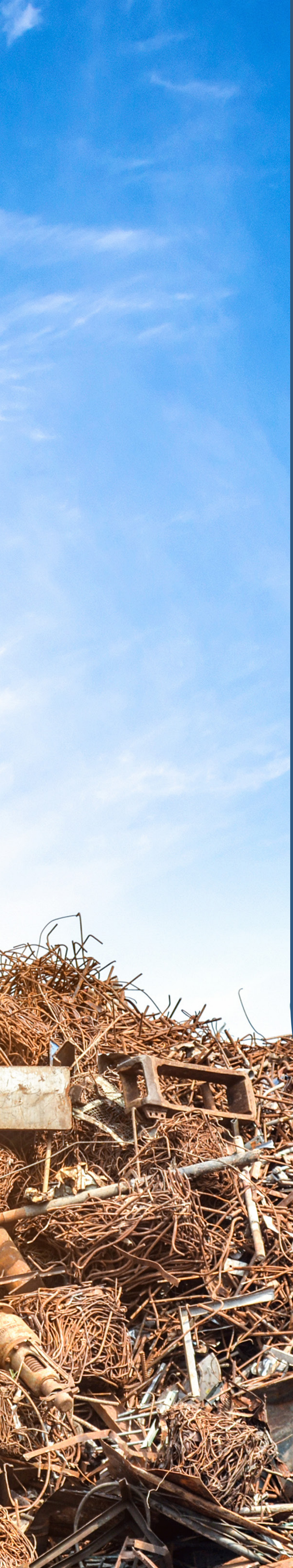
LOW CARBON STEEL DEVELOPMENT IN JAPAN:

Assessing industry preparedness to reduce emissions and become globally competitive in green steel production

November 2023



CONTENTS

KEY TAKEAWAYS

- Without rapid integration of electric arc furnaces (EAF) into steelmaking fleets, and rapid phased retirements of blast furnaces, Japanese steel companies will struggle to meet emissions reduction targets and compete in the global green steel market.
- Japan's three largest steel companies are falling short of the necessary emissions reductions needed to stay on course with a 1.5°C target. Transition Asia analysis of announced corporate plans and policies shows that these steel companies surpass their corporate 1.5°C carbon budgets by substantial margins. Nippon Steel, JFE and Kobe Steel are projected to exceed their carbon budgets by 821 $MtCO_2$, 527 $MtCO_2$ and 137 $MtCO_2$, respectively, between 2019 and 2050.
- Renewable energy (RE) needs to be deployed to EAFs. Transition Asia has calculated the future RE needs for green steel development in Japan, and estimates requirements of 1TWh of RE electricity in 2031 and 38TWh of RE electricity in 2050.

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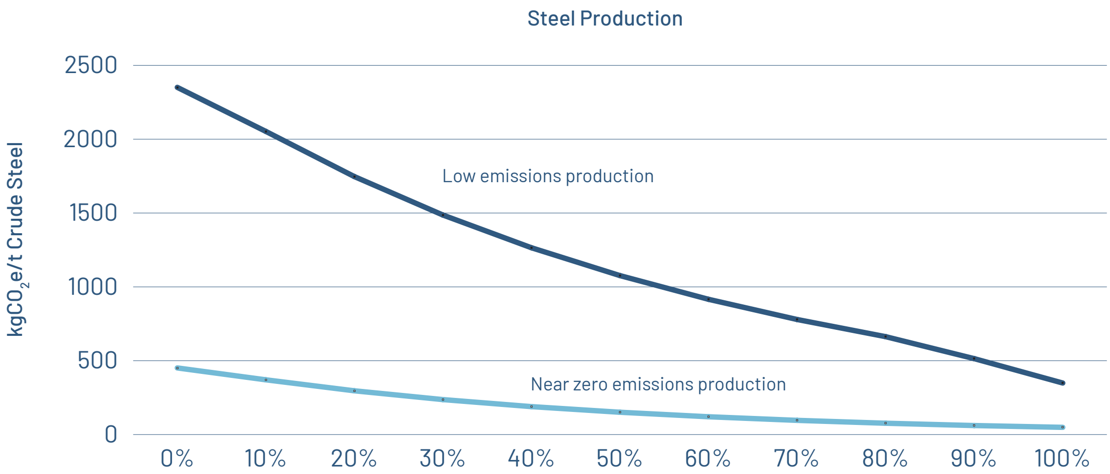
INTRODUCTION

By focusing emissions reduction efforts on the steel industry, supply chains can be decarbonised at the source.

The decarbonisation of the steel industry plays a critical role in the fight against climate change, as steel production currently accounts for 11 percent of global carbon emissions. It is estimated that the world will need to double existing steel production over the next 30 years, and do so while rapidly reducing emissions by more than 90 percent in order to meet the Paris Agreement goals.[1] The need to decarbonise the steel industry cannot be understated, as its climate performance is intertwined with supply chains that span across high-emitting sectors including utilities, automotive, construction, etc. By focusing emissions reduction efforts on the steel industry, supply chains can be decarbonised at the source.

For this reason, "green steel" is a key driver of change that requires the buy-in of a wide range of stakeholders - from policymakers to corporations, and also to consumers. Due to the inconsistency of indicators such as the subject of investigation and calculation scope, the world has not yet reached a consensus on the definition of "green steel." Although definitions may vary, Responsible Steel and the International Energy Agency (IEA) have developed a widely accepted definition of near zero emission steel detailed in Figure 1.

Figure 1: IEA's near zero emission crude steel production threshold as a function of scrap use and proposed classification system[2]



Source: Transition Asia analysis

The boundaries for the definition proposed by Responsible Steel and the IEA illustrate that depending on the proportion of scrap used, the carbon intensity of near-zero emission steel is between 50 and 400 kgCO_2e/t crude steel.[3] In this paper, references to "green steel" refer to steel with a maximum emissions intensity of 220 kilogrammes CO_2e per tonne of steel; This level is derived from Transition Asia's Green Steel Model. This level ensures that low-carbon technologies and resources operate as they commercially do today. These technologies include renewable energy (RE)-based hydrogen (H_2)-Direct Reduced Iron (DRI) -Electric Arc Furnace (EAF) and RE-powered EAF technology.

The Japanese steel industry emits 14 percent of total CO_2 emissions domestically and is the largest emitter among manufacturing industries.

In this report, we outline key barriers preventing the development of the green steel industry in Japan, in addition to solutions and recommendations that can help the country to play a competitive role in the regional and global industries, we analyse the supply and demand side barriers, scrap steel and short-sighted technologies such as COURSE50. Throughout this report we highlight steps taken by the top three steel companies in Japan: Nippon Steel Corporation (Nippon Steel), JFE Holdings (JFE) and KOBELCO (Kobe Steel); and lastly, present analysis into each company's emissions reduction policies and plans.

THE STEEL INDUSTRY IN JAPAN

According to World Steel Association data, Japan was the third largest producer of steel in 2022, following only China and India, contributing 4.7 percent of annual global production.[4] The Japanese steel industry emits 14 percent of total CO_2 emissions domestically and is the largest emitter among manufacturing industries, which makes it a crucial sector to address in reaching the country's 2050 net zero target.[5]

The steel industry in Japan is heavily reliant on blast furnaces (BFs) to meet production needs, with the iron produced in BFs accounting for 76 percent of total steel production.[6] However, since 2017, some of Japan's steel companies have committed to decarbonising the industry. EAF technology has emerged as the only commercial and serious technology to produce steel with low emissions and a high recycling rate. In Japan, this method of steel production uses scrap steel as the primary raw material, reducing the need for iron ore and coal; resulting in significantly lower emissions.

EAF technology is a mature steelmaking method that has produced the majority of steel in the United States since 2002.[7] Currently 43 percent of the world's planned steel production capacity is from EAF technology.[8] Japan's 24 percent share of EAF as a proportion of total steel production leaves it behind global competitors – US: 70%; EU: 42%; South Korea: 32%.[9]

However, Japan's top steel companies, Nippon Steel, JFE and Kobe Steel, still have yet to show a significant shift to capitalise on the emissions reductions of EAF technology. It is estimated that approximately half of the country's BFs will reach the end of operation by 2030, but there are few plans to replace that capacity with EAFs. If re-linings of existing BFs occur, this extension of BF lifetimes will ultimately result in the lock-in of even more greenhouse gas (GHG) emissions.

