Decarbonization of Japan's Steel Industry: Economics and Path Forward

December 3, 2025

BloombergNEF

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Section 1. Executive summary

$639

Levelized cost of producing steel in an existing EAF plant in Japan in 2025

$1,052

Japan's levelized cost of producing steel using hydrogen-based DR-EAF production pathway in 2030

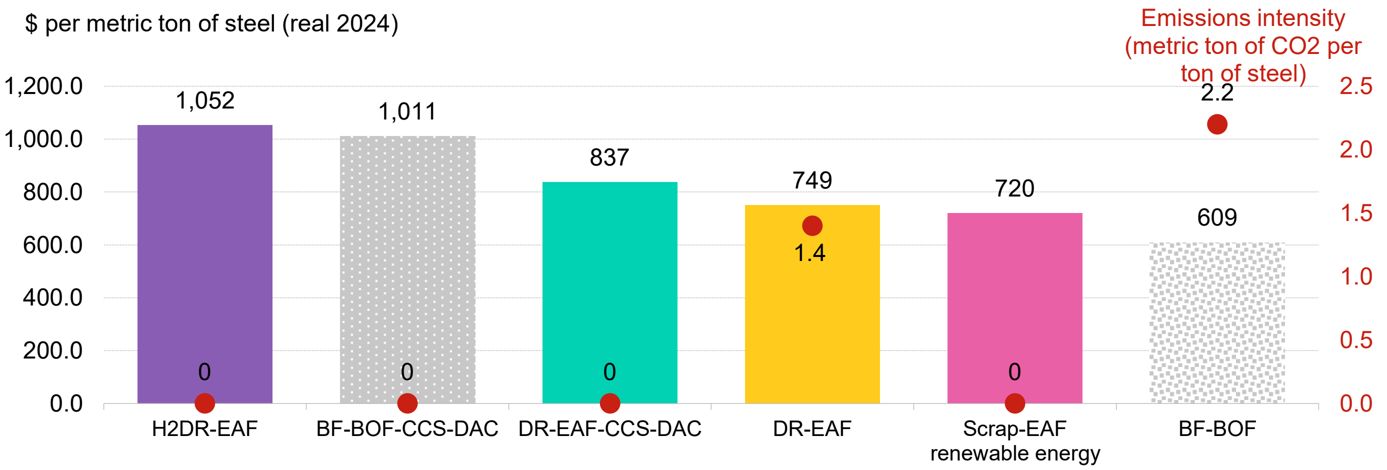
$202

Premium needed per ton of CO_2 for making hydrogen-based DR-EAF competitive in 2030 compared to BF-BOF

Japan's steel industry faces both structural and economic pressures as it moves toward decarbonization. The sector, responsible for about 13% of the country's emissions, faces mounting challenges amid structural decline, shrinking domestic demand and intensifying competition from peers like India and China. Meeting Japan's climate targets will require both technological innovation and stronger, more coordinated policies that leverage the full range of low-carbon steel technologies while preserving global competitiveness.

- **Decarbonization of Japan's steel sector requires addressing emissions from its coal-based steel production.** Japan's steel production is currently dominated by traditional blast furnace-basic oxygen furnace (BF-BOF) technology. Crude steel output in Japan has fallen to 84 million metric tons in 2024 from 120 million in 2007, but 74% of production still relies on the coal-intensive BF-BOF route.
- **Steel decarbonization is unlikely without financial support or stringent carbon pricing.** Low-emissions steel is expensive. Existing and fully depreciated BF-BOF assets remain Japan's lowest-cost steel production pathway in the absence of a carbon price. Scrap-based electric arc furnaces (EAFs), producing steel at around $639 per ton in 2025, are only 5% costlier than BF-BOF but offer a 77% emissions reduction. Hydrogen-based and CCS-integrated routes, by contrast, remain prohibitively expensive at more than $1,000 per ton in 2030.

Figure 1: Japan levelized cost of producing steel in 2030, by production pathway



Source: BloombergNEF. Note: BF-BOF-CCS-DAC and BF-BOF represent retrofits while others represent new builds. Hydrogen based on cracking blue ammonia from Saudi Arabia. Carbon capture and storage (CCS) based on pipeline and offshore storage. BF-BOF is blast furnace-basic oxygen furnace (BF-BOF) emissions. DAC is direct air capture. H2DR-EAF is hydrogen-based direct reduction-electric arc furnace.

- Marginal abatement cost analysis highlights that a carbon price of $59 per ton of CO_2 today would make renewable-powered EAF production competitive with conventional BF-BOF steel. By contrast, hydrogen-based direct reduction and BF-BOF with CCS would require carbon prices above $180 and $200 per ton in 2030, underscoring the need for stronger policy incentives and decrease in overall deployment costs of technology to close the competitiveness gap.

A green steel definition based on measurable emissions reduction recognizing all decarbonization pathways

- **A mutually agreed green steel definition could provide clarity to steelmakers on the decarbonization trajectory required.** Japan currently lacks an official green steel definition which recognizes all decarbonization pathways. Establishing a transparent, third party-verified standard grounded in a product carbon footprint (PCF) and covering Scope 1 and 2 emissions would help provide credibility and comparability.
- **Green steel standards may need to evolve over time and recognize all decarbonization technologies and efforts.** Japan's steel sector should leverage all available low-carbon steel pathways to decarbonize. Accordingly, any green steel standard must adopt an inclusive framework or have varying frameworks that recognize the diverse approaches that all contribute to emissions reduction in the steel sector.
- Integrating such a green steel definition into government-led demand initiatives such as the Act on Promoting Green Procurement would create predictable demand and accelerate market formation.

A green steel push accompanied by long-term infrastructure and supply chain planning

- **Access to zero-emission electricity:** In 2024, power-related emissions accounted for about 19% of total fuel emissions in Japan's steel industry. Simply switching to clean power can abate almost one-fifth of the sector's Scope 1 and 2 emissions. The government can aid the sector's decarbonization by enabling wider renewable energy adoption by steelmakers through expanded corporate renewable power purchase agreements (PPAs), and by addressing grid connection and land-use constraints.
- **Strengthening the availability and quality of domestic scrap supply:** Japan exported about 6.9 million tons of steel scrap in 2023. Redirecting this export volume to domestic EAFs could enable production of 5.8 million tons of lower-emission steel and avoid nearly 10 million metric tons of CO_2 emissions each year. Policymakers can consider export restrictions around steel scrap, stronger recycling mandates and improved processing for quality.
- **Establishing supply chains for new low-carbon iron feedstocks through technology and trade partnerships:** Most pathways to low-carbon steel will require a shift in long-established trade dynamics. As Japan's steel production asset base moves from one dominated by BF-BOFs to technology pathways compatible with its 2050 carbon neutrality goal, new feedstock supply chains must be established. Developing and securing access to other low-carbon iron feedstocks, such as direct reduced iron (DRI), can provide future certainty for Japanese steelmakers.

A robust carbon market to drive investment in low-carbon steel production

- Japan's upcoming compliance-based emission trading (GX-ETS) offers a critical lever to accelerate steel decarbonization. Tightening emission benchmarks and gradually phasing down free allowances will strengthen decarbonization signals and guide investment toward steel decarbonization technologies.

