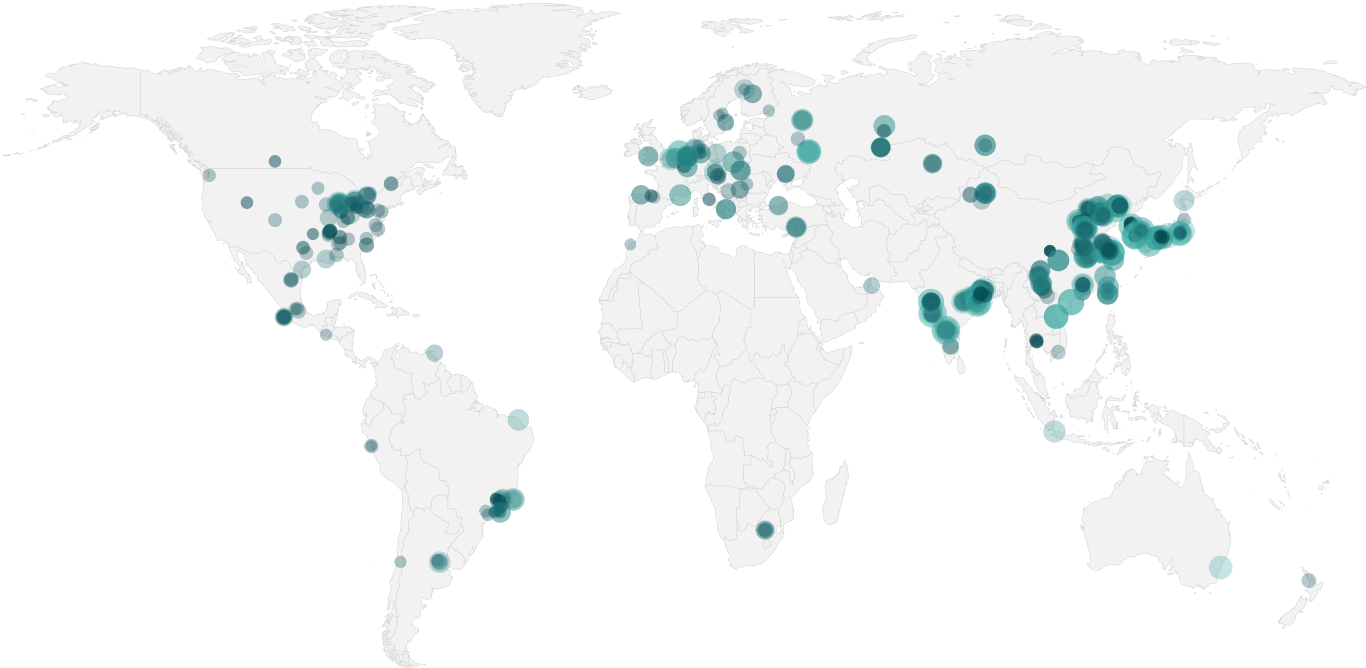
Figure 1. Company summary

Company	Ticker	Headquarters	Market capitalisation, US$m	Crude steel capacity, Million tonnes
Baowu Group	SBSA CH	China	-	133
ArcelorMittal	MT NA	Luxembourg	29190	83
Nippon Steel	5401 JP	Japan	15704	66
Ansteel Group	AGANGZ CH	China	-	63
Shagang Group	JSGGCZ CH	China	-	49
Posco	005490 KS	South Korea	17445	45
HBIS Group	HEBEEZ CH	China	-	41
JFE Holdings	5411 JP	Japan	7095	38
Tata Steel	TATA IN	India	13349	34
Nucor	NUE US	USA	31096	32
JSW Steel	JSTL IN	India	15404	29
Hyundai Steel	004020 KS	South Korea	4532	25
SAIL	SAIL IN	India	4449	23
Cleveland Cliffs	CLF US	USA	10888	21
US Steel	X US	USA	6281	20
China Steel	2002 TT	Taiwan	19690	20
NLMK	NLMK RM	Russia	17485	19
Gerdau	GGBR4 BZ	Brazil	8346	17
Evraz	EVR LN	Russia	11878	16
ThyssenKrupp	TKA GR	Germany	6581	16
Severstal	CHMF RM	Russia	17940	15
MMK	MAGN RM	Russia	10402	15
Ternium	TX US	Argentina	8725	12
JSPL	JSP IN	India	4790	10
Erdemir	EREGL TI	Turkey	7449	10
SSAB	SSABA SS	Sweden	5976	9
Voestalpine	VOE AV	Austria	7411	8
Kobe Steel	5406 JP	Japan	2453	7
Salzgitter	SZG GR	Germany	1935	7
BlueScope Steel	BSL AU	Australia	8293	6

Source: Bloomberg, Company reports, Signal Climate Analytics

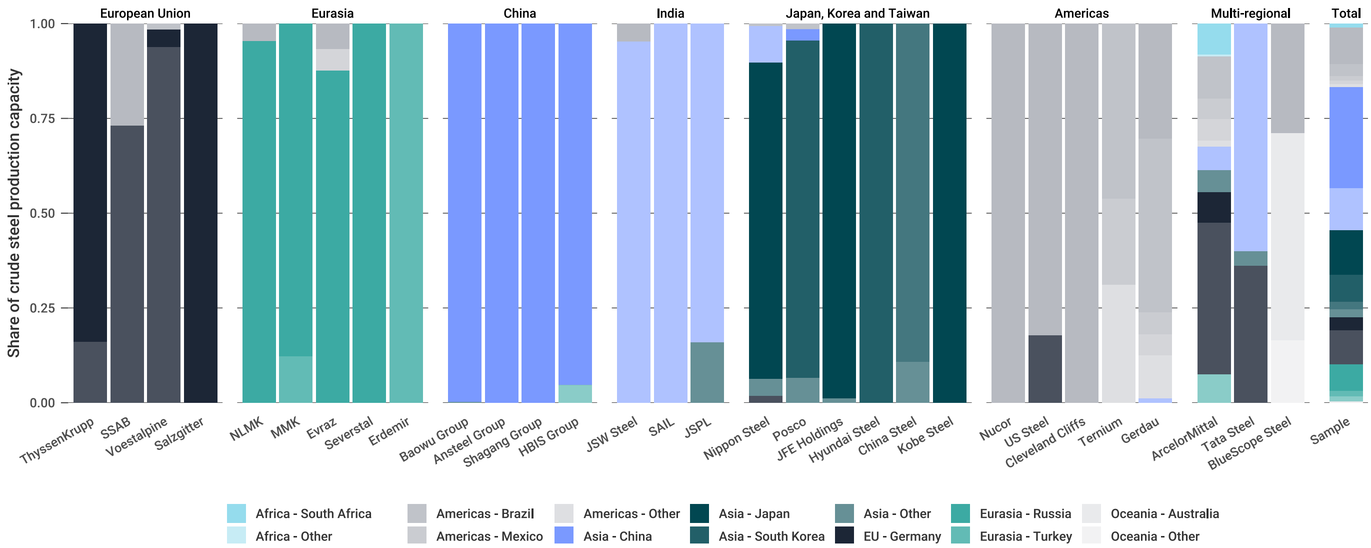
Against this backdrop, we score company performance over 13 metrics and 4 themes based around the TCFD framework: transition risks, transition opportunities, climate governance and strategy, and physical risks. Our bottom-up analysis is built on physical asset-level data, covering 280 steel production sites across the globe. Scores are generated over a three year period to understand the "direction of travel" among the 30 companies.