For example, Nippon Steel aims for EAFs to represent 8 percent of all steel produced by 2030, but regional competitors in countries such as China are working to increase their EAF share to 15-20 percent by 2025.[10] Similarly in the US, the expansion of EAFs powered by RE has led to a steel sector that emits half the CO_2 per tonne of steel produced in Japan.[11] The lack of cohesive policy and planning in Japan makes steel companies vulnerable to trends in the global steel industry and unprepared for decarbonisation requirements.

Transition Asia (TA) analysis shows that without rapidly expanding and integrating EAFs across Japan, key steel producers will fail to make significant emissions cuts by 2030, and continue to fall behind global competitors as green steel becomes increasingly in demand across global supply chains.[12] This scenario analysis suggests that there is very little room for additional blast furnace re-linings from these companies, instead these assets must be largely replaced with other low or zero carbon iron-producing technologies or scrap steel as an input to EAFs. BF re-linings occur at the end of an asset's campaign; typically 15-20 years. Importantly, their financial lifetimes are similar in length meaning that once commissioned, the subsequent emissions are locked in unless investors and companies absorb the financial implications of early mothballing.

Furthermore, RE expansion needs to occur simultaneously with EAF development as a power source, providing even more emissions reductions per tonne of steel, driving competition for low carbon products in the international market.

For example, a 100 percent scrap steel-charged EAF that is powered by the current national grid would result in steel emissions over four times higher than the levels required to categorise it as near-zero emission due to the residual grid emission factor. This could be reduced to half just by powering the EAF with an RE source such as solar or wind. Although Japan's Ministry of Economy, Trade and Industry's (METI's) latest assessment shows the RE sector grew by an impressive 10 percent over the last financial year, Japan's RE use still remains far behind other countries, such as the US, UK, Germany and China.

PART ONE:
MARKET FACTORS OF GREEN STEEL IN JAPAN

DEMAND FOR GREEN STEEL

Globally, the demand for green steel is rising rapidly; however, the growth of EAFs producing Japanese steel has stalled indicating the country is falling behind on its ability to meet future demand for green steel.[13] Japan's large steelmakers cite the uncertainty of domestic and export steel demand outlook as the main reason they are cautious about making a large-scale investment into green steel production, including large-scale EAFs and direct reduced iron (DRI).

While some steps are being taken by Japanese steelmakers to produce steel with lower emissions, this is often not "green steel" as TA defines it or "near-zero emission steel" as Responsible Steel and the IEA define it. Kobe Steel, for example, has entered into several commitments to produce steel with reduced emissions, this steel, marketed as 'Kobenable', uses hot briquetted iron (HBI) from the Midrex process as a feedstock to BFs.[14] As absolute emission reductions per tonne of steel are not considered within the methodology employed to market this steel, TA is unable to consider this a meaningful approach to decarbonising their production processes. Similarly, JFE has also made commitments to produce low carbon steel in a push to elongate the lives of their BFs. This steel, marketed as JGreeX, also employs the mass balance approach to measure CO_2 reduction. Lastly, Nippon Steel has made no significant production contracts for green steel.

Table 1: Japanese steel company commitments to produce reduced emissions steel by industry

Company	Auto	Shipbuilding	Construction	Planned Total Volume of Supply
Kobe Steel	Engine parts for Toyota's racing car Toyota's H_2 racing car Nissan's passenger cars (component not specified)	Bulk Carrier by Imabari Shipbuilding	Property by IHI, Mitsubishi Estate and Kashima Construction	8k t (FY 2022) 1m t (2030) Cf. Nikkei
JFE	No Announcement Yet	Dry Bulk Carrier for 8 customers Dry Bulk Carrier for Onomichi & Higaki	No Announcement Yet	200k t (FY2023)
Nippon Steel	No Announcement Yet	No Announcement Yet	Materials for geothermal project in the Netherlands' with the following link: https://www.nipponsteel.com/en/news/20230928_200.html	300k t (FY 2023)

[14] The Midrex Process is a method for producing DRI, HBI or sponge iron from iron ore fines. It is a metallurgical process used in the steel industry to create a more pure form of iron that can be used as a feedstock in EAFs or other steelmaking processes. The Midrex Process is one of several technologies used for DRI production, but it is widely recognised and has been in use since the 1960s.

This current pipeline exemplifies the weak demand for steel marketed as green or low carbon in the domestic market in Japan, perhaps reflecting corporate appetite to source more concrete and verifiable emission reduced steel through long term contracts. This in contrast to branded steel offerings providing incremental decreases in emissions seen on the Japanese market.

In China, there has been rapidly growing demand, particularly in the automotive sector. One of these examples includes one of China's largest steel producers, HBIS Group, announcing a memorandum with BMW for lower emission steel supply.[15] The volume of supply of steel itself is not disclosed, but the production facility of BMW in Shenyang where the company will receive the steel from HBIS produces as much as 650 thousand vehicles per year.[16] In addition to this, Baosteel also plans to start reduced emissions steel supply to BBAC (Beijing Benz Auto Co.), but also does not disclose the volume.[17] While it is a positive step to see meaningful emissions reductions being incorporated into global corporate plans, it is important to note that most efforts for reduced emissions steel is not in line with TA or Responsible Steel and IEA's "green steel" or "near-zero emission steel" definitions.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A NOTE ON THE 'MASS BALANCE APPROACH' FOR QUANTIFYING EMISSION REDUCTIONS

The mass balance approach to evaluate emission reductions serves as a method to account for and quantify material flows and emissions within a specific system or process. It provides a structured methodology for tracking inputs, outputs and changes in materials, allowing for the measurement of emissions and the assessment of the impact of emission reduction measures within that system or process.

For example, introducing HBI into a BF can lead to emission reductions when assessed using the mass balance approach. Initially, a baseline assessment determines emissions associated with the conventional BF process, including CO_2 emissions from coke combustion. When HBI is introduced, it replaces a portion of traditional raw materials. A post-implementation assessment recalculates emissions, considering both the BF process and HBI production. The difference between baseline and post-implementation emissions reflects the reduction achieved through HBI utilisation, primarily due to HBI's efficiency and lower carbon intensity compared to traditional materials. These differences can then be aggregated and subsequently allocated towards individual products.

When Kobe Steel claims a 100 percent reduction compared to conventional products through its Kobenable premier steel, it is the aggregation of the difference between the baseline assessment and the post-HBI implementation assigned to single products. The actual emissions reductions between conventional products and Kobenable are not being referenced here. As HBI from the Midrex process represents a 30-40 percent decrease in emissions reductions compared to pig iron from the BF and the total proportion charged into the BF is unlikely to be substantial, TA's view is that this should not replace long-term near-zero emission solutions.

When steel companies aim to offer low carbon products, it is essential that they account for the emissions generated during production using a recognised and verifiable carbon accounting system, such as Life Cycle Assessment (LCA), the Greenhouse Gas Protocol, or similar established methodologies. This is to ensure transparency and credibility in assessing the carbon footprint of their products. The claim that BF-based steel production can provide 100 percent CO_2 reduction is disingenuous marketing and does not provide absolute emissions reduction information.