- **An effective carbon scheme needs a sufficiently high carbon price that incentivizes decarbonization with appropriate levels of free allowances.** To ensure long-term decarbonization efforts, Japan's carbon program should establish a clear pathway for progressive tightening of benchmarks aligned with net-zero objectives. Free allocation should decline predictably and help drive investment into production pathways with larger decarbonization potential.

Scaling demand for low-carbon steel

- **Japan could accelerate the development of its local green steel industry through stronger demand signals.** Japan's Act on Promoting Green Procurement already provides a foundation for environmentally responsible purchasing and can evolve into a key driver of industrial decarbonization. Establishing clear, verifiable thresholds for embodied emissions in steel used for public projects within the country's procurement framework helps drive substantial and measurable physical emissions reductions in the steel sector.
- Japan's green public procurement program has an opportunity to acknowledge the diverse portfolio of available steel decarbonization technologies, and allow a level playing field and access to support for all domestic steel producers regardless of which decarbonization pathway they pursue.

This whitepaper provides economic analysis of steel production pathways in Japan, estimating levelized costs of producing steel and marginal abatement costs across conventional and emerging technologies. It identifies the least-cost decarbonization routes, carbon price thresholds needed for competitiveness, and policy recommendations for decarbonization of country's steel industry.

This whitepaper has been funded by Tokyo Steel Manufacturing Co. All findings reflect BloombergNEF's independent analysis and views.

Section 2. State of Japan's steel industry

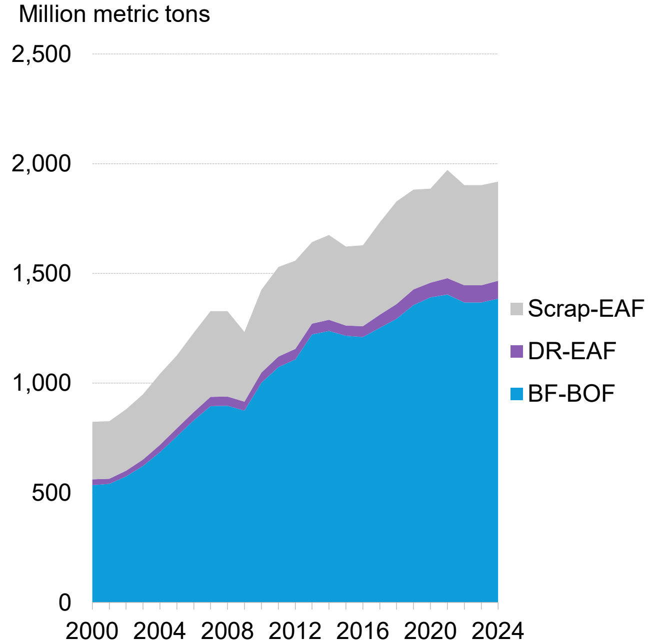
Japan's steel industry is a foundational pillar of its economy. The steel industry played a central role in Japan's rapid post-war economic recovery and subsequent industrialization. It is also a key contributor to Japan's export-oriented manufacturing sectors, such as the automotive industry. As global demand for low-emission steel products increases, driven by factors such as the expansion of mandatory compliance carbon markets across multiple jurisdictions, Japan faces increasing pressure to decarbonize its steel industry.

2.1. Current state of Japan's domestic steel industry

Japan remained the third-largest producer of crude steel globally as of 2024 but is facing structural challenges. A shrinking population leading to weaker domestic demand, coupled with intensifying competition from lower-cost producers in China and India, has led to a decline in domestic steel production capacity. The country's crude steel output peaked in 2007 at 120.2 million metric tons, but has declined since then, reaching just 84 million metric tons in 2024.

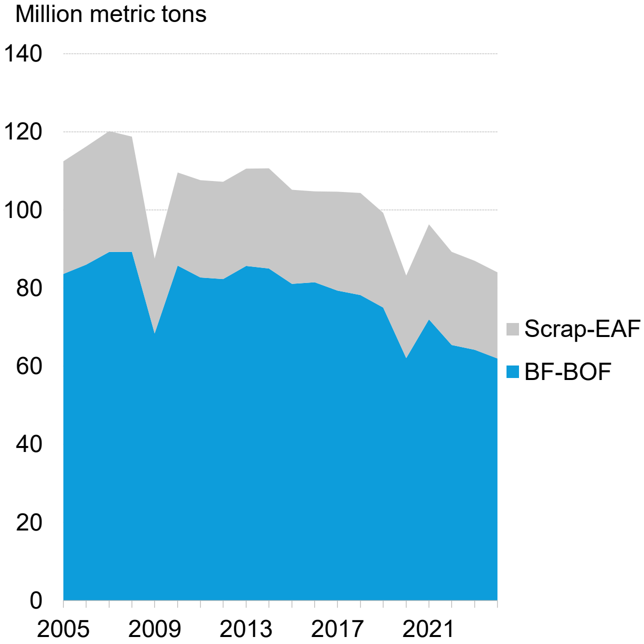
In contrast, global demand has been rising steadily, fueled by strong consumption and supply growth in developing economies such as India and China (Figure 2). Both nations are dominant global steel producers and exporters, having invested heavily in steel production capacity expansion to support infrastructure development and the industrialization of their economies.

Figure 2: Global steel production by process



Source: BloombergNEF. Note: BF-BOF is blast furnace paired with basic oxygen furnace, DR-EAF is direct reduction paired with electric arc furnace.

Figure 3: Japan's steel production by process



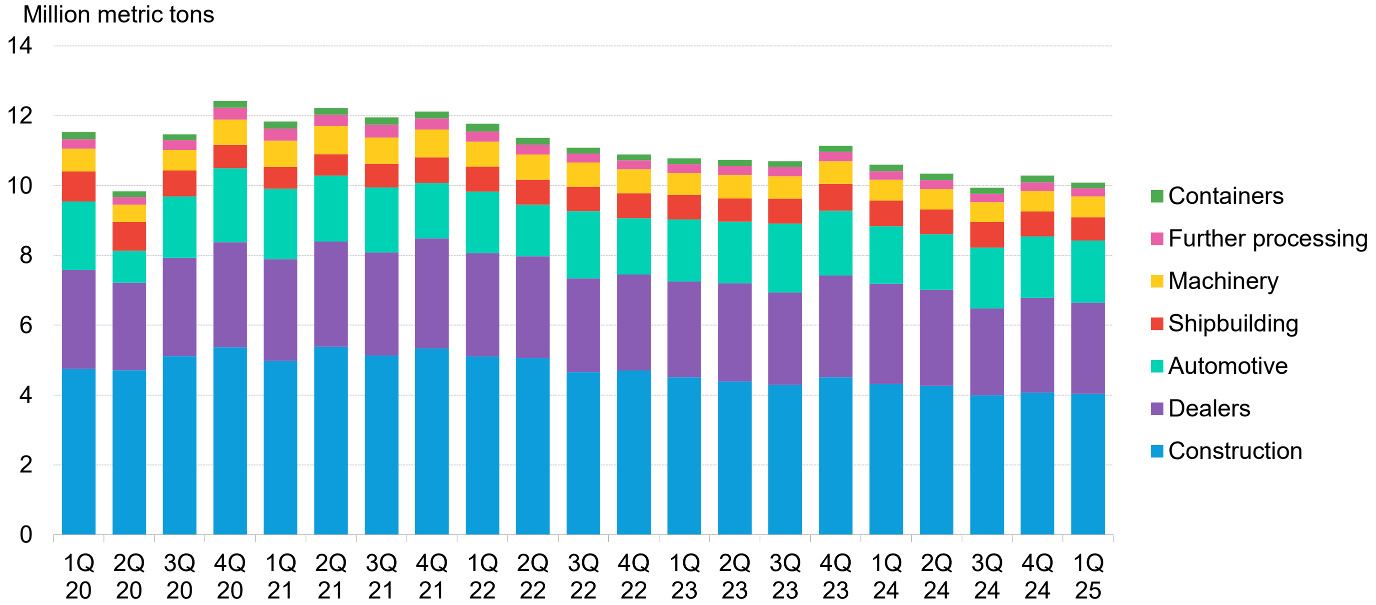
Source: BloombergNEF, Japan Iron and Steel Federation. Note: BF-BOF is blast furnace paired with basic oxygen furnace. EAF is electric arc furnace.