Figure 2. Global map of company steel production assets



Source: Global Energy Monitor

Figure 3. Geographical distribution of company steel production capacity



Source: Company reports, Global Energy Monitor

Sector overview

Coal as a feedstock

The steel sector accounts for 9% of direct CO_2 emissions globally[1]. It is the largest single emitting industrial sector and highly energy and emissions intensive.

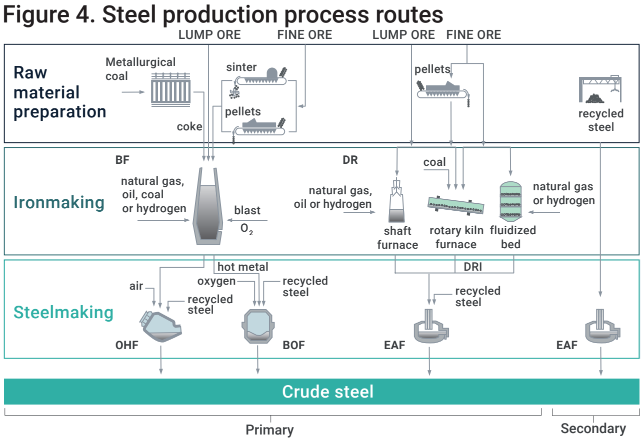
The structure of the steel sector is best defined by the balance of primary and secondary steel production. Primary steel production is the conversion of iron ore into steel, and makes up 80% of total production. It is performed almost exclusively today via the Blast Furnace - Basic Oxygen Furnace (BF-BOF) route. Secondary steel production is met via the Electric Arc Furnace (EAF) into which steel scrap is charged and remelted. This recycling process requires a fraction of the energy and relies on electricity, which can be decarbonised.

Due to the turnover of significant stocks of construction steel in China, increased scrap availability will shift the balance of secondary to primary steel over the next 30 years from 20-80 to nearly 50-50[2]. While this will reduce emissions, it cannot achieve a near zero sector without the primary route itself decarbonising.

The problem facing the industry is the blast furnace. The blast furnace must use coal. For the process to function, metallurgical coal is first refined into coke, which is then fed into the furnace where it serves three functions: 1. It provides heat energy to raise temperature, 2. It provides carbon for chemical reduction, and 3. It has specific physical properties necessary to support other inputs while allowing off-gases to permeate through and exit the furnace top.

It is the physical properties that prevent biomass, in the form of charcoal, being a viable substitute except for very small furnaces. Coke may be partially substituted by injecting other energy carriers, including hydrogen, into the furnace. But while producers claim green credentials for adopting this measure, it can only achieve around 20% of emissions reduction because it cannot serve all the functions of coke.

Figure 4. Steel production process routes



The great decoupling

The blast furnace is inflexible, not only for its dependence on specific grades of coal, but for its operational and ancillary requirements. Blast furnaces are huge structures built on-site and invested in to last 40 years. After the first 20-25 years of operation, the furnace is relined for an additional 15 years and further relines can ensue.

The lighting of the furnace is ceremonial because it initiates many years of continuous operation. Served by coke ovens and sinter plants, the blast furnace is the heart of the traditional integrated steel mill and the bottle-neck of energy and materials flowing through it. The product is molten "pig iron" which must be converted into steel in the BOF quickly to avoid thermal losses. Because energy and raw material flows account for 70% of production costs, the producer must ensure smooth, uninterrupted operation or else risk lower profit margins, which are already thin in the steel industry.

But there is a solution: Direct Iron Reduction. In this process, a syngas reduces iron ore pellets directly into "sponge iron", without the need to melt it. The syngas is most commonly derived from natural gas, but may also be synthesised from coal. More recently, SSAB has proven it can come from hydrogen, which can be produced via electrolysis powered by renewables (green hydrogen). Furthermore, equipment suppliers of direct reduction plants - Midrex and Tenova - claim that existing natural gas based units can operate with high levels of hydrogen without major modification[3].

The direct reduction (DR) plant is modular and can be redeployed if necessary. It is most commonly coupled with an EAF in the DR-EAF steelmaking route. However, it is not necessary to couple them. The sponge iron, also known as Direct Reduced Iron (DRI), may instead be compacted into Hot Briquetted Iron (HBI) for ease of storage and shipping to an EAF located elsewhere. The EAF melts the DRI or HBI with scrap, the proportion of which is highly flexible.

All of this could lead to a great 'decoupling' of iron and steel production. Whereby large DRI production hubs could be established in regions with abundant land, iron ore reserves and plentiful cheap renewables for green hydrogen production, allowing existing sites to continue operating without blast furnaces and produce green steel for customers at a premium.

One limitation associated with DRI production is its requirement for high-grade iron ore, the supply of which is limited. However, Thyssenkrupp, Voestalpine, Posco, ArcelorMittal, and Bluescope are developing methods for producing DRI from blast furnace grade iron ore fines and pellets. And Finish equipment supplier Metso Outotec has just built a commercially sized HDR plant, based on their Circored technology, that can process iron ore fines[4].

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[1] Based on a complete sector boundary, incorporating emissions from off-gasses which derive coal consumption. By comparison, the International Energy Agency use a boundary optimised for energy statistics and report 7%.
[2] IEA, 2020, Iron and Steel Technology Roadmap
[3] ESTEP, 2021, Green steel for Europe: Investment needs
[4] Green Steel World, 2022, Metso Outotec launches DRI Smelting Furnace to support decarbonisation of iron and steel industry

A green steel revolution

In the past few years, two game-changing developments have contributed to an emerging revolution in green steel. The first was SSAB's successful demonstration of hydrogen direct reduction (HDR) under the HYBRIT project in Sweden[5]. The second is the huge global proliferation of national hydrogen strategies with the goal of accelerating cost reductions and deployment of electrolysers and supply infrastructure.

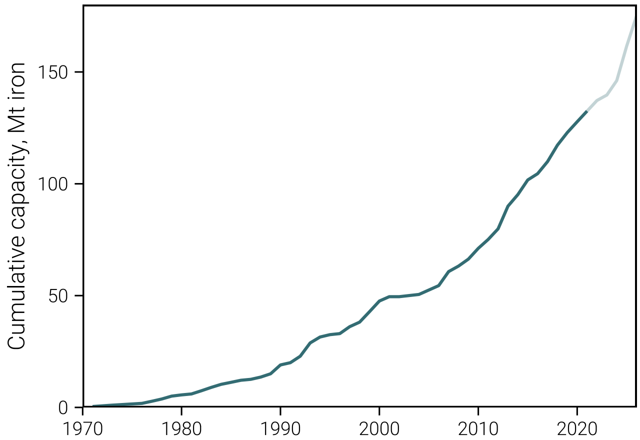
Deployment of DR units is accelerating quickly. In the past few years, companies have proposed projects amounting to an additional 43 Mt of capacity by 2026. Simultaneously, a boom in electrolyser capacity is expected with China assessing a potential 100 GW and Europe planning to add 118 GW[6] and halve production cost to 1.5 US$/kg hydrogen by 2030[7].