Widening the scope in East Asia, South Korea is also becoming a competitor for green steel through POSCO, South Korea's largest steelmaker, which has secured several green steel agreements from Japanese companies. POSCO has made an agreement with Honda (one of Japan's largest automakers) that includes research and development (R&D) cooperation in electric vehicle (EV) production and green steel supply.[18] This case in particular implies additional evidence that the Japanese steel industry is already falling behind its regional competitors. POSCO has already announced a plan to complete an H_2-DRI-based green steel R&D project by 2028 and commercialise that technology by 2030.[19] In contrast, the Japanese steel industry is aiming for H_2-DRI implementation around or even post-2050.[20][21]

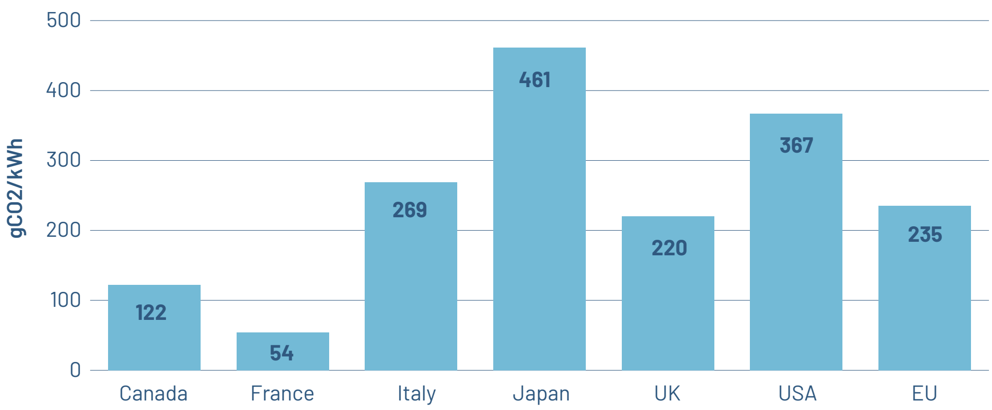
RENEWABLE ELECTRICITY FOR GREEN STEEL

Grid-based emissions from the use of electricity are the main source of emissions from using an EAF but they can be drastically reduced through the use of clean RE.

A key issue affecting the supply of green steel is RE availability. Grid-based emissions from the use of electricity are the main source of emissions from using an EAF but they can be drastically reduced through the use of clean RE (note that BFs on the other hand are powered by coking coal). However, Japan still relies heavily on electricity from fossil fuels, making up 72 percent of electricity generation in 2021.[22]

As shown in Figure 2, Japan's grid emission factor (carbon emissions per unit of electricity generated) is very high compared to other G7 countries. The Japanese government has been unambitious in its deployment of RE thus far, and still relies heavily on imported fossil fuels as a source of energy.[23]

Figure 2: Grid Emission Factors of the G7

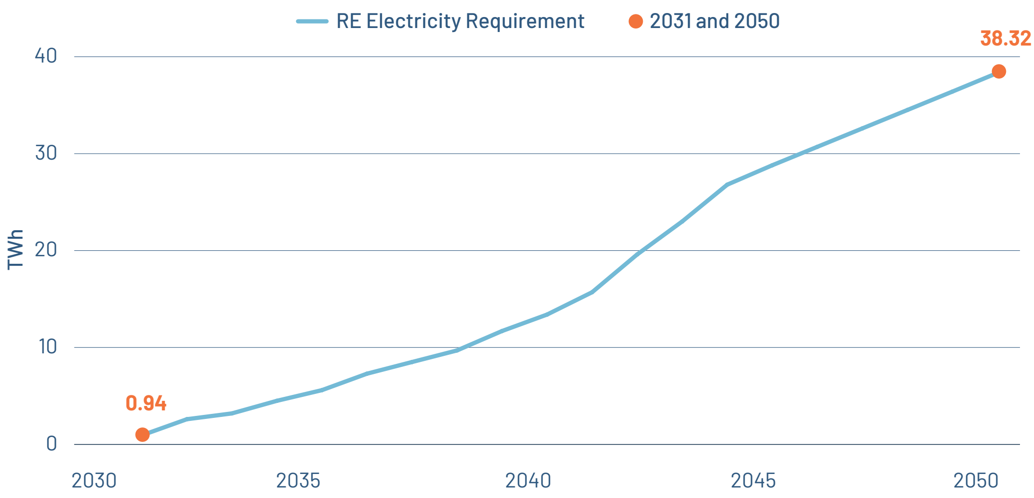


Source: IEA, Emissions Factors 2022

Regardless, RE is growing in Japan, with the country's Strategic Energy Plan setting a target of 38 percent of the energy mix by 2030 (up from 20 percent in 2022). This growth is important for the development of green steel, as EAF technology for the production of steel will increase electricity demand. Without relying on the national grid emissions, steel companies will need to procure RE to produce green steel, and will therefore need to secure renewability claims to the electricity used by EAFs. Although spot-based or long-term contracts for certificates such as J-Credits can do this, power purchase agreements (PPAs) are a more attractive mechanism as prices can be hedged and electricity supply can be bundled with renewability claims.[24] Facing numerous headwinds to fully decarbonise the steel industry due to emission manifested in logistics, supply chain and DRI production, securing RE to power scrap-charged EAFs is the quickest and most cost efficient way to make material progress on producing green steel.

Transition Asia has calculated the future RE needs for green steel development in Japan, and estimates requirements of 1TWh of RE electricity in 2031 and 38TWh of RE electricity in 2050. We believe that this level of power is feasible for companies to secure in the short-term.

Figure 3: RE electricity requirement for green steel in Japan



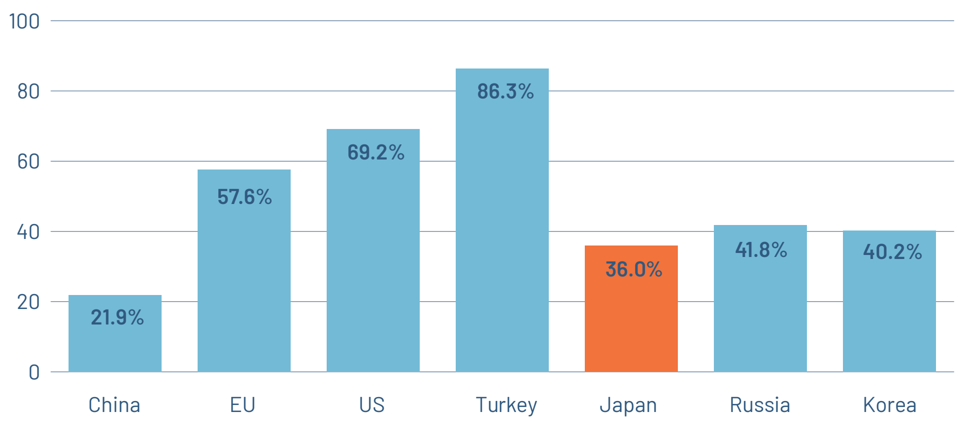
Source: Transition Asia analysis

SCRAP STEEL

Steel is the most recycled material in the world, as it can be infinitely recycled without losing any of its properties.[25] Although scrap steel is used in both BF and direct reduced (DR) integrated processes, it is predominantly used in stand-alone EAF facilities.[26]

A healthy scrap market is conducive to EAF market growth, as an EAF can be charged with 100 percent recycled material. Japan's crude steel output comprises around 35 percent scrap, of which the majority is charged into the country's EAFs, although BF mills are purchasing higher grades of scrap to decrease the emissions intensity of their product.[27] International peer comparison of scrap ratios (Figure 4) shows Japan at the lower end of scrap use, reflecting the country's position as a net exporter of scrap steel with local EAF mills competing against higher export prices.

Figure 4: Scrap steel ratio in Japanese domestic consumption, 2021



Source: BIR [28]

Most of Japan's scrap steel has historically been sent to South Korea, Vietnam and Taiwan; however, newer markets in countries aiming to create a domestic steel industry such as Bangladesh are becoming strategically important to exporters. As a net exporter of scrap, Japan sends about a quarter of all scrap abroad for processing.

Due to limited scrap availability in Japan, several technical advancements have been made to dilute impurities, including DRI and scrap charged together into an EAF. This solution enables steelmakers to use lower grade scrap without investing large amounts for new facilities. This is an example of a solution that may allow Japan to compete on green steel production regionally. But in order to do this, domestic stakeholders will need to assure the procurement of DRI. JFE has shown that DRI will have to be secured from abroad in the short term, and has entered into an agreement to import natural gas-based DRI from the UAE .[29]

[26] For more information, see Transition Asia's scrap steel explainer here: https://transitionasia.org/scrap-steel-explainer/

Although scrap steel is often manufactured into low-grade steel products for use within the construction sector, a growing segment of high-grade steel derived from scrap steel for uses within the automotive sector is under development. Steel-intensive industries are providing clear demand signals to steelmakers requiring decarbonised steel products. EAFs charged with DRI or Pig Iron mixed with high-grade scrap have provided the American automotive industry with cleaner steel for years. Offtake agreements for green steel such as the high profile contracts signed between Hybrit and Volvo and Ford Europe and Tata signal a shift away from high-emission BF-BOF-based steel.