Construction, automotive are the largest direct domestic consumers of Japanese steel

Domestically, Japanese crude steel is used across a wide range of industries, with construction and automotive sectors representing the largest direct end-use (Figure 4). The relationships between local steelmakers and auto manufacturers are long-standing, built over decades of collaboration and mutual knowledge sharing. This deep integration has enabled Japanese steel producers to tailor their products to the exact standards and material specifications required by domestic automotive manufacturers.

Beyond direct industrial customers, dealers and trading companies also play a role in Japan's steel supply chain. These intermediaries purchase steel from primary manufacturers and resell to end users, making them the second-largest group of customers after construction industry.

Figure 4: Japan's quarterly domestic steel direct consumption by end-use industry



Source: Japan Iron and Steel Federation, BloombergNEF. Note: Dealers refer to steel distributors, and trading companies that buy steel from primary manufacturers and resell it to end users.

2.2. Steel production pathways and decarbonization options

Today, the two main technologies for primary steel production globally are the blast furnace-basic oxygen furnace (BF-BOF) and the direct reduction-electric arc furnace (DR-EAF). Currently, both processes are heavily reliant on fossil fuels as a reductant and as a source of heat. Secondary production of steel is dominated by electric arc furnaces (EAF) using scrap steel as feedstock. Emissions associated with the EAF and DR-EAF processes are significantly lower than the BF-BOF process.

There is a growing consensus among governments and steelmakers globally on the need to decarbonize. Commonly pursued low-emission steel production pathways include retrofitting existing BF-BOF and DR-EAF plants with carbon capture and storage, complementing with direct air capture or substituting fossil fuels with low-carbon alternatives such as biochar for coal and hydrogen for natural gas. Emissions for EAF and DR-EAF can also be lowered by procuring clean power.

Blast-furnace with basic oxygen furnace (BF-BOF)

The blast furnace–basic oxygen furnace (BF-BOF) route is the primary technology for steelmaking globally. In 2023, it accounted for 71.1% of total crude steel production around the world. The technology is mature and cost-competitive, and well-integrated into existing supply chains.

Under the BF-BOF pathway, iron ore is reduced to hot metal in a blast furnace using metallurgical coal for both heat and as a reductant. This is followed by refining the molten pig iron in a basic oxygen furnace to produce steel (Figure 7). Its high reliance on coal makes it the most carbon-intensive option among all steelmaking processes at a benchmark emissions intensity of 2.2 metric ton of CO_2 per ton of steel (Figure 6). This raises questions about the technology’s relevance in future steel supply chains in an increasingly decarbonized world.

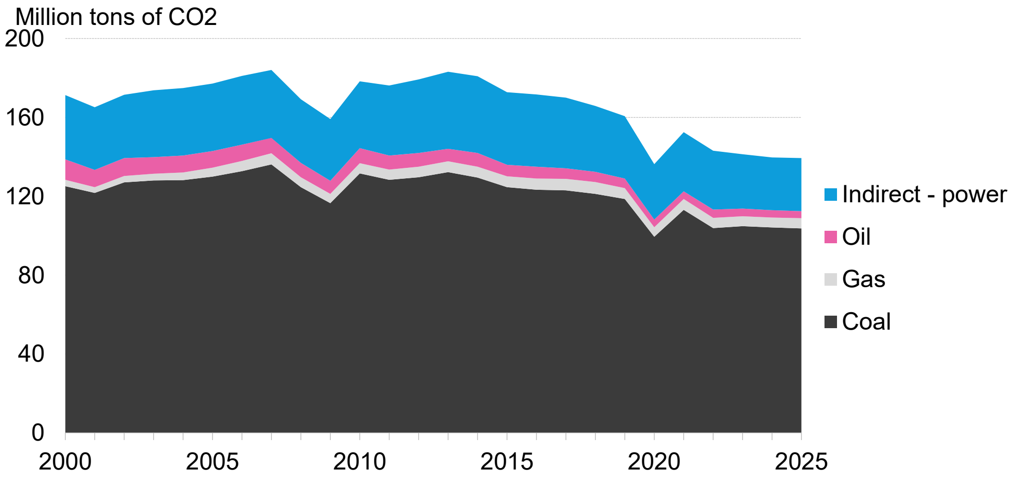
For Japan, with a relatively large BF-BOF fleet, reducing emissions from these existing assets will be crucial in lowering overall emissions. The traditional BF-BOF pathway produced almost three quarters of total crude steel manufactured in Japan last year.

Coal makes up the main fuel in Japan’s steel industry

Steel industry emissions stood at 13% of total emissions in Japan in 2023. The reliance on BF-BOF plants means coal is the dominant source of direct fuel emissions in Japan’s steel industry. In 2024, coal use in BF-BOF production accounted for about 93% of total direct fuel emissions.

Electric arc furnace (EAF) production has a different emissions profile. Most of its emissions are linked to the source of electricity used. In 2024, electricity emissions accounted for 19% of fuel-related emissions from Japan’s steel industry (Figure 5).