The momentum with HDR is mainly in Europe, with SSAB and start-up H2 Green Steel committed to 3.7 Mt of capacity by the mid-2020s. Excitement around iron ore electrolysis (IOE) is also growing, particularly in the US where venture capital-backed start-ups Boston Metal and Electra are aiming for first-of-a-kind commercial scale deployment this decade. ArcelorMittal is also developing electrolysis with a similar time-line in France, and has just invested US$ 36 million towards the Boston Metal project[8].

In comparison to these trends, progress with carbon capture and storage (CCS) technology is slow. The Course50 project in Japan, involving Nippon Steel and JFE Holdings, is not expected to reach the stage of commercial scale demonstration until 2030. Meanwhile, there has been little update on the status of Tata Steel's HISarna project. A plan is in place to develop a large-scale pilot in India, but with no disclosure on time-line nor any plan to link it with CO_2 storage[9].

Such is the pace of change, the current IEA Net Zero Emissions (NZE) scenario has become out-dated. Published in 2021, the IEA outlined a 2050 future in which CCS technology makes up over 50% of primary steel production. The IEA updated their assessment of progress in CCS in their 2023 Energy Technology Perspectives (ETP) report[9], but failed to accompany their findings with an updated NZE scenario.

Figure 5. Direct reduction plant capacity forecast



Source: Midrex, Tenova, Signal Climate Analytics

What is green steel?

Numerous collaborative initiatives have spawned in recent years focusing on green steel. There are private and public procurement initiatives such as the First Movers Coalition (FMC), SteelZero, and the Industrial Deep Decarbonisation Initiative (IDDI). Finance initiatives include the Climate Bonds Initiative, Centre for Climate Aligned Finance, and Glasgow Financial Alliance for Net Zero (GFANZ). For these initiatives to accelerate the steel transition, it must first be defined what "green steel" actually is.

Green steel is often described as "near zero emissions steel", as a small amount of residual emission is inevitable. In order to certify near zero steel, the ResponsibleSteel international standard has created its own definition, in which a series of performance bands grade how green a company's steel is in relation to the proportion of scrap it uses as a feedstock. In response to a request by the German Government under its 2022 Presidency of the G7, the IEA published a report[10] that builds on the ResponsibleSteel methodology and incorporates upstream emissions, including methane, from the supply of raw materials and fossil fuels (known under the GHG protocol as Scope 3 category 1 and 3, respectively).

The need for standardization is manifestly clear in the area of private procurement. A growing number of steel producers are partnering with downstream sectors to secure off-take agreements for a future supply of green steel. This promises a "green premium" for producers looking to recoup some of the additional investment associated with early adoption. Unsurprisingly, with such a nascent market, agreements take many forms.

There are the genuine green steel products, such as SSAB's Fossil-free steel based on their HYBRIT HDR process, Thyssenkrupp's Bluemint steel based on the tkH2Steel HDR concept, and products from start-up H2 Green Steel, who have already signed-off on 1.5 Mt of green steel to be supplied from 2025, when their HDR-EAF plant begins producing[11].

Then there are the emission reduction certificates, issued by companies to customers, enabling them to reduce upstream Scope 3 emissions today. ArcelorMittal's XCarb certificates and Tata Steel's Zeremis Carbon Lite are two examples. While these do reward emission reduction measures, they risk the perverse effect of delaying true structural change because they equate new investment in existing processes, such as blast furnaces and coke ovens, with green steel. For example, Zeremis list the "Installation of a new Coke Oven Gas holder" as one such measure[12].

[5] SSAB, 2021, "The world's first fossil-free steel ready for delivery"
[6] SWP 2022, Electrolysers for the Hydrogen Revolution
[7] HyDeal 2020, Mass-scale green hydrogen hubs
[8] ArcelorMittal, 2023, "ArcelorMittal invests $36 million in steel decarbonisation disruptor Boston Metal"
[9] IEA, 2023, Energy Technology Perspectives 2023
[10] IEA, 2022, Achieving Net Zero Heavy Industry Sectors in G7 Members
[11] H2 Green Steel, 2022, "H2 Green Steel has pre-sold over 1.5 million tonnes of green steel to customers"
[12] Tata Steel, 2022, Zeremis

Dead-end pathways

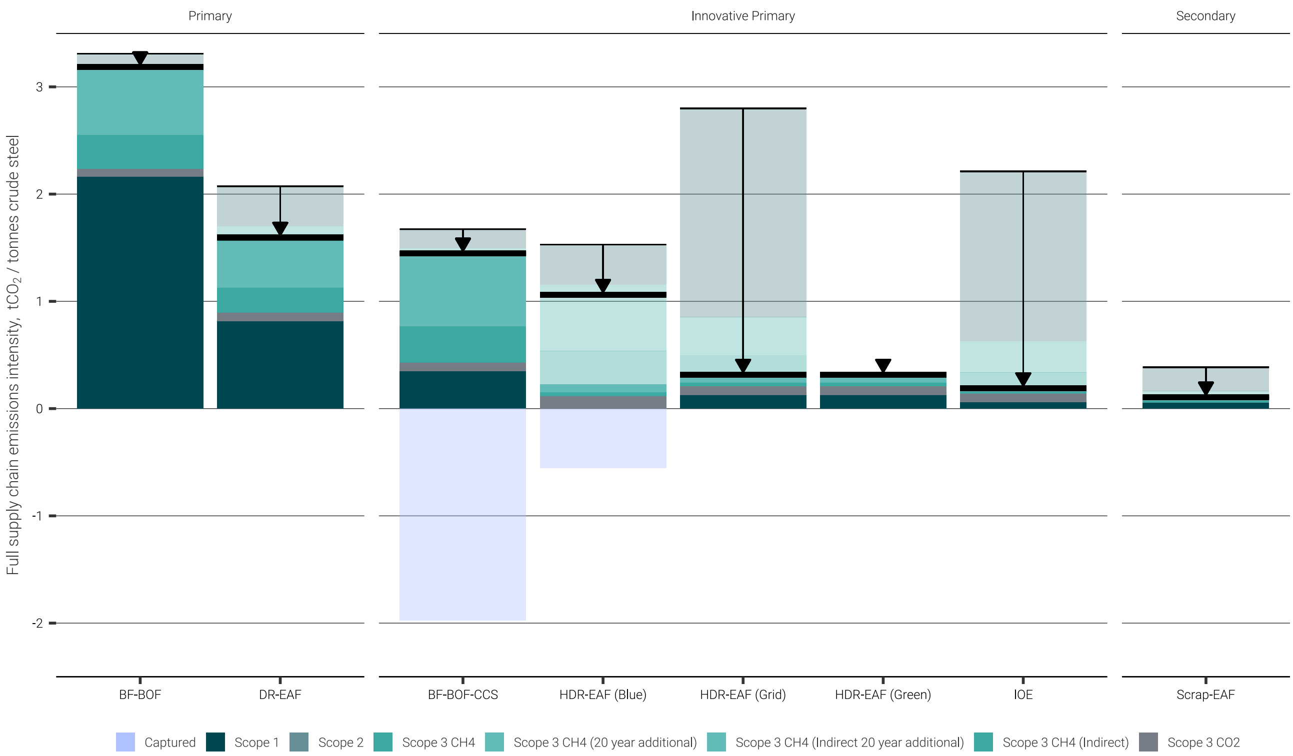
A standard is only useful if it promotes technology decisions that are optimal for minimising emissions. While the IEA's G7 report goes some way in levelling the playing field for different technology options, it lacks in two areas.