Although most impurities in scrap can be removed during the formation of slag, technological limits still exist for scrap steel. Even after screening and separation, scrap steel can still be contaminated by metals such as copper and tin at very low concentrations. The presence of these "tramp" elements therefore limits the quality and performance of recycled steel output. By developing Japan's scrap market to reduce the occurrence of tramp element contamination, the shift to EAF technology can be further incentivised. Companies should be identifying solutions to use more scrap steel, while policymakers need to be making scrap steel a more sound investment at home.

EMISSIONS REDUCTION TECHNOLOGY NOT FIT FOR A NET ZERO FUTURE

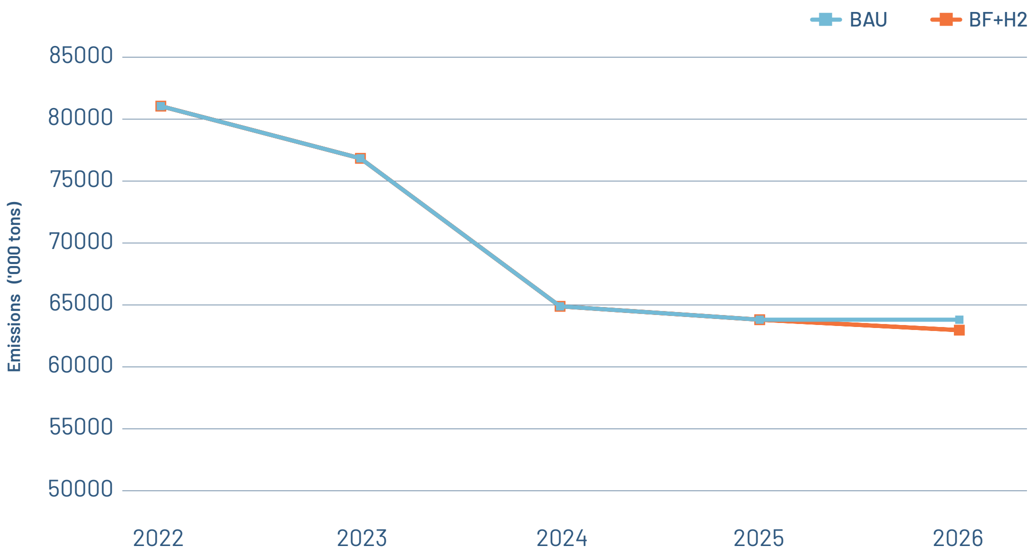
COURSE50 remains an unproven at scale and high cost technology [...] Its carbon reduction effectiveness is only a theoretical 30 percent. Moreover, 20 percent of that 30 percent is reliant on CCS.

In the pursuit of emissions reductions, steel companies have endorsed the development of retrofitted technologies for BFs. In Japan, the most well-known and prominent solutions for achieving such reductions is via a technology called COURSE50.

COURSE50 is a technology under development by the three largest Japanese steelmakers (Nippon Steel, JFE and Kobe Steel). The core of the technology is injecting hydrogen back to BFs, which is retrieved from by-product gas emitted from the BFs. Injected hydrogen works as a reducing agent for iron ore and partially replaces the primary reducing agent, i.e. coking coal. This will bring a 10 percent emission reduction in comparison to full coke-based iron making. Additionally, COURSE50 will employ carbon capture and storage (CCS) technology and the aggregated emissions reduction effectiveness is a maximum of 30 percent in total. COURSE50 is planned to be developed into SuperCOURSE50.[30] Companies are hoping that this technology will result in emissions reductions of up to 50 percent compared with conventional BF-BOF steel, which still leaves a large gap from meeting the aforementioned definitions for green steel.[31]

COURSE50 remains an unproven at scale and high cost technology that has been under development since 2008 and is still not expected to be in commercial operation until 2030 - an expected development timeline of more than 20 years.[32] Its carbon reduction effectiveness is only a theoretical 30 percent. Moreover, 20 percent of that 30 percent is reliant on CCS, known for being technologically and economically challenging due to low BF CO_2 concentrations, amine volatility and the additional energy requirements for the equipment.

Figure 5: Effect of BF+H_2 integration versus BAU for Nippon Steel



Source: Transition Asia analysis

Integration of this new technology into the Kimitsu Area BF—which makes up around 10 percent of total production of Nippon Steel— would result in a group annual emission reduction of 1 to 2 percent in 2026 compared to our business-as-usual (BAU) scenario. Note that this reduction is the maximum fixed amount and will not increase. Steel companies can only reduce their emissions in the long-term by shifting their production fleet of BFs to EAFs, integrating the use of DRI and scrap and increasing the use of RE.

OTHER AVENUES FOR GREEN STEEL IN JAPAN

HYDROGEN PRODUCTION AND DRI IMPORT

The Japanese Government released the newly revised Hydrogen Strategy in June 2023.[33] This revised strategy sets the annual target for hydrogen availability up to 3 million tonnes by 2030, around 12 million tonnes by 2040 and around 20 million tonnes by 2050, which was approximately six times higher than the previous targets. While this is a positive step forward, it is important to address what resources the planned hydrogen will come from.

Although the Japanese government states that carbon intensity in the production processes of hydrogen is important, it does not specify the type of hydrogen or colour of hydrogen that is planned such as grey, blue, etc. (these colours denote its source material and therefore carbon intensity).[34] The definition of green hydrogen in the strategy is set at 3.4kg-CO_2e/kg of hydrogen and this target can be realised with some abating solutions such as CCS. However, the strategy itself admits that installation of CCS at a commercial and full-scale level is expected around 2030 and does not specify the timeline over when the 3.4 kilogram intensity target comes into force.

Even if these concerns were solved in some way, the challenge of high cost remains. The strategy defines the cost target as:

- 30 JPY (approx. 20 US cents)/Nm^3 or 334 JPY (approx. 3 USD)/kg by 2030; and
- 20 JPY (14 cents)/Nm^3 or 222 JPY (2 USD)/kg by 2050.

In addition to cost constraints, the availability of hydrogen is also far less than the amount the industry requires. The government is targeting 20 million tonnes across all the industries by 2050 and estimates the demand for the steel industry to be 7 million tonnes in 2050[35]. However, the government also acknowledges the demand in the steel industry may reach up to 20 million tonnes at the maximum, meaning that the total hydrogen availability of 20 million tonnes that the government is aiming for may only be able to meet the demand of the steel industry alone.

Japanese steel companies can expand investment into large-scale EAFs within Japan while simultaneously continuing to develop and expand overseas steel operations.

However, for Japan the idea of importing green hydrogen, or any other type, such as grey hydrogen produced from fossil fuels, is unlikely. The main issue is that gaseous hydrogen has a very low volumetric energy density, necessitating expensive and energy-intensive processes like compression, liquefaction (to temperatures as low as -253°C), or conversion to ammonia (NH_3, which liquefies at -33°C) for efficient storage and transport. Given this, and considering that the steel industry is already largely dominated by multinational corporations, the most competitively priced decarbonised steel is likely to originate from regions with abundant and cost-effective RE production and iron ore resources.

This will drive Japanese steel companies to look outside Japan and toward other countries in which to build greenfield H_2-DRI-EAF plants that have access to the key steelmaking feedstocks.

While BF-BOF processes have led to highly integrated steel mills, there's an opportunity with DRI technology. DRI can be compacted into hot briquetted iron (HBI) at high temperatures, offering storage and transportation at costs similar to iron ore. This opens up a strategic possibility for Japanese steel producers: separating HBI production from EAF steelmaking and expanding the latter to cater to Japan's green steel market.[36] A similar geographic separation of H_2-DRI from EAF has been implemented by ArcelorMittal in Spain, showcasing the potential of this approach.

In this context, Japanese steel companies can expand investment into large-scale EAFs within Japan while simultaneously continuing to develop and expand overseas steel operations.