Figure 5: CO_2 emissions by fuel, including indirect emissions in Japan’s steel industry

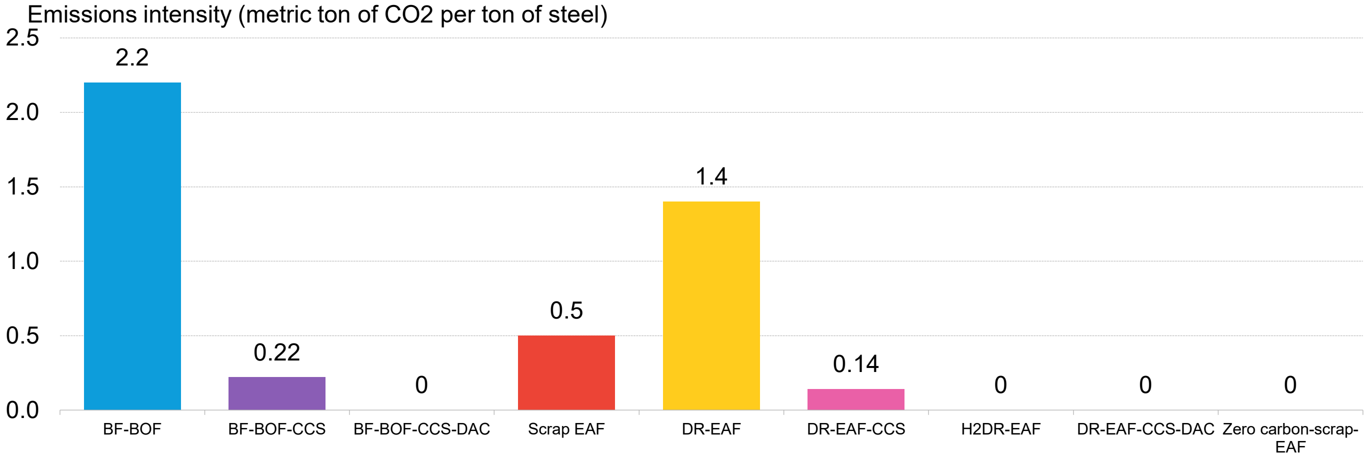


Source: BloombergNEF. Note: 2025 is estimate.

BF-BOF with carbon capture and storage (CCS)

One option to reduce emissions from BF-BOF is to retrofit existing BF-BOF facilities with carbon capture and storage (CCS) (Figure 7). CCS is a series of technologies that isolate, purify, capture, transport and store carbon dioxide (CO_2). It can be applied to several carbon-emitting processes in steel production including the sintering and coking phase, the blast furnace and to off-gas combustion in boilers.

Figure 6: Emission intensity by steel production pathway, global average benchmark



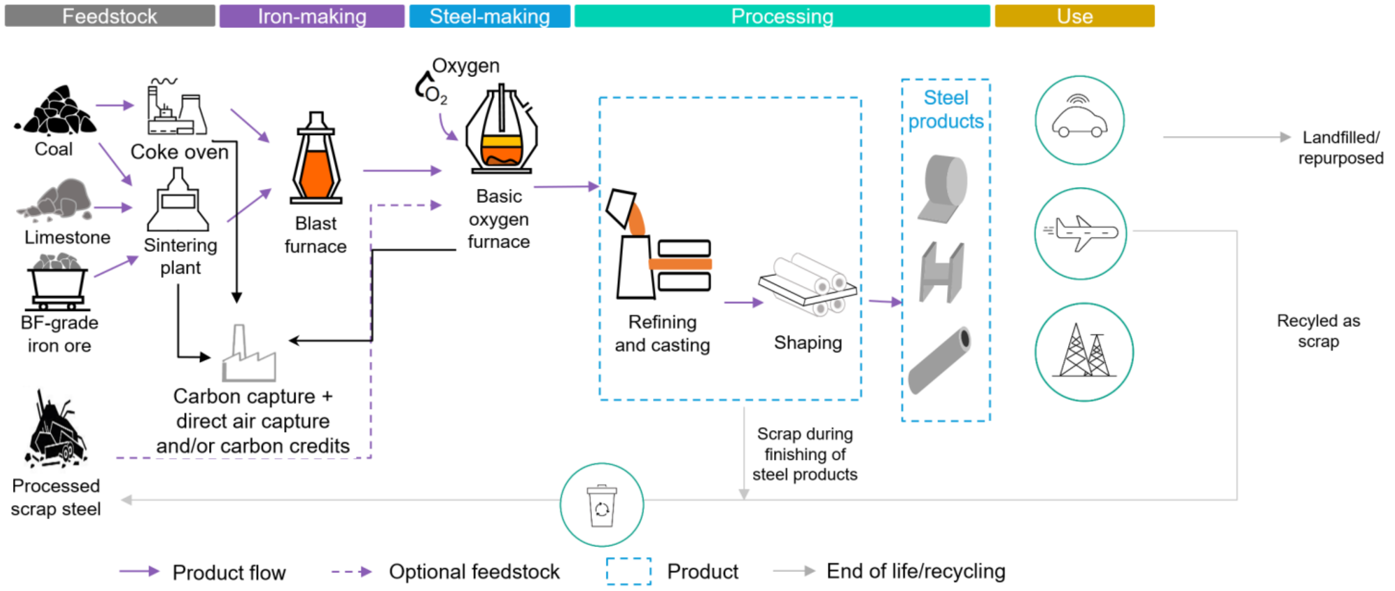
Source: BloombergNEF. Scrap-electric arc furnace (EAF) emissions assume 0.45 kilograms of carbon dioxide per kilowatt-hour of electricity consumption; remaining emissions come from scrap preheating, ladle heating, carbon electrode oxidization and other ancillary processes. BF-BOF refers to blast furnace-basic oxygen furnace. CCS is carbon capture and storage. DR is direct reduction. DAC is direct air capture. The H2DR-EAF production process relies on hydrogen produced with emissions abated and powered by renewable energy. Figures based on BNEF's global emissions intensity benchmark and include only Scope 1 and 2 emissions.

CO_2 generated during these processes is captured and transported to geological storage sites. This allows for the continual use of existing BF-BOF assets but can add complexity, higher capital costs, and additional energy demand for capture operations. Assuming a theoretically possible 90% capture rate, retrofitting a BF-BOF plant with CCS can reduce the benchmark emissions intensity significantly, to 0.22 tons of CO_2 per ton of steel. However, it is still a partial abatement solution (Figure 6). The incomplete carbon removal by a CCS facility will need to be complemented with carbon removals, such as direct air capture (DAC), to offset residual releases by pulling CO_2 out of the atmosphere.

Globally, CCS projects in steel and other heavy industries are among the first of their kind in their respective regions. In the iron and steel sector, operational CCS capacity currently amounts to only 1.75 million metric tons of CO_2 per year, just 3.9% of total global operational carbon capture capacity and less than 1% of global fuel-based emissions in the steel industry in 2024. *See CCUS Projects Database (web | terminal).*

CCS projects often face delays, cost overruns, and challenges linked to technical challenges, limited operational experience and knowledge gaps, and policy uncertainty. Furthermore, the economics of CCS are highly location-specific, with proximity to suitable geological storage sites a major determinant of project feasibility. *See Section 3 for detailed economic analysis.*

Figure 7: Integrated blast furnace-basic oxygen furnace (BF-BOF) retrofitted with carbon capture and storage (CCS)



Source: BloombergNEF.

BF-BOF with biomass

The BF-BOF with biomass pathway substitutes a share of metallurgical coal or coking coal with biomass-derived carbon, such as bio-coke or biochar. This reduces the volume of coal needed, lowering emissions, while still leveraging existing BF-BOF assets and infrastructure.