Firstly, it uses a 100 year Global Warming Potential (GWP) for methane, which equates methane to CO_2 by a factor of 30[13]. However, to avoid overshooting 1.5°C, a 20 year GWP of 83 is more relevant. Secondly, it excludes upstream methane generated from the supply of imported energy carriers: electricity and hydrogen. This is important because hydrogen based on natural gas (grey hydrogen), or even natural gas with CCS (blue hydrogen), has a significantly higher footprint than water electrolysis (green hydrogen)[14].

Shown below are the emission intensities of key steelmaking routes, adapted from the IEA G7 report to include indirect supply chain methane and the 20 year GWP. The downward arrows show the reduction in intensity from a decarbonising electricity grid.

With this boundary it is not possible to achieve near zero emissions steel with a blast furnace, with or without CCS, and it is not possible to achieve near zero emissions steel with blue hydrogen. The only available technology pathways for achieving near zero steel are green HDR and IOE, and of these only green HDR has been proven at an industrial scale.

Figure 6. Emissions intensity, including supply chain emissions, by steel production route



Source: IEA 2022, Howarth and Jacobson 2021, Signal Climate Analytics

The rise of India

With the goal of doubling steelmaking capacity to 300 Mt by 2030[15], India has set the conditions for rapid capacity expansion and companies are getting in on the act.

Tata steel plans to double its Indian capacity to 40 Mt. JSW Steel is eying 50 Mt, up from 27 Mt, while SAIL aims for 35 Mt from 20 Mt, and Jindal Steel (JSPL) - a relatively small producer - is attempting an astonishing five-fold increase to 50 Mt. And those are just the national companies, ArcelorMittal and Nippon steel aim to triple the Indian capacity of their joint venture AM/NS to 30 Mt, and Posco is breaking into the Indian market through a US$ 5 billion partnership with Adani for a new steel plant.

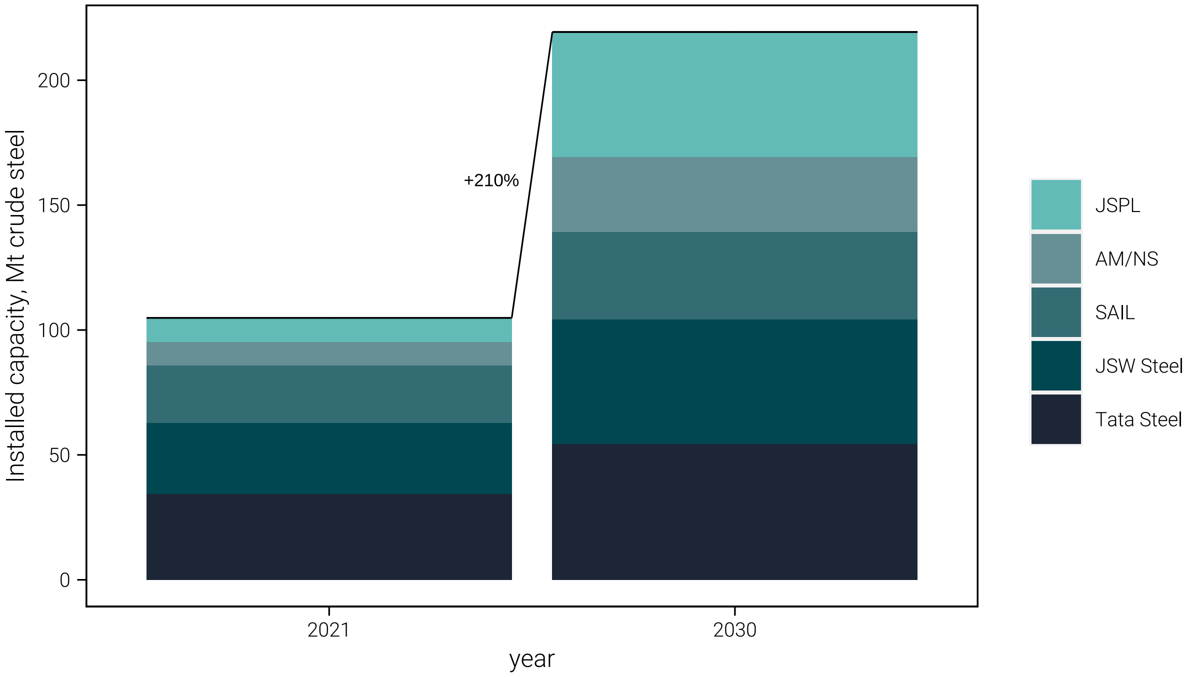
Based on plans announced, this would entail the deployment of more blast furnaces. Indeed, the proposed addition of blast furnace capacity far outweighs that coming from DR plant deployments elsewhere.

What does this mean for the achievement of net zero targets? For global steel companies pursuing new Indian plant capacity, 2050 net zero targets are at risk of being derailed.

In addition to this, climate models indicate that India is of the most at risk countries from heat and water stress.

[13] IPCC, 2021, Sixth Assessment Report. Working Group I: The Physical Science Basis. p1017
[14] Howarth and Jacobson, 2021, How green is blue hydrogen? Energy Science and Engineering
[15] Government of India, 2018, Rise in India's Country's Crude Steel production

Figure 7. Planned steel production capacity expansion from assessed Indian companies



Source: Company announcements, Signal Climate Analytics

Green Steel and the US Inflation Reduction Act

By Caitlin Swalec

Global Energy Monitor

The United States passed the Inflation Reduction Act (IRA) in August 2022, earmarking US$ 370 billion[16] for clean energy development and climate programs, which will require a significant amount of steel to build wind turbines, solar panels, and other infrastructure components. Just the Biden Administration's goal of 30 Gigawatts[17] of offshore wind energy by 2030 could result in demand for approximately 7 million tonnes of steel[17], an increase of nearly 8% of current US production rates.

The IRA includes[18] a domestic manufacturing tax credit to support US based steel production and it also allocates US$ 6 billion of public funding to reduce GHG emissions in heavy industries like iron and steel[16]. However, the US government is missing a key opportunity to drive green steel demand through private procurement by creating an emissions based tax incentive for low emissions steel production. The US Buy Clean policy[19] is an important federal programme to incentivise procurement of green steel (and other building materials) for public works projects, but the US government should also create incentives for private industries to purchase lower emissions steel, in order to ensure that the IRA driven renewables build-out will also fuel the US green steel transition.