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Transition Asia

PART TWO:
TRANSITION ASIA ANALYSIS INTO CORPORATE DECARBONISATION

JAPANESE STEEL COMPANIES' DECARBONISATION PATHWAYS AND THEIR ROLE IN GREEN STEEL MARKET DEVELOPMENT

DECARBONISATION PLANS AND TARGETS

Nippon Steel, JFE and Kobe Steel, together referred to as "the Big Three", have set decarbonisation targets with a focus on reducing their emissions by 30 percent by 2030, relative to a baseline year of 2013. These companies have also established long-term decarbonisation targets (covering Scopes 1 and 2), aiming to achieve carbon neutrality by 2050. As of 2023, Nippon Steel has made the most substantial progress, achieving a 61 percent reduction toward its 2030 target, while JFE and Kobe Steel have achieved reductions of 32 percent and 38 percent, respectively.

Despite these efforts, none of these corporations have adopted science-based targets or are members of the Science-based Targets initiative (SBTi). Furthermore, a net zero target has not been announced by any of these companies, focusing instead on what is fast becoming an outdated concept: carbon neutrality. Similarly, their goals are not yet aligned with the IPCC AR6 1.5°C pathway, indicating room for further alignment with the latest climate science. Although these targets portray a collective commitment to reducing carbon emissions within the steel industry, they are with varying degrees of progress and there is substantial room for enhanced alignment with the technology needed to reach a 1.5°C-aligned target.

Table 2: Japanese steel company climate commitments, targets and progress

Indicators	Nippon Steel	JFE	Kobe Steel
Emission reduction targets of the three corporations: Nippon Steel[37] JFE[38] Kobe Steel[39]	Target year: 2030 Scopes: Scope 1 and Scope 2 Base year: 2013 Reduction: 30% Target year for reaching carbon neutrality: 2050		
Current progress on 2030 target[40]	61%	32%	38%
Science-based targets/SBTi membership[41]	No		
Net zero target	No		
IPCC AR6 1.5°C-aligned target	No		

[40] Calculation based on 2021's results shown in company's latest 2022 reports.

The Big Three's public decarbonisation plans show very limited decarbonisation solutions to enable green steel production. Most of the emissions reduction solutions are expected to be implemented in 2030 and after, and the current focus is on reducing emissions from existing BFs and continuing to reline them.

The Big Three's public decarbonisation plans show very limited decarbonisation solutions to enable green steel production.[42 43 44] Most of the emissions reduction solutions are expected to be implemented in 2030 and after, and the current focus is on reducing emissions from existing BFs and continuing to reline them, rather than shift significant production capacity to EAFs or H_2-DRI. As noted previously, maintaining production from BFs will only enable a finite amount of emissions reductions.

Before 2030, the Big Three are primarily focused on enhancing the efficiency of their BFs and implementing incremental changes to reduce emissions. These efforts include improving BF efficiencies, transitioning from coking coal to biomass and introducing HBI charging in BFs, as well as increasing scrap utilisation in the BF-BOF process. These measures are aimed at reducing carbon emissions associated with their traditional steel production processes.

Looking ahead to the period after 2030, these steel companies have outlined their strategies for further emissions reduction. Nippon Steel, for instance, plans to introduce COURSE50 technology, as mentioned in Part One of this report.[45] However, the timeline for full-scale implementation and the associated CAPEX remains uncertain, as this technology has been in development since 2008 and is still not yet ready for extensive testing.

JFE, on the other hand, is betting heavily on carbon capture recycling technology for their BFs, which is planned for rollout in 2030. This technology aims to capture and recycle carbon emissions, offering a potential reduction of up to 20 percent per tonne of steel, a solution that is also short-term in emissions reduction focus.

Meanwhile, Kobe Steel is taking the least action, reducing emissions by producing "lower-carbon" products in their BFs and exploring the use of artificial intelligence to enhance operational efficiencies, but not providing many details on any of the potential emissions reduction expectations.

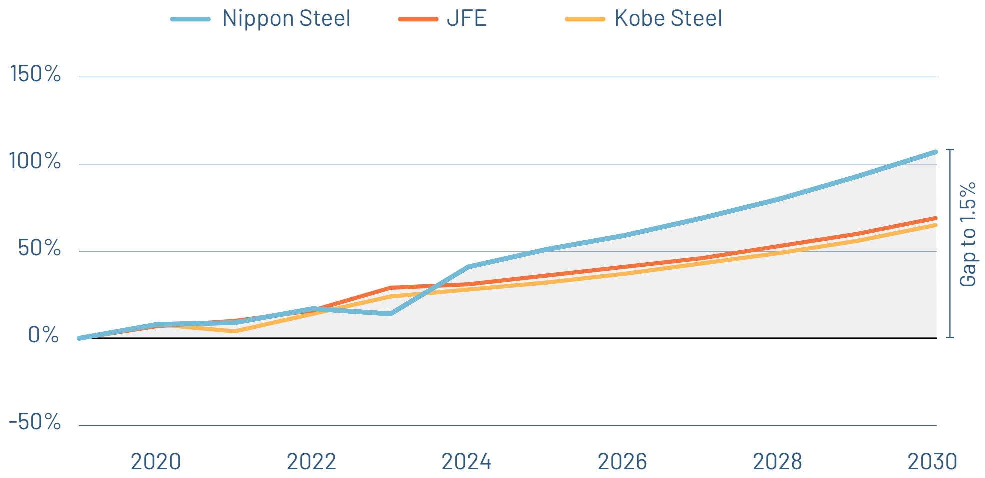
In addition to these efforts, all three steel companies plan to incorporate large-scale EAFs in their production processes and transition to using H_2-DRI with RE-based hydrogen. However, these technologies are not expected to contribute significant emissions reductions for the majority of steel produced post-2030. H_2-DRI with RE-based hydrogen is already operational in Sweden, and EAF-based steel production is well-established and known for its emissions efficiencies, posing the question: why are these large steel companies investing in unproven technologies that will not meet 2050 emissions reduction requirements?

BIG GAPS IN CARBON INTENSITY BETWEEN DISCLOSED CORPORATE TARGETS AND A 1.5°C PATHWAY

Under their existing targets and strategies, all three companies are falling short of the necessary emissions reductions required to stay on course with a 1.5°C pathway.

To determine steel emissions, a combination of historical data from 2019 to 2021 and forecasting data from 2022 to 2030 is utilised in TA's analysis. Specifically, the emissions for the years 2022 to 2030 are projected through a linear decrease starting from the disclosed emission target for 2022 and extending to the corporate target year of 2030. Carbon intensity is defined as the ratio of steel emissions to steel production. Regarding steel production, it is derived from a similar data combination, using historical data from 2019 to 2021 and forecasted data from 2022 to 2030. The forecasting for steel production during 2022 to 2030 relies on the corporate's disclosed production plans; in cases where no such disclosure is available, a flat production rate is assumed.

Figure 6: The Big Three's gaps in carbon intensity between disclosed targets and 1.5°C pathway (gap %)



Source: Transition Asia analysis

In this analysis of the Big Three, we have plotted and forecasted each company's carbon intensity trajectory. The results of this analysis reveal a critical misalignment with a 1.5°C target. Under their existing targets and strategies, all three companies are falling short of the necessary emissions reductions required to stay on course with a 1.5°C pathway.

When examining the extent of this misalignment, it becomes apparent that Nippon Steel is projected to face the largest gap, with emissions intensity forecasted to be a staggering 107 percent above the 2030 1.5°C benchmark. JFE follows closely behind with a 69 percent gap, while Kobe Steel is left with a 65 percent deviation from the required 1.5°C emissions intensity. While these companies have disclosed planned reductions in steel production, TA analysis suggests that their current efforts are insufficient and would need to nearly halve between 2019 and 2030 to align with a 1.5°C pathway.

It is clear that the steps being taken by these companies are not compatible with the ambition required to adhere to a 1.5°C trajectory by 2030. Moreover, there is a concern that the Big Three may be ill-prepared to meet post-2030 targets and the ultimate objective of achieving net zero emissions by 2050. To navigate this critical juncture successfully, these steel industry leaders must intensify their efforts, explore proven technologies and collaborate extensively with stakeholders across the value chain.