Large-scale scaling up of this pathway is dependent on the development and reliable availability of suitable biomass feedstocks. Traditional biomass feedstock used for power generation generally has lower calorific values compared to metallurgical coal and coke and thus cannot serve as a full substitute. Existing biochar supply chains globally are nascent and potentially costly. For more, please refer to *The Biochar Value Chain: From Farm Waste to Carbon Credit* (web | terminal).

Direct reduction shaft furnace with electric arc furnace (DR-EAF)

The direct reduction-electric arc furnace (DR-EAF) process, on the other hand, uses gas-based reducing agents including natural gas and 'syngas' (a mixture of hydrogen and carbon monoxide). In the direct reduction shaft furnace, iron ore is reduced to sponge iron, which is then melted in the electric arc furnace into molten crude steel (Figure 8).

Compared to BF-BOF, this pathway emits less CO_2, at a global emissions intensity benchmark of 1.4MtCO_2 per ton of steel (Figure 6). This production technique is increasingly popular in regions with abundant supply of natural gas such as in the Middle East.

However, the scaling up of DR-EAF globally may face iron ore feedstock constraints. Direct reduction of iron ore requires a higher grade of iron ore than blast furnaces. While lower grade iron ores do not affect the direct reduction process, higher gangue content will affect the energy consumption of the electric arc furnace, directly impacting the economic viability of the process. BNEF's analysis shows that adequate supply of the high-grade iron ore required for DR-EAF could be a bottleneck. *See Direct Reduction-Grade Iron Ore: A Green Steel Bottleneck (web | terminal).*

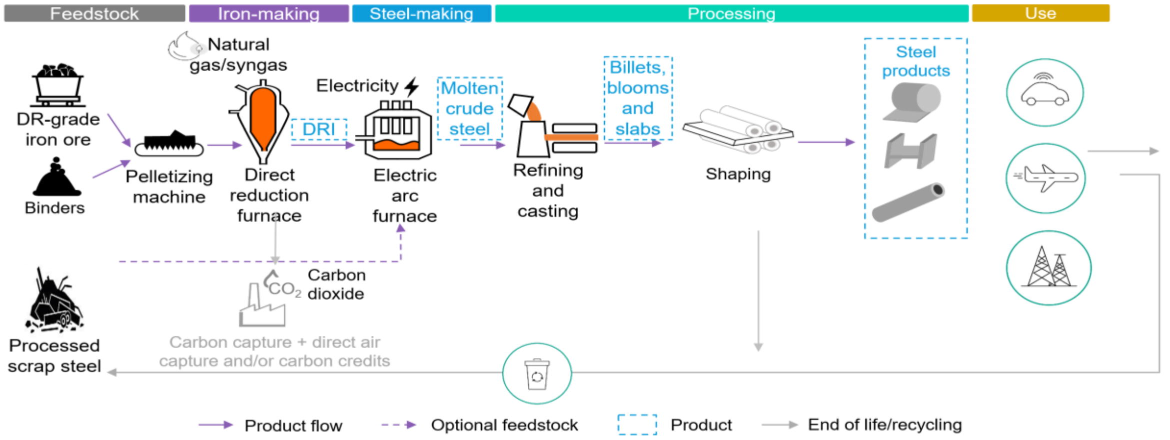
Japan currently doesn't have any existing commercial-scale facilities producing steel from this pathway due to factors such as Japan's high cost of natural gas imported as LNG.

DR-EAF with CCS

Although it is less carbon-intensive than BF-BOF, DR-EAF's fossil fuel reliance means it may face rising risks under stricter future decarbonization policies and may need to be complemented by other decarbonization options.

One option for fossil-fueled based DR-EAF plants to reduce emissions is through the addition of CCS facilities (Figure 8) to capture emitted CO_2 from the use of natural gas. This hybrid approach reduces the carbon footprint of DR-EAF plants to a global benchmark of 0.14MtCO_2 per ton of steel produced, down from 1.4MtCO_2 per ton of steel.

Figure 8: Integrated direct reduction electric arc furnace (DR-EAF) retrofitted with carbon capture and storage (CCS) and direct air capture (DAC)



Source: BloombergNEF.

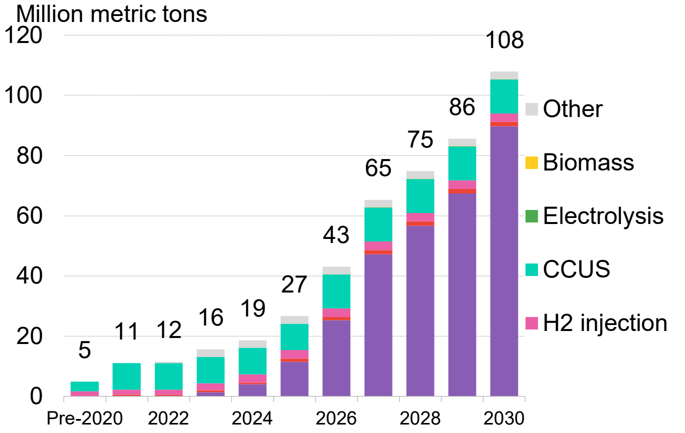
Although CCS can extend the longevity of natural gas use in steelmaking, the additional capital and operational complexity are significant. As with BF-BOF with CCS, economics are highly dependent on market design and the presence of supportive carbon policy frameworks which are lacking in Japan currently.

Hydrogen-based DR-EAF

Hydrogen-based direct reduction coupled with an EAF remains one of the most discussed near-zero carbon pathways for the steel sector. Under this pathway, hydrogen is used both as the source of heat and reducing agent instead of natural gas. This pathway could achieve almost zero emissions if the hydrogen used is produced without emissions (for example via electrolysis powered by renewables).

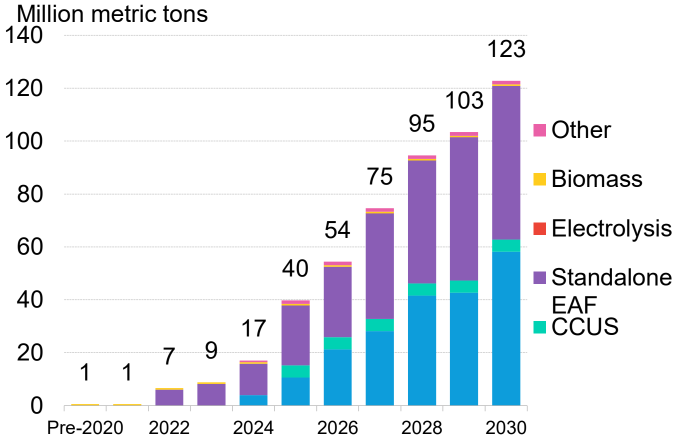
Steelmaking today is largely an integrated process, with manufacturers producing both iron and steel in the same facility. According to Midrex, 80-85% of steel's Scope 1 emissions occur during the ironmaking stage. This has put low-emission iron production at the center of the global steel decarbonization discussion.