About GEM's Global Steel Plant Tracker

The Global Steel Plant Tracker (GSPT)[20] provides information on global crude iron and steel production plants, and includes every plant currently operating with a capacity of five hundred thousand tonnes per year (ttpa) or more of crude iron or steel. The GSPT also includes all plants meeting the five hundred ttpa threshold that have been proposed since 2017 or retired or mothballed since 2020. The GSPT map and underlying data are updated annually. Each plant included in the tracker is linked to a wiki page on GEM.wiki, which provides additional details.

[16] BPC, 2022, Inflation Reduction Act Summary
[17] The White House, 2021, FACT SHEET: Biden Administration Jumpstarts Offshore Wind Energy Projects to Create Jobs
[18] UC Berkeley, 2022, The Inflation Reduction Act Charts a Path that is Pro-Climate and Pro-Worker
[19] Office of the Federal Chief Sustainability Officer, 2022, Federal Buy Clean Initiative
[20] GEM, 2022, Global Steel Plant Tracker

Methodology

Scoring approach

Metric scores range from 0 to 100 and the scoring approach is based on three elements: benchmarks, thresholds, and weights.

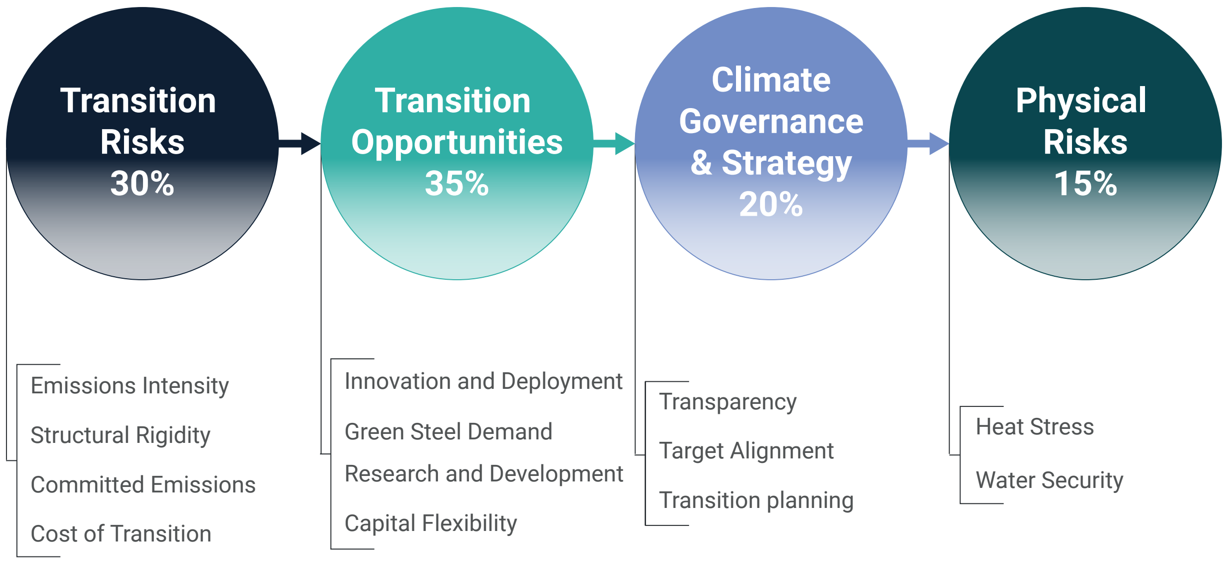
The benchmark is the standard against which company performance is measured. For example, the benchmark for metric "committed emissions" is the emissions budget allocated from a net zero scenario for steel production. The score is "absolute" because it is set against an external standard – the net zero budget – rather than the best performer, as with relative scoring. This means that even the best performer can attain a low metric score.

For some metrics, thresholds (or limits) may be introduced, where companies achieving above a certain threshold cap will achieve the maximum 100 score, or if achieving below a certain threshold floor, will be allocated a score of zero.

After all metrics have been scored, the scores are then aggregated to the theme- and company-level with the use of weights, where the weights assigned to each metric reflect its level of importance to the overall score.

Our metrics are categorised into four themes informed by recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD). These are: Transition Risks, Transition Opportunities, Climate Governance and Strategy, and Physical Risks.

Figure 8. Scoring themes, weights, and metrics



Transition risk metrics

Emissions intensity

- **Emissions intensity and scrap fraction**: Companies are compared on average greenhouse gas emissions per tonne crude steel production. As proposed by the IEA, the boundary includes carbon dioxide and methane from Scope 1, Scope 2, Scope 3 category 1 (raw material supply), and Scope 3 category 3 (fossil fuel supply). Intensities are then plotted against scrap consumption fraction and scored based on the formulation used to define performance bands A-F.

- **Emissions intensity trend**: The compound annual growth rate (CAGR) of emissions intensity over the past five years is benchmarked against the CAGR implied by the IEA net zero emissions (NZE) scenario over the period to 2030. The allocation is weighted to the company's split in primary and secondary steel production.

Structural rigidity

- This metric quantifies the capacity of coal-based process plant as a proportion of total steel production capacity. This includes blast furnaces, coke oven batteries, and coal mines. The more structurally embedded a company is on metallurgical coal as a feedstock, the less flexible it is at transitioning to alternative fuels and feedstocks.

Committed emissions

- Committed emissions are the emissions that would arise from capital assets were they to remain active until their natural retirement. Central to this is the blast furnace, which will emit carbon for 15-30 years between relines. This means that furnaces invested in today could impede a company’s ability to limit emissions without writing them off prematurely as ‘stranded assets’. We compare committed emissions to an allocated net zero emissions budget.

Transition opportunity metrics

Innovation and deployment

- Significant sums of money are going into innovative solutions or deployment of available technologies that represent a structural change away from blast furnace production.

  Adapted from the methodology of de Beer[21], we assess technological solutions over two dimensions: Technology Readiness Level (TRL), and Emissions Reduction Potential (ERP). The ERP uses a scalability factor that embodies limits on diffusion. For example, an Electric Arc Furnace (EAF) is limited to the availability of scrap.

  Finally, we collect or estimate project investment and normalise it as an intensity of steel production capacity. As such, this measure incorporates the scale of structural change required for the company to fully shift its capital stock and complete the transition to green steel.

Green steel demand

- Exposure a company has to markets in green steel can indicate potential gains from the "green premium". We weight potentials to the company by its breakdown of sales by end-market, such as automotive manufacturing and construction.

Research and Development

- Corporate investment in research and development, when taken as fraction of sales revenue, is one indicator of how far a company engages with the innovation chain.

Capital Flexibility

- Capital flexibility reflects the health of a company's balance sheet and can indicate its ability to raise finance for new projects. It takes into consideration free cash flow yield, capex ratio, net debt to equity, and net debt to ebitda.

Climate governance and strategy metrics

Transparency

- For transparency we quantify the evolution of a company over a series of steps in corporate disclosure: 1. Scope 1-2 disclosure, 2. Reporting standards and verification, 3. Scope 3 category disclosure, 4. Keystone metric, and 5. Target disclosure. We create a relevance ranking for scope 3 categories and define the keystone metric as: the emissions performance measure for benchmarking progress to net zero.