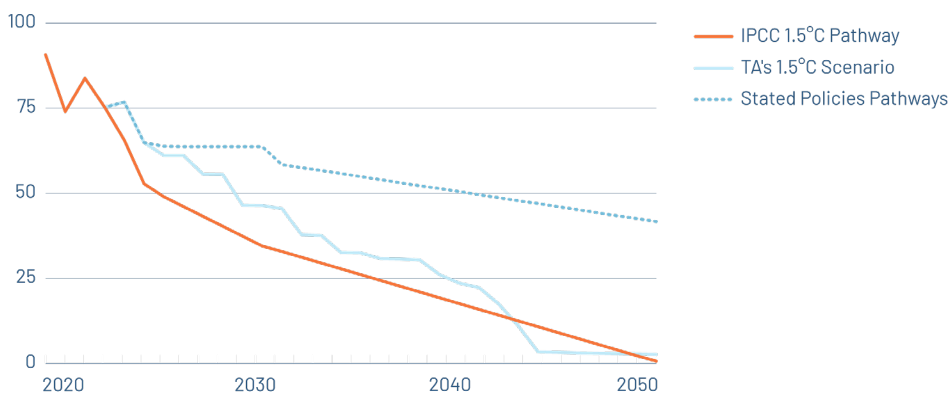
ABSOLUTE EMISSIONS TRAJECTORIES OF THE BIG THREE FROM 2030 TO 2050

This analysis presents a comprehensive view of the absolute emissions trajectory for the Big Three from 2030 to 2050. To achieve this, a "stated policies scenario" has been modelled that maps out the anticipated emissions reductions resulting from planned technologies within our forecast. Within this scenario, we have scaled up the deployment of technologies like COURSE50 and large-scale EAFs in alignment with the companies' indicated technology adoption timelines. In cases where specific information on the proportional production of steel from each technology is not available, considered assumptions have been made.

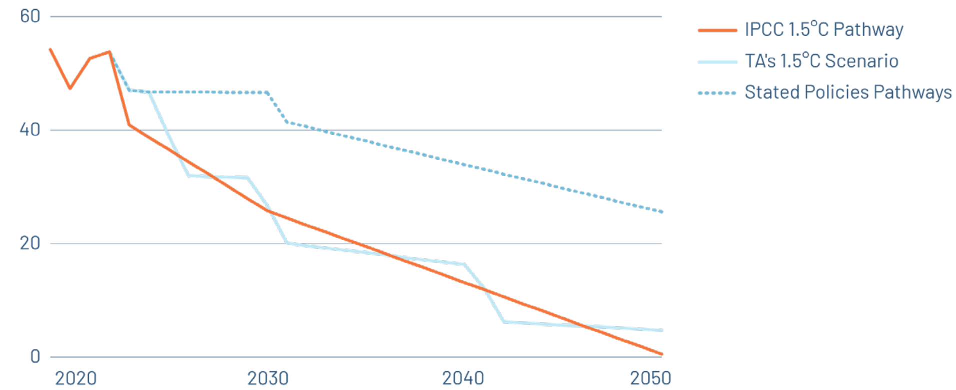
For a 1.5°C pathway, we have modelled technologies that demonstrate significant and proven emissions reductions while also incorporating planned technologies that may not achieve near-zero emission steel production. This scenario ensures that emissions stemming from steel production remain within the confines of the "corporate carbon budget" derived from company disclosures and the latest IPCC climate science. Steel production forecasts have been held constant throughout these scenarios, providing a forward-looking perspective on emissions trajectories.

Figures 7 (Nippon Steel), 8 (JFE), 9 (Kobe Steel), 10 (Big Three, consolidated): Emission pathways 2019-2050 ($MtCO_2$)

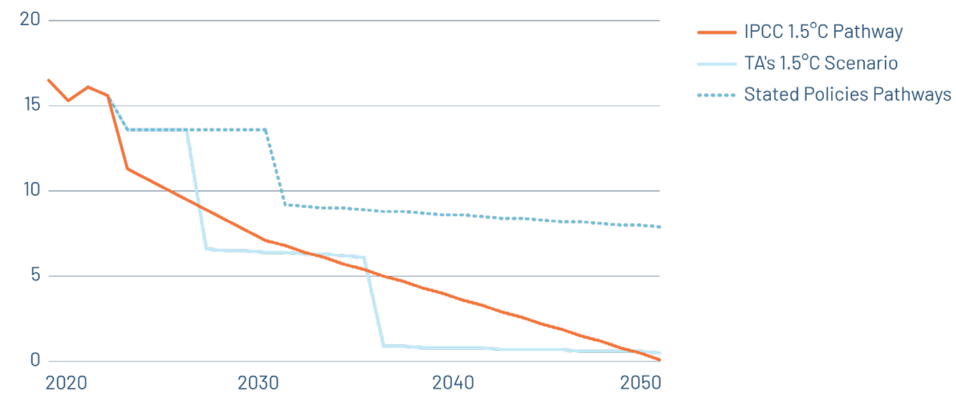
Nippon Steel



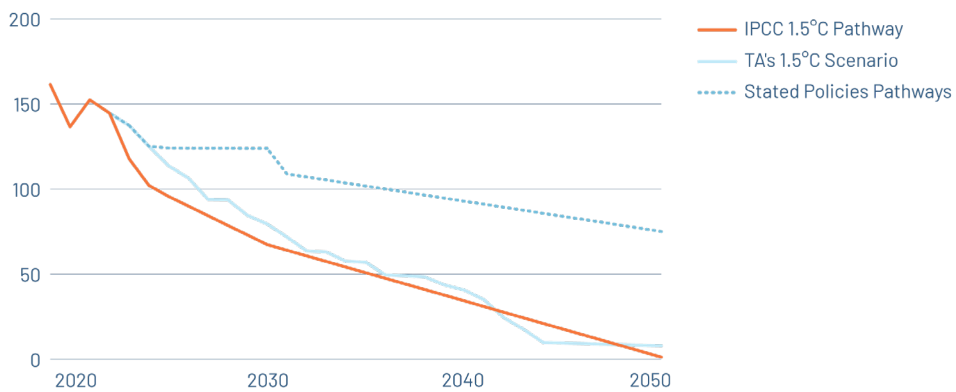
JFE



Kobe



The Big Three, Consolidated



Source: Transition Asia analysis

All of the emissions reductions pathways illustrate that emissions from the companies are set to decrease significantly as they get closer to 2050, due to expected technological advancements that will come online in this time period such as hydrogen co-firing and large-scale EAFs. These pathways also take into account the expected decrease in steel production between 2019 and 2030.

The Big Three's Stated Policies Pathways put them on trajectories that are far off a 1.5°C pathway and show that total emissions between 2019 and 2050 exceed Nippon Steel, JFE and Kobe Steel's corporate carbon budgets by more than 821 $MtCO_2$, 527 $MtCO_2$ and 137 $MtCO_2$, respectively.

Each of the steel companies have one key technology under development, Nippon primarily focuses on COURSE50, the charging of Hydrogen into a BF incorporated with CCS; JFE primarily carbon recycling + CCU; Kobe Steel primarily on HBI charging into BFs. All three technologies are BF-based, reflecting that all iron making facilities owned by the Big Three in Japan are BFs. This proves a critical headwind for these steel companies as steel making outside of the traditional BF-BOF route is either scrap-EAF or DRI/HBI-EAF based. Noticeably, Kobe Steel is utilising its position as the owner of the DRI producing Midrex technology to develop HBI supply chains into Japan.

The Big Three's Stated Policies Pathways put them on trajectories that are far off a 1.5°C pathway and show that total emissions between 2019 and 2050 exceed Nippon Steel, JFE and Kobe Steel's corporate carbon budgets by more than 821 $MtCO_2$, 527 $MtCO_2$ and 137 $MtCO_2$, respectively. This is further evidence that the current technologies employed and planned are nowhere close to delivering the needed emissions reductions.