Figure 9: Disclosed production capacity from announced iron decarbonization projects, by technology



Source: Public announcements, BloombergNEF. Note: Data as of October 10, 2025. Year is expected commissioning year. Projects without a commissioning year are not included. Only includes disclosed material production capacities. For example, some direct reduction with electric arc furnace (DR-EAF) projects have not disclosed their iron production capacity and is not captured in the direct reduced iron capacity. CCUS – carbon capture utilization and storage.

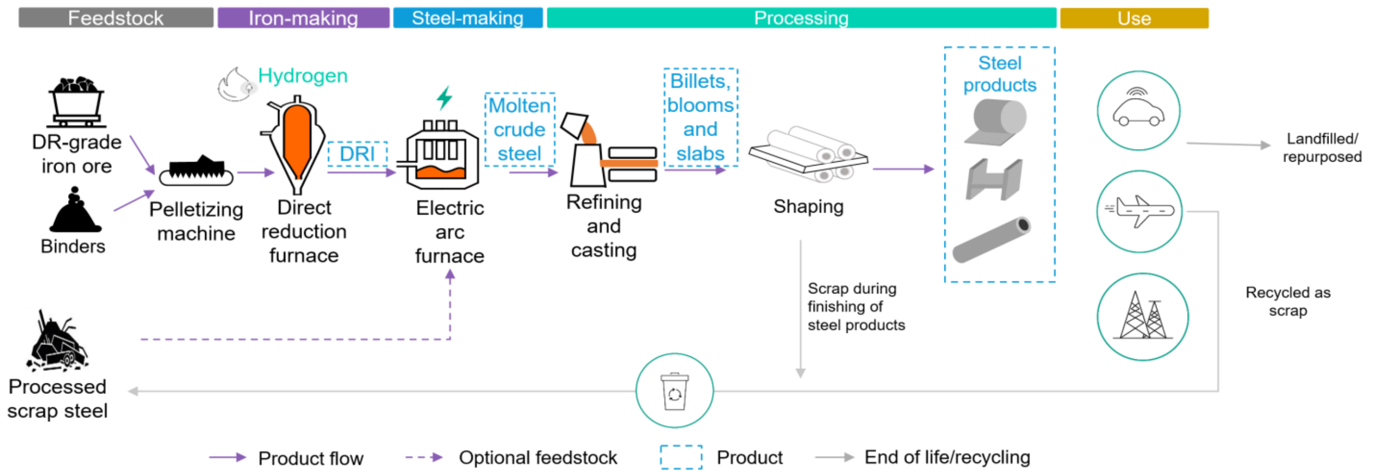
Figure 10: Disclosed production capacity from announced steel decarbonization projects, by technology



Source: Public announcements, BloombergNEF. Note: Data as of October 10, 2025. Year is expected commissioning year. Projects without a commissioning year are not included. Only includes disclosed material production capacities. For example, some direct reduction with electric arc furnace (DR-EAF) projects have not disclosed their iron production capacity and is not captured in the direct reduced iron capacity. CCUS – carbon capture utilization and storage.

Steelmakers around the world are focusing on the production of green iron through hydrogen-based direct reduction. Of the 108 million metric tons of green iron capacity proposed by 2030, more than 83% are hydrogen-based routes (Figure 9), although some projects intend to run on natural gas first before switching to hydrogen. It is also important to note that most of these projects are awaiting final investment decision. *See Decarbonizing Steel: Project Database (web | terminal).*

Figure 11: Integrated hydrogen based direct reduced-electric arc furnace (H2DR-EAF)



Source: BloombergNEF.

Standalone electric arc furnace (EAF)

Steel recycling via electric arc furnaces is the most mature low-emission steel technology today. Besides the typical integrated steel production pathways, EAFs are a mature, flexible, and widely adopted technology in regions with abundant scrap and cost-competitive electricity. Standalone EAFs are expected to contribute to the growth of global green steel production capacity. Out of the 123 million metric tons of announced low-emission steel production capacity to come online by 2030, EAFs account for 47%, based on publicly disclosed data gathered by BNEF.

Secondary steel production, with high-quality scrap steel fed to an electric arc furnace, is less energy intensive compared to primary steelmaking using BF-BOF. Even when powered by electricity from the grid[1], scrap-EAF is 77% less carbon intensive than the traditional BF-BOF pathway, at a benchmark emissions intensity of 0.5MtCO_2 per ton of steel (Figure 6). When powered with zero-emissions electricity, the emissions can fall further, leaving direct emissions of around 0.03~0.1MtCO_2. EAFs accounted for 26% of Japan's crude steel production in 2024, supported by the country's domestic supply of ferrous scrap and well-established scrap supply chains.

Other novel solutions

Incumbent steelmakers and startups are also developing more novel solutions such as electrolysis to produce primary steel. These processes can use renewable electricity directly to produce iron and steel, cutting direct emissions from furnaces. However, most of these solutions are in the very early stages of research and development and are much more expensive today than the options discussed above. BNEF expects electrolysis pathways to reach commercial scale in the 2040s, when it could start competing with facilities using hydrogen and carbon capture. For more, see *Decarbonizing Steel: Technologies and Costs* (web | terminal). We do not explore the potential of these yet-to-be-proven-at-scale technologies for Japan in this report.

2.3. Japan's steel decarbonization policy landscape

Decarbonizing Japan's steel industry is of paramount importance to the country's 2030 and 2035 emission reduction targets as well as the legislated goal of net-zero emissions by 2050. The country's steel industry is the largest source of industrial emissions. However, decarbonized steel production is costlier than the traditional fossil-fuel based routes. Without stringent emissions reduction targets, subsidies or some form of carbon pricing, decarbonization of the steel sector is unlikely to occur.

Japan has three major supply side policies for decarbonizing the steel industry

To kickstart the transition of Japan's steel sector, the government has introduced three supply-side policies for low-emission steel production to support further steel decarbonization technology innovation and development, and to incentivize steelmakers to green their production.

Japan's Ministry of Economy, Trade and Industry's (METI) Energy & Manufacturing Process Conversion Support Project for Hard-to-Abate (HtA) Sectors scheme focuses on the conversion of production pathways from the current fossil-fuel based ones to lower emission options. The scheme looks to subsidize up to a third of capital investment for plant conversions from blast

[1] Emissions intensity of the grid assumed at 0.45 kilograms of carbon dioxide per kilowatt-hour of electricity.

furnaces to new electric arc furnaces, fuel switching, and process upgrades in the steel, chemicals, cement, and pulp & paper sectors.