Target alignment

- Many companies have established what they describe as ‘net zero’, ‘carbon neutral, or ‘climate neutral’ targets. For this metric, short-, medium-, and long-term emissions targets are compiled and modelled into emissions intensity pathways for each company over the course to 2050. If the modelled emissions over time are greater than the allocated budget, the target is misaligned with net zero and is not 'science based'.

Transition planning

- A target defines 'what' the objective is for emissions reduction, but it does not explain 'how' the objective will be achieved. We define what a sufficient transition plan is and compare the company transition plan to this standard. We require that companies are transparent and explicit on: what technologies will be used, when they will be used, and by how much their use will contribute to the achievement of net zero.

Physical risk metrics

Heat stress

- This metric comprises sub-metrics at asset-level, accounting for annual humid heat days with heat index > 35°C, extreme temperature days with maximum temperature > 42°C, and a warm spell duration index. Projected changes for each of these indicators from recent historical baseline are weighted 70%, current absolute values 30%. Heat stress conditions are projected forward under three climate scenarios, representing high emissions, moderate emissions cuts similar to present day stated policies, and a low emissions / high mitigation scenario.

Water Security

- Water risks at steel company asset locations are assessed using the WRI Aqueduct tool[22]. The metric is comprised of present-day "stressors" including demand, drought severity, and flooding. Future changes in water stress to 2040 under a moderate emissions cuts scenario are also included in the analysis.

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[21] de Beer, J., 2000, Potential for Industrial Energy-Efficiency Improvement in the Long Term
[22] WRI, 2022, Aqueduct

Highlights

League table performance

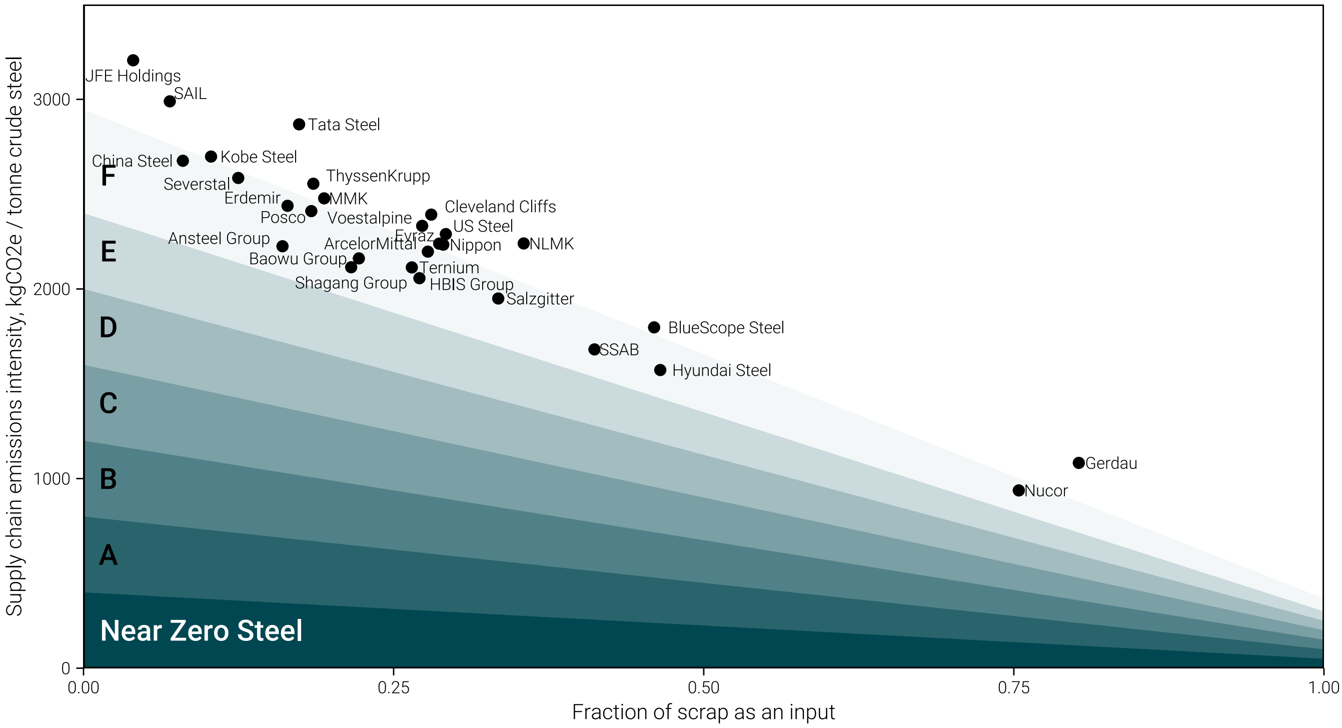
- Posco has achieved the greatest increase in performance. This is mostly a result of recent investment announcements, including a commitment to invest US$ 28 billion on green steel technology by 2040 (transition opportunities).
- Indian companies perform particularly badly as they are investing heavily in new coal-based primary steel production (transition risk) and lack net zero targets or transition plans (governance and strategy). They are also most exposed to heat and water stress (physical risk).
- Conversely, Chinese companies are improving thanks to their recent adoption of net zero targets (governance and strategy) following from China's nationally determined contribution (NDC). Because Chinese steel production is set to decline and scrap availability to increase, it is also easier for companies, such as Baowu, to set bold absolute emissions reduction targets.
- ArcelorMittal and Nippon Steel have seen a general decline in performance. This has mostly resulted from announcements in coal-based steel capacity expansion from their Indian joint venture AM/NS (transition risk). Furthermore, the pace of innovation and technology deployment from ArcelorMittal and Nippon Steel has slowed in recent years relative to the competition (transition opportunities).
- Overall the steel sector has improved the most in target setting (governance and strategy). This follows the movement for "net zero" generated by nation states leading up to the COP26 in Glasgow.
- The risk imposed by committed, or "locked-in", emissions is growing (transition risk). This is because with each passing year there is less emissions budget remaining, and many companies are investing in new blast furnace capacity or extending the life of old furnaces.

Figure 8. Company league table

Company	Headquarters	Transition risk	Transition opportunities	Climate governance & strategy	Physical risk	Total Score	Rank	Rank 2020	Rank 2019
SSAB	Sweden	38	73	91	82	68	1	1	1
Posco	South Korea	29	56	86	50	53	2	6	18
Salzgitter	Germany	19	44	83	98	52	3	7	6
Nucor	USA	85	25	22	78	50	4	4	4
ThyssenKrupp	Germany	17	48	63	94	48	5	3	3
BlueScope	Australia	45	29	70	73	48	6	2	2
Kobe Steel	Japan	29	40	74	66	47	7	5	16
Voestalpine	Austria	18	26	81	86	43	8	8	5
Gerdau	Brazil	66	3	57	67	42	9	14	11
China Steel	Taiwan	27	13	82	68	39	10	21	19
US Steel	USA	36	7	60	85	38	11	11	9
NMLK	Russia	31	16	50	79	37	12	17	17
ArcelorMittal	Luxembourg	9	20	84	69	37	13	9	7
JFE Holdings	Japan	7	19	76	80	36	14	13	8
Nippon Steel	Japan	15	15	75	71	35	15	10	14
Hyundai Steel	South Korea	13	30	61	56	35	16	26	25
Baowu Group	China	8	11	84	75	34	17	16	23
Ternium	Argentina	61	3	28	57	33	18	12	13
Evraz	Russia	36	8	45	67	32	19	18	15
Cleveland Cliffs	USA	25	15	21	90	30	20	19	10
Severstal	Russia	36	3	24	86	30	21	15	12
Ansteel Group	China	14	8	56	65	28	22	25	24
HBIS Group	China	5	13	57	61	26	23	27	27
Shagang Group	China	18	8	0	87	21	24	22	21
Erdemir	Turkey	38	2	0	57	21	25	23	22
Tata Steel	India	7	11	60	12	20	26	24	26
MMK	Russia	38	2	12	30	19	27	20	20
JSW Steel	India	8	5	29	18	13	28	28	28
JSPL	India	6	11	18	13	11	29	30	30
SAIL	India	6	3	11	13	7	30	29	29
Median:		22	13	58	68	35			