Transition Asia's 1.5°C scenarios for each of the companies model how the use of technology with proven emission reductions can provide stable steel production while delivering an emissions forecast within an IPCC 1.5°C carbon budget. The key factor in what we have assumed is that BFs that reach the end of their lifespan (20 years) are decommissioned rather than relined, and are replaced with EAFs.

Our scenarios have also incorporated the stated emissions reducing technologies of the Big Three. However, as these technologies do not provide the appropriate emission reductions needed, their use in the model has been increased inline within the limits of a permissible 1.5°C carbon budget and subsequently decreased as the model projects emissions towards 2050. Where BFs are retired, emission reducing technology associated with BFs such as carbon capture recycling has also been retired.

Electricity used to power EAFs is gradually shifted from forecasted residual grid emission factors to zero emissions RE (wind, solar etc.). EAFs are used as they can be charged with either zero emissions H_2-DRI/HBI or scrap steel. The model also assumes that EAFs are charged with a type of iron or steel and attributes near zero emissions.

Assessing the contribution of the various technologies proposed by the Big Three on reaching a 1.5°C target, TA has modelled how each major technology will contribute to aligning to our 1.5°C pathway over time. Both COURSE50 and Carbon recycling + CCU have been incorporated into the technology pathway plans, aligning them with the Big Three's company's plans however both these technologies are retired rapidly to ensure alignment with a 1.5°C is kept.

By 2035, COURSE50 is expected to reach its peak utilisation point. However, beyond this point, the proportion of steel produced through this technology will gradually decline. This reduction is part of our deliberate strategy to align with the necessary retirements of BFs to meet the 1.5°C budget targets. Similarly, our forecast for Carbon recycling + CCU is projected to achieve its highest level of utilisation by 2040. However, in line with our 1.5°C pathway, we forecast a rapid decrease in the technology beyond this point.

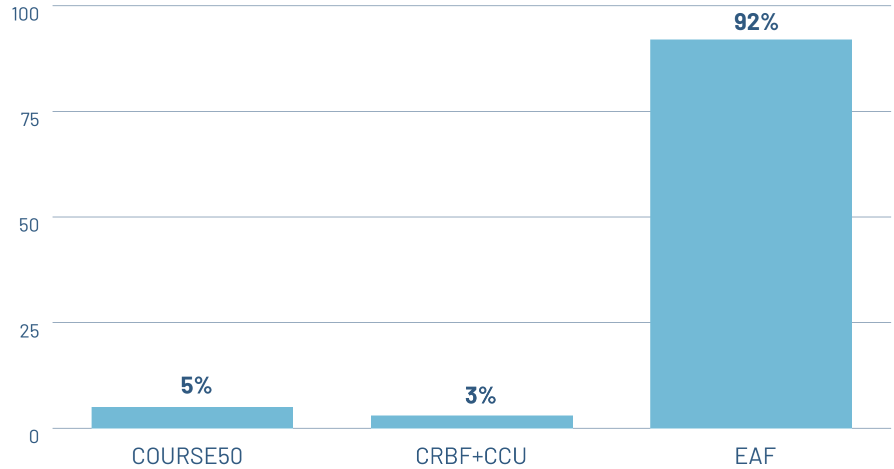
Table 3: 1.5°C Pathway: Timeline of the carbon reduction effect of various technology changes compared to 2050

Technology Changes	2031	2035	2040	2045	2050
COURSE50[46]	11.2%	15.1%	13.2%	0.8%	1.0%
Carbon recycling BF + CCU	3.1%	4.9%	5.7%	1.3%	1.7%
Grid EAF	46.2%	4.2%	0%	0%	0%
RE EAF[47]	39.5%	75.7%	81.1%	97.9%	97.2%

Alternatively, EAFs experience rapid expansion and maintain their dominance in the Big Three's steel production landscape through 2050. By the year 2035, renewable electricity will take the forefront as the primary power source for EAFs, aligning with expected corporate uptake and lower RE levelised cost of electricity (LCOE) in Japan. Inputs into EAFs are assumed to be entirely zero-emission, sourced from either renewable H_2-DRI/HBI or scrap.

From present through to 2050, TA analysis implies that a total of 1010 Mt of steel produced by EAFs would have to occur. By 2030, this will be produced by 10 large-scale EAFs of a capacity of 300tLS pa. By 2050, this will increase to 23 EAFs of the same capacity.

Figure 11: Carbon reduction effect of different technologies between 2030 and 2050



Source: Transition Asia analysis

Although the 1.5 °C pathway incorporates each of the company's decarbonisation technology plans, an analysis of the carbon reduction effect of each technology illustrates that only 8 percent of CO_2 reduction between 2019 and 2050 are non-EAF based. Raising the question why Japanese companies are so heavily invested in developing as of yet, unproved technologies at commercial scale. These technologies, even if developed to operate at commercial scale as planned, are not being designed to reduce emissions close to what is required to operate at scale within a 1.5°C pathway.

[46] SuperCOURSE50 is not considered in TA's 1.5°C Roadmap, because at the time of writing it was scheduled to be implemented around 2050, when BF's are phased out. Nippon Steel has now moved this date forward to 2040.

[47] H_2-DRI route is included in the RE EAF route.

Despite a robust scrap market that implies cost advantages for scrap-based EAF steel over traditional BF-BOF steel, the Big Three have been slow in adopting EAF-based steel facilities and establishing efficient scrap or HBI supply chains. It's worth noting that Kobe Steel has initiated the development of an HBI import supply chain, capitalising on its global network of Midrex plants. Currently, this HBI is being used in BFs, resulting in incremental emission reductions. However, shifting the focus toward EAF-based steel production could potentially offer a competitive advantage over other steel industry players, particularly those lacking the expertise and networks in DRI-based ironmaking facilities.

CONCLUSION

We present this analysis as an overview of Japan's transition toward a near-zero emission steel industry, and also to show the factors slowing down the transition, the actions of the current players and the solutions available to remain competitive in the growing market.

The role and responsibility of corporations and governments to transition to low emissions business is more vital than ever as the world pushes against the upper boundary of the carbon budget. The steel sector, as a highly polluting industry that's decarbonisation has wide-ranging effects on other sectors, is key in corporate and national pathways toward net zero emissions and staying within a 1.5°C carbon budget. Japan has the technological capacity and maturity within its steel sector to push forward the necessary transition.

Transition Asia analysis of the Big Three's announced plans and policies shows that each surpasses their corporate 1.5°C carbon budgets by substantial margins between 2019 and 2050. This is due to a heavy reliance on BF-based steel production; locking in emissions that are on track to exceed the carbon budget unless steps are taken to integrate large-scale EAF into their steel production mixes. BF re-linings need to cease in the near future with plans to decommission these assets.

This transition requires cooperation between industry and the Japanese government due to the need for RE procurement and scrap availability domestically. Companies need to play a proactive role in securing PPAs to power production facilities and also in lobbying the government to expedite the transition to RE. Alongside this, the government needs to deliver RE at a much faster rate than currently planned, encourage the transition to EAFs disincentivise BF re-linings and enable a more active scrap market domestically.

GLOSSARY

Big Three - Nippon Steel, JFE and Kobe Steel

BF - Blast Furnace

BOF - Blast Oxygen Furnace

DRI - Direct Reduction Iron

EAF - Electric Arc Furnace

ETS - Emissions Trading System

H_2 - Hydrogen

HBI - Hot Briquetted Iron

IEA - International Energy Agency

LCOE - Levelised Cost of Electricity

METI- Ministry of Economy, Trade and Industry

PPA - Power Purchase Agreement

RE - Renewable Energy

DATA AND DISCLAIMER

This analysis is for informational purposes only and does not constitute investment advice, and should not be relied upon to make any investment decision. The briefing represents the authors' views and interpretations of publicly available information that is self-reported by the companies assessed. References are provided for company reporting but the authors did not seek to validate the public self-reported information provided by those companies. Therefore, the authors cannot guarantee the factual accuracy of all information presented in this briefing. The authors and Transition Asia expressly assume no liability for information used or published by third parties with reference to this report.

ENDNOTES

1 Hasanbeigi, A. 2022. Steel Climate Impact - An International Benchmarking of Energy and CO_2 Intensities. Global Efficiency Intelligence. Florida, United States.