Table 1: Comparison of three major supply side policies for decarbonization of Japan's steel industry

Feature	Hard to Abate (HtA) sector support project	Green Innovation Fund (GIF)	Strategic Sector Domestic Production Promotion Tax System (戦略分野国内生産促進税制)
Purpose	Support capital investments in hard-to-abate sectors (such as steel, chemicals, pulp and paper, cement) for process conversion to lower emission intensive ones	Supports demonstration and implementation of projects to develop and commercialize innovative low-emission technologies. GIF is intended to take projects from early/mid stages through to commercialization	Incentivize manufacturers to produce materials such as green steel, cement by providing tax credit
Eligible scope	In the steel sector, the scheme supports the shift from blast furnaces to lower emissions processes such as electric arc furnaces, and hydrogen based DR-EAF. Current scheme excludes deployment of new EAFs from eligibility, and only supports process conversion.	In case of steel, to support hydrogen utilization in iron and steelmaking processes	• ¥12 billion of minimum investment in the project • Project plans ≥200,000 tons per year crude steel output • Meets steel quality impurity standards (nitrogen, phosphorus limits) • Existing BF-BOF are eligible if they make expected reduction from current BF-BOF. Excludes existing EAF players despite having a lower emission profile
Budget	¥422 billion	Varies by project. ¥449.5 billion available to support hydrogen utilization in iron and steelmaking processes project	As tax credit, there is no defined budget
Support	Government subsidizes up to one-third of eligible capital investment expenses in HtA Support Projects.	Grants for research and development and legal support	¥20,000/ton of steel produced. Total tax credit is capped at 40% of eligible companies’ corporate tax liability
Timeframe	FY2024 to FY2029 (A fiscal year runs from April 1 to March 31 of the following year)	Varies by project. Scheme supports research and development for hydrogen utilization in steelmaking over FY2021 to FY2030.	Up to 14 years. FY2025~FY2035 with extension applicable for another four years
Expected emission reduction	Required to deliver large emission reductions by process and/or fuel conversion. For example, achieving significant emission reduction from switching to EAF from BF-BOF. However, program does not publish a uniform % reduction target per project.	GIF projects often have explicit emission reduction targets. For example, the hydrogen utilization in steelmaking project aims for >50% reduction in CO_2 emissions from steelmaking processes by 2030	In case of steel, achieves ≥50% CO_2 reduction compared to BF-BOF route
Technology readiness level	Focuses on deployment of commercially ready technologies by process conversion and plant upgrades	Eligible technologies at early- to mid-stage of development and commercialization.	Deployment stage and aimed at process conversion. Already commercialized or near to commercialize technologies such as EAF

Source: Ministry of Economy, Trade and Industry (METI), New Energy and Industrial Technology Development Organization (NEDO), BloombergNEF.

Japan’s declining domestic steel demand and increasing competition on the export market challenges growth of the country’s operational iron and steel production capacity. BNEF expects that these supply-side schemes will drive conversion of existing BF-BOF plants to lower emissions plants, rather than adding significant new steel production capacity.

The second, the New Energy and Industrial Technology Development's (NEDO) ¥2 trillion Green Innovation Fund (GIF) is a decade-long program that looks to finance large-scale research and development, and demonstration projects. The fund looks to enable the commercialization of decarbonization technologies, including projects such as hydrogen reduction-based steel production and CCS pilots.

To complement METI's HtA and NEDO's GIF schemes, Japan is also offering a green steel production tax credit of ¥20,000/ton of steel produced to support low-emission steel projects during the operation phase. Existing scrap EAF plants are not eligible for this subsidy despite being lower emissions profile. Please see Table 1 for details of each subsidy.

Major demand side policies for decarbonization of steel in Japan

The Japanese government is also providing demand-side policies as further market incentives for domestic low-emission steel production. Securing firm off-take is critical for the scaling of low-emission steel supply chains. The policies aim to build up the sustained demand for low-emission steel that manufacturers require to back the investments they will have to make. These include leveraging Japan's automotive sector, currently the third-largest consumer of domestically produced crude steel, and government and public institutions to drive demand for low-emission steel.

Table 2: Comparison of major demand side policies for decarbonization of Japan's steel industry

Policy	What it does
Clean Energy Vehicle (CEV) subsidy with green steel component	• METI has introduced subsidies for electric vehicles, plug-in hybrids and fuel cell vehicles that uses low-emission steel to incentivize green steel procurement by automakers
Act on Promoting Green Procurement (グリーン購入法)	• Government agencies and public institutions are encouraged or required to prefer eco-friendly goods and services, including goods with lower carbon emissions • Recent revisions aim to prioritize procurement of green steel. The current definition excludes scrap-EAF based steel despite their low emissions profile.

Source: Ministry of Economy, Trade and Industry (METI), New Energy and Industrial Technology Development Organization (NEDO), BloombergNEF.

Hydrogen contract-for-difference (CfD) scheme could help steel producers

In addition to the supply and demand side incentives, a hydrogen contract-for-difference scheme introduced to build supply of low-emission hydrogen in Japan could support steelmakers and help in improving the economic viability of hydrogen-based iron or steel.

Japan introduced a contract-for-difference (CfD) scheme for low-emission hydrogen under the Hydrogen Society Promotion Act of 2024. The ¥3 trillion program, backed by Japan's Green Transformation (GX) economic transition bonds, targets to close the cost gap between conventional fossil-based fuels and low-emission hydrogen or ammonia. Subsidies are offered for 15 years under the scheme to hydrogen projects that begin supply by fiscal year 2030, and support both domestically produced and imported hydrogen.

If successful, the CfD mechanism could help drive increased supply of low-emission hydrogen in Japan and make downstream adoption economically feasible for industries. It also benefits steelmakers planning to pursue hydrogen as a decarbonization pathway, such as Nippon Steel which is piloting hydrogen-based direct reduction iron as part of its decarbonization plan. It is important to note that other industries are also eligible to bid for this CfD program. A limited amount of hydrogen may therefore be available for the steel industry. See *Japan's $19 Billion Bet Moves Hydrogen From Talk to Action* (web | terminal).

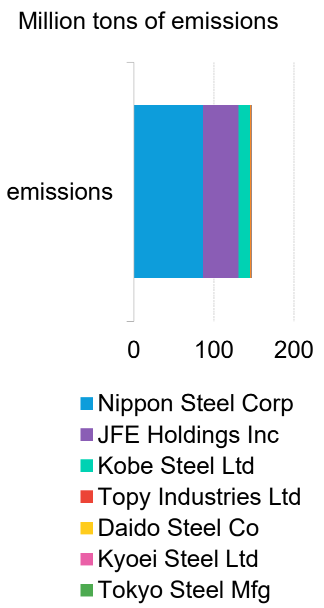
Japan plans to introduce a compliance carbon market.

In addition to incentives and subsidies, Japan is rounding out its policies to drive industrial decarbonization with its carbon pricing mechanism. One approach the government has taken is to tighten its Green Transformation Emissions Trading Scheme (GX-ETS). The scheme, begun as a voluntary trading system, will transition to a compliance market with implementation beginning in FY2026. Based on current market proposals, major Japanese steel companies such as Nippon Steel Corp., JFE Holdings and Kobe Steel Ltd. will be under the compliance GX-ETS (Figure 12).

This shift will mark Japan's first nationwide mandatory carbon trading market, bringing heavy industry, including large steelmakers into emission intensity based carbon market. Under the proposed design, companies with average direct CO_2 emissions above 100,000 tons per year (based on the average of the three most recent fiscal years) are mandated to participate.