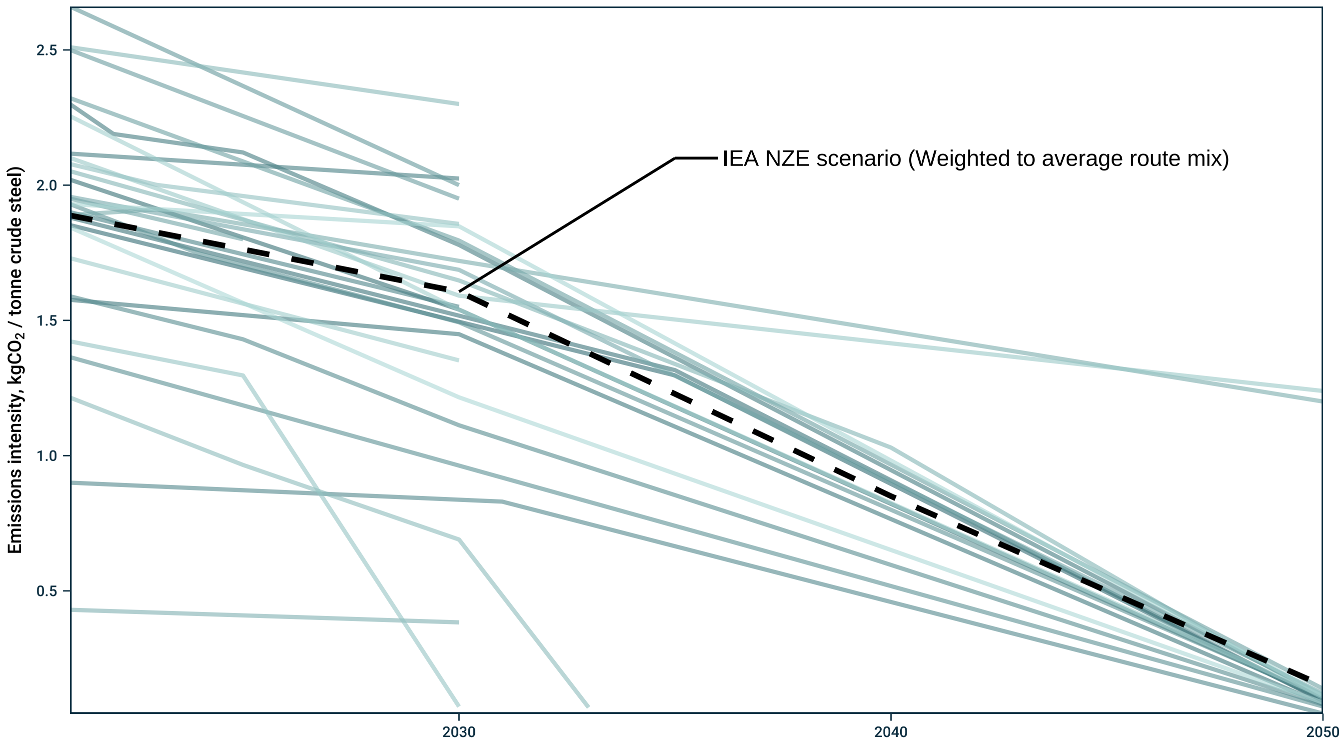
Source: Signal Climate Analytics

Figure 9. Estimated emissions intensity and scrap fraction of companies against IEA performance bands



Source: IEA 2022, Company reports, Signal Climate Analytics

Figure 10. Company target and IEA NZE Scope 1+2 emissions intensity pathways



Source: IEA 2021, IEA 2022b, Company reports, Signal Climate Analytics

Key findings

Transition risks

Emissions intensity

- All companies score F for emissions intensity based on the IEA's proposed formulation for "low emission steel". This may be unsurprising in that the journey of transition for the steel sector, and power sector supplying it, has only just begun.
- The four Indian companies - Tata Steel, JSW Steel, SAIL, and JSPL - are the most emissions intensive due primarily to the operation in India of inefficient rotary kilns based on low grade coal.
- Because scrap consumption is factored in, low intensity companies Nucor and Gerdau still perform as badly as the rest of the group for emissions intensity.

Structural rigidity

- Three highly integrated companies – Evraz, SAIL, and Severstal – perform the worst as they own significant coal mining and coke oven capacity.
- JSPL, MMK, and Cleveland-Cliffs, though integrated, perform well as they depend less on the blast furnace route to produce steel.
- Nucor does not own any blast furnaces and is thus considered the most flexibly structured company from a transition perspective.

Committed Emissions

- There is no longer any room for new unabated blast furnaces. After accounting for the remaining life of existing capacity, relines, and announced additions, there is practically no room on aggregate for new blast furnace deployment without exceeding the allocated net zero emissions budget.
- Companies involved in Indian capacity expansion perform the worst. This includes JSPL, JSW Steel, SAIL, Tata Steel, ArcelorMittal, and Nippon Steel.
- In the case of ArcelorMittal, Nippon Steel, and Bluescope, recent capacity announcements have contributed to demotions in league table position in 2021.

Cost of Transition

- Steel companies are far from able to afford the initial capex of HDR-EAF with on-site electrolysis (about $US 800 per tonne of crude steel) from their own cash flows. This is why they typically rely on public-private partnerships, or some other form of subsidised financing.
- After accounting for the additional cost of production required by HDR-EAF in 2021, only two companies – Severstal and Ternium – would have generated a positive free cash flow.