2 Hasanbeigi, A.; Sibal, A. 2023. What is Green Steel? Definitions and Scopes from Standards, protocols, initiatives, and Policies around the World. Global Efficiency Intelligence. Florida, United States.

3 Hasanbeigi, A.; Sibal, A. 2023. What is Green Steel? Definitions and Scopes from Standards, protocols, initiatives, and Policies around the World. Global Efficiency Intelligence. Florida, United States.

4 *"Total Production of Crude Steel ." Worldsteel.Org,* Worldsteel Association , 6 Dec. 2022, worldsteel.org/steel-topics/statistics/annual-production-steel-data/?ind=P1_crude_steel_total_pub%2FJPN.

5 *Technology Roadmap for "Transition Finance" in Iron and Steel Sector,* Ministry of Economy, Trade and Industry, Oct. 2021, www.meti.go.jp/policy/energy_environment/global_warming/transition/transition_finance_technology_roadmap_iron_and_steel_eng.pdf.

6 Japan Metal Daily, "Steel Yearbook 2021" (2021)

7 Hickman, Luke. "The Rise of EAFs Provides Flexibility to Steel Producers." The Freedonia Group, 3 Apr. 2017, www.freedoniagroup.com/blog/the-rise-of-eafs-provides-flexibility-to-steel-producers.

8 Swalec, Caitlin, and Astrid Grigsby-Schulte. "Pedal to the Metal 2023." Global Energy Monitor, July 2004, globalenergymonitor.org/wp-content/uploads/2023/07/GEM_SteelPlants2023.pdf. Accessed 31 Oct. 2023.

9 Hasanbeigi, A., Lu, H., Zhou, N. 2023. Net-Zero Roadmap for Chinese Steel Industry. Lawrence Berkeley National Laboratory, and Global Efficiency Intelligence. LBNL-2001506

10 Transition Asia. *Nippon Steel Emission Pathway Analysis*. Sept. 2022, transitionasia.org/wp-content/uploads/2022/09/Nippon-Steel-Emissions-Pathway-Analysis_EN.pdf. Accessed 31 Oct. 2023.

11 Climate Leadership Council. *Leveraging a Carbon Advantage: Impacts of a Border Carbon Adjustment and Carbon Fee on the U.S. Steel Industry*. clcouncil.org/reports/leveraging-a-carbon-advantage-key-findings.pdf?v3. Accessed 31 Oct. 2023.

12 Transition Asia. *Japan Steel Producers Climate Analysis*. 17 Jan.2023, transitionasia.org/wp-content/uploads/2023/01/Japan-Steel-Producers-Climate-Analysis_17Jan2023.pdf. Accessed 31 Oct. 2023.

13 BloombergNEF. "Green Steel Demand Is Rising Faster Than Production Can Ramp up | BloombergNEF." *BloombergNEF*, 26 June 2023, about.bnef.com/blog/green-steel-demand-is-rising-faster-than-production-can-ramp-up.

14 The Midrex Process is a method for producing DRI, HBI or sponge iron from iron ore fines. It is a metallurgicalprocess used in the steel industry to create a more pure form of iron that can be used as a feedstock in EAFs orother steelmaking processes. The Midrex Process is one of several technologies used for DRI production, but it is widely recognised and has been in use since the 1960s.

15 *BMW Brilliance: News*. www.bmw-brilliance.cn/cn/en/news/news/2022-8-4.html.

16 *BMW Brilliance: Plants* in Shenyang. www.bmw-brilliance.cn/cn/en/pr/shenyang.html.

17 Mercedes-Benz Beijing and Baosteel Group have officially signed a Memorandum of Cooperation - Joining Forces to Build a Green Steel Supply Chain. www.bbac.com.cn/CN/4/41/3098.html.

18 *Honda Global | April 11, 2023 POSCO and Honda Begin Exploring Comprehensive Partnership Toward the Realization of Carbon Neutrality*. global.honda/newsroom/news/2023/c230411eng.html.

19 *POSCO Group Focusing on Green Materials to Achieve Sustainable Growth.* forbesasiacustom.com/posco-group-focusing-on-green-materials-to-achieve-sustainable-growth.

20 Nippon Steel. *Nippon Steel Carbon Neutral Vision 2050*. 30 Mar. 2021, www.nipponsteel.com/en/ir/library/pdf/20210330_ZC.pdf. Accessed 31 Oct. 2023.

21 JFE Holdings Inc. *Environmental Vision 2025*. 25 May 2021, www.jfe-holdings.co.jp/en/investor/zaimu/g-data/2020/May2021-210525-release01.pdf. Accessed 31 Oct. 2023.

22 *International - U.S. Energy Information Administration (EIA).* www.eia.gov/international/analysis/country/JPN.

23 *"Enerdata."* Enerdata, www.enerdata.net/estore/energy-market/japan.

24 *J-Credit Scheme*. japancredit.go.jp/english

25 Iberdrola. "GREEN STEEL." *Iberdrola*, 22 Apr. 2021, www.iberdrola.com/sustainability/green-steel.

26 For more information, see Transition Asia's scrap steel explainer here: https://transitionasia.org/scrap-steel-explainer/

27 "WORLD STEEL RECYCLING IN FIGURES 2017 – 2021: Steel Scrap – a Raw Material for Green Steelmaking." *Bureau of International Recycling*, Bureau of International Recycling, 2022.

28 BIR Webservice. *BIR - Ferrous Metals*. www.bir.org/the-industry/ferrous-metals.

29 *MENA, a Potential New Hub for Green Steel and Green Iron Metallics* | IEEFA. ieefa.org/resources/mena-potential-new-hub-green-steel-and-green-iron-metallics.

30 Nippon Steel has recently brought forward the expected commercialisation date of SuperCOURSE50 from 2050 to 2040. This would generally be welcome news however the predecessor technology is still unproven and not available on a commercial scale BF despite being under development since 2008 leaving the credibility of this announcement in doubt.

31 Federation Japan Iron and Steel. "COURSE50 | the Japan Iron and Steel Federation." *COURSE50* |, 1 Mar. 2021, www.course50.com/en.

32 Research | COURSE50 | the Japan Iron and Steel Federation." *COURSE50* |, 10 Mar. 2021, www.course50.com/en/research.

33 Ministry of Economy, Trade and Industry Japan. 水素基本戦略. 6 June 2023.

34 *Revised Basic Hydrogen Strategy Offers No Clear Path to Carbon Neutrality.* Renewable Energy Institute, July 1991.

35 資源エネルギー庁 省エネルギー・新エネルギー部 資源・燃料部. 水素・アンモニア サプライチェーン投資促進・需要拡大策について. 18 Apr. 2022.

36 Eurometal, and Eurometal. "ArcelorMittal Confirms Hybrid EAF Investment in Spain - EUROMETAL." EUROMETAL - *the Voice of European Steel, Tubes and Metal Distribution Representing All Types of Steel Intermediation.*, 9 Aug. 2023, eurometal.net/arcelormittal-confirms-hybrid-eaf-investment-in-spain.

37 Nippon Steel Corporation. *Nippon Steel Sustainability Report*. Oct. 2022.

38 JFE Group. JFE Group Report 2022. *Integrated Report*. 2022

39 Kobe Steel, Ltd. *Climate Change 2022*. 2022

40 Calculation based on 2021's results shown in company's latest 2022 reports.

41 "Companies Taking Action - Science Based Targets." *Science Based Targets*, sciencebasedtargets.org/companies-taking-action.

42 Nippon Steel Corporation. *Nippon Steel Sustainability Report*. Oct. 2022.

43 JFE Group. *JFE CSR Report 2022*. 2022

44 Kobe Steel, Ltd. ESG Data book 2022. 2022

45 "Technologies to Reduce CO_2 Emissions | COURSE50 | the Japan Iron and Steel Federation." *COURSE50* |, 12 Mar. 2021, www.course50.com/en/technology/technology01.

46 SuperCOURSE50 is not considered in TA's 1.5°C Roadmap, because at the time of writing it was scheduled to be implemented around 2050, when BF's are phased out. Nippon Steel has now moved this date forward to 2040.

47 H_2-DRI route is included in the RE EAF route.

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