Each covered company will receive emissions allowances. Those emitting above their allocation will need to purchase extra credits, while those below can sell or bank their surplus. *See Japan's New ETS Could Unlock a $1 Billion Carbon Market (web | terminal).*

Figure 12: Estimated annual Scope 1 greenhouse gas emissions by company



Source: Bloomberg terminal. Note: Estimated Scope 1 greenhouse gas emissions. For methodology, please refer to {FLDS EG001 <GO>} on Bloomberg terminal.

Section 3. Economic analysis of Japan's steel production pathways

Japan will need to balance economic growth and cost-competitiveness of its exported products with its decarbonization goals. Technologies to fully decarbonize primary steel production are still at an early stage. This chapter investigates the economics (evaluated as levelized cost of producing steel) and the marginal cost of abatement of the different low-emission steel production pathways explained in 2.2.

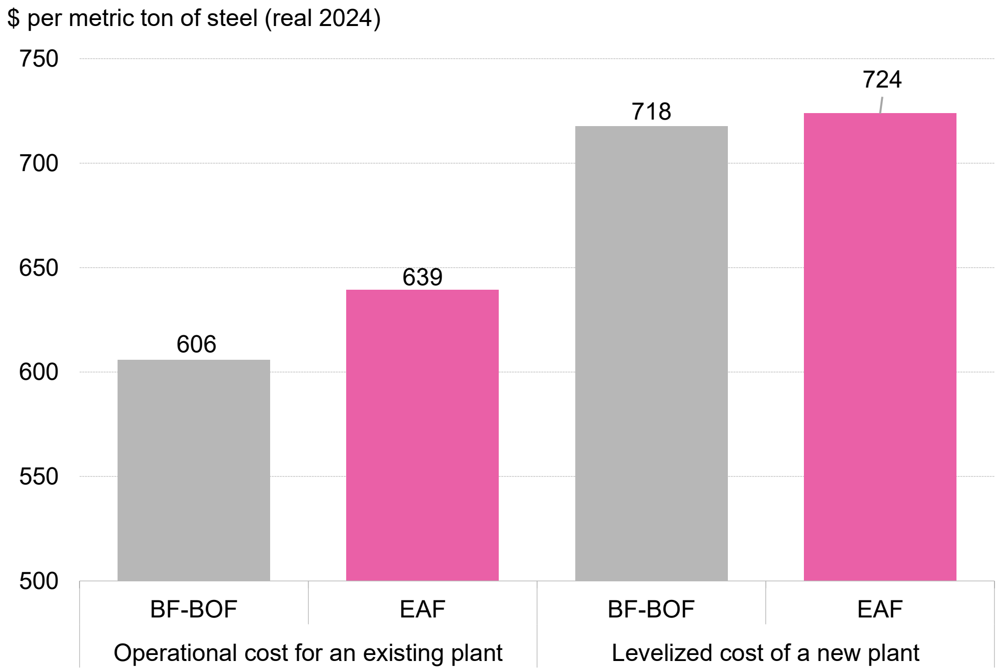
Understanding the economics and cost of producing steel for each decarbonization pathway will shed light on the least cost decarbonization option for the country's steel industry, allowing policymakers to map out their industrial strategies and identify the priorities for efficient subsidies and infrastructure spend.

Other emerging pathways such as hydrogen injection into blast furnaces or imports of intermediary low-emission iron feedstocks (other than iron ore) are out of the scope of this report.

3.1. Japan's levelized cost of steel production

Existing BF-BOF assets in Japan remain the cheapest production pathway through to 2050 in the absence of a carbon price, supported by mature feedstock supply chains and long-term contracts that reduce raw material price volatility for Japanese steel manufacturers. This is especially so if the assets are fully depreciated and only operational costs are involved.

Figure 13: Japan's levelized cost of steel in 2025, BF-BOF versus scrap-EAF



Source: BloombergNEF. Note: BF-BOF is blast furnace basic oxygen furnace. EAF is electric arc furnace.

Scrap-based steel production

Maximizing production at existing scrap-EAFs is the most economic option in short term to reduce emissions

Japan already has an existing EAF fleet it could leverage to immediately lower emissions from its steel sector. Operational cost from existing fully depreciated scrap-based electric arc furnace (EAF) production is only 5% higher than an existing BF-BOF plant, at $639/ton of steel, but offers a 77% reduction in emissions per unit of output.

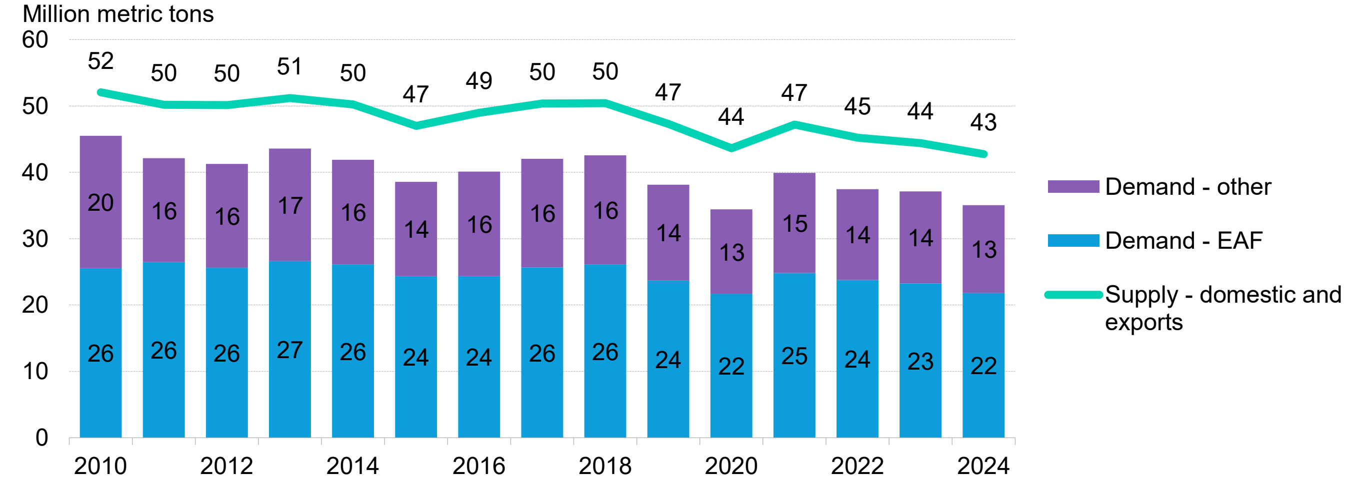
Emissions from EAF operation can be decarbonized by powering them using clean electricity. Based on power prices coupled with current prices of renewable energy certificates (RECs), the 2025 levelized cost of steel goes up around $20 per ton of steel produced compared to current industrial tariff-based electricity. This brings the marginal cost of abatement for scrap-EAF powered by clean power to $59/ton of CO_2 when compared to the operational cost of an existing BF-BOF plant.

Between now and 2030, new scrap-EAFs are the most accessible and economically viable choice for low-emission steel manufacturing in Japan. The pathway allows steelmakers to produce lower carbon steel at $724/ton of steel today (Figure 13), 19% higher than the $606/ton operational cost for a fully depreciated existing BF-BOF asset in Japan but with significantly fewer Scope