Transition opportunities

Low carbon technology

- Based on announcements, Posco is associated with by far the largest investment in "green steel" production, amounting to US$ 28 billion by 2040, which is intended to take advantage of cheap solar electricity and plentiful raw materials in Australia.
- On a specific investment basis (investment per tonne of owned steel capacity) Posco is still ranked first for green steel, followed by SSAB, Salzgitter, and Thyssenkrupp, with specific HDR projects ongoing or in the pipeline amounting to a specific capacity of US$ 150-200 per tonne.
- Posco is committed to the largest specific investment in green hydrogen production, estimated at around US$ 1000 per tonne. Salzgitter and ThyssenKrupp follow with specific investments in the range US$ 300-450 per tonne.
- ArcelorMittal is associated with the largest project investment in CO_2 storage, owing to its involvement in the Northern Lights project.
- The key participants in carbon capture utilization and storage (CCUS) projects are ArcelorMittal and Japanese companies Nippon Steel and JFE Holdings, each with estimated investments in the range US$ 200-600 million.
- Most capture projects are classified as carbon capture and utilization (CCU) with no link to CO_2 storage. It is not possible to attribute any meaningful emissions reduction to them.
- Most companies investing in new DR plants are not themselves innovating, but are customers of equipment suppliers Midrex and Tenova. Such is the flexibility of the DR route, these technologies can consume a mix of natural gas or hydrogen, depending on the availability and price of their supply.
- Technologies we classify as most transformational are low-grade iron ore HDR and Iron ore electrolysis (IOE). Steel companies involved in the development of these innovations are: Posco, ThyssenKrupp, Voestalpine, ArcelorMittal, and Bluescope.

Climate Governance and Strategy

Target alignment

- A third of companies have target emission pathways that would not exceed the allocated 2050 budget. These companies either aim for net zero before 2050 or employ commensurate medium-term targets. The top five performing companies are: SSAB, Salzgitter, HBIS, Voestalpine, and Thyssenkrupp.
- SSAB and Salzgitter perform particularly well because they have net zero target years of 2030 and 2035, respectively. In both cases, resulting emissions would consume around half of the allocated emissions budget.
- HBIS has a 2050 target year but performs particularly well, owing to a strong medium-term target of 30% by 2030, and short-term target of 10% by 2025.
- Some companies have only short- or medium-term targets: Severstal, Nucor, JSW Steel, Cleveland Cliffs, Ternium, Evraz, MMK, and JSPL.
- With the exception of Jaingsu Shagang, Chinese companies – HBIS, Ansteel, and Baowu – have net zero targets, which are preceded by the overarching ambitions of the state.

Transition planning

- Disclosure around transition planning is highly variable and is lacking in detail and coherence.
- Companies that perform well are specific about: what technologies will be used, when they will be used, and by how much their use will contribute to the achievement of net zero. Companies can be specific about plans to 2030 but are often vague about the long term.
- SSAB, Salzgitter, Baowu, ArcelorMittal, and Posco, present the most coherent transition plans.

Transparency

- China Steel tops the list in 2021, in part because it discloses annually on nearly all Scope 3 emission categories of the GHG Protocol.
- SSAB is the best discloser of targets data and was ranked first overall in 2020. However, because SSAB only disclose Scope 3 biennially, it is demoted to 4th in 2021.
- A significant number of companies are good disclosers of emissions intensity, but are let down by an incomplete account of scope 3 emissions. The lack of transparency on scope 3 category 11 "use of sold products", for example, is a notable omission.
- Disclosure around the use of offsets in the achievement of targets is poor. Only six companies - ArcelorMittal, Nippon Steel, China Steel, Bluescope, US Steel, and NLMK - are transparent in this area.
- There is significant ambiguity in target disclosure around the incorporation of avoided emissions and whether Scope 2 is measured on a location or market basis.

Physical Risks

Heat stress

- Indian companies SAIL, JSPL, Tata Steel, and JSW Steel are projected to be most impacted by increases in heat stress conditions from the present day, in large part due to an increase in the number of extremely hot days, with maximum temperature exceeding 42°C.
- Salzgitter, Severstal, NLMK, Kobe Steel, Evraz, and Hyundai Steel form a group of companies not projected to be at risk of increased heat stress from extreme heat conditions based on their asset locations.

Water Security

- European and US based companies tend to be at lower risk with water security. Voestalpine, Cleveland Cliffs, US Steel, ThyssenKrupp, and Salzgitter are least at risk.
- All steel assets in India are in locations rated at either ‘High’ or ‘Extremely High’ water risk due to high demand and scarce supply. These impacts are projected to worsen in future as a result of climate change. Companies most affected are SAIL, JSPL, Tata Steel, and JSW Steel. ArcelorMittal and Nippon Steel are also at risk through their Indian joint venture AM/NS.

Climate Scenarios and Pathways

The effects of climate change are often explored through the use of modelled scenarios, which are projections, with uncertainty ranges, of different possible futures. Underlying assumptions about technology market share, socio-economic development, population growth and consumption patterns translate to cumulative greenhouse gas emissions and, in-turn, profiles of climate warming and physical impacts.

The IEA Net Zero Emissions by 2050 Scenario (NZE) is an emissions trajectory towards a particular goal: holding global temperature rise to below 1.5°C (with 50% probability), as aspired to by the Paris Agreement, in an orderly energy transition. Aside from this, the IEA's Announced Pledges Scenario (APS) projects the outcome of countries meeting their pledged Nationally Determined Contributions (NDCs), and the Stated Policies Scenario (STEPS) which provides a trajectory built on today's policy settings and serves as a useful baseline.

IPCC scenarios use representative greenhouse gas concentration pathways (RCPs) and shared socio-economic pathways (SSPs) in integrated assessment models (IAMs) of climate and society. The relevant radiative forcing levels for the Paris Agreement are 2.6 W/m^2 leading to warming of "well below" 2°C and 1.9 W/m^2 limiting warming to 1.5°C or below, as captured by RCP 2.6 and RCP 1.9, respectively.

The SSPs are narratives about future development patterns, from SSP1 (intense mitigation and adaptation) to SSP5 (fossil-fuelled development)[23]. The IEA NZE scenario falls within the bounds of IPCC 1.5°C scenarios, the APS within the range of IPCC 2°C scenarios, and STEPS is closer to 3°C scenarios.

A 12 $GtCO_2$ "ambition gap" exists between APS and NZE in 2030 and, because cumulative emissions are what matters, it is extremely challenging to make up lost ground later. Constant emissions for 6 years will use up the remaining emissions budget for a 1.5°C future. The steep reduction rate implied has led many scientists and organisations to see "no credible pathway to 1.5°C in place" – UNEP[24].

Figure 11. Peak temperature rises in the IEA scenarios

Source: IEA

Implications for the steel sector

As our analysis has shown, there is significant disparity in exposure to physical risks among the world's major steel producing companies. This is a direct result of the geographical sensitivity inherent to heat stress and water security risk, and the wide distribution of steel producing assets.

There are also technological considerations. Iron ore reduction in a blast furnace occurs at temperatures in excess of 1,500°C, whereas a direct reduction plant reaches temperatures of around half this because it is not necessary to smelt the raw material. Blast furnace operation, therefore, has a greater requirement for cooling water than has direct reduction. Furthermore, where hydrogen is used as the reducing agent, emissions are not of carbon dioxide but of water vapour, which can be collected and recycled back into the process.

This would suggest that the blast furnace route may be more at risk from water security. This is particularly relevant for India, where water security risk is high and a considerable expansion in blast furnace capacity is taking place. Blast furnaces and associated ancillary plants must be co-located, use up more land area, and require a larger concentrated workforce per tonne of steel. Because new steel plants are invested in to last for 40 years, physical risks should be considered before projects in India are given the go-ahead.

[23] IPCC, 2021, Sixth Assessment Report. Working Group I: The Physical Science Basis.
[24] UNEP, 2022, Emissions Gap Report 2022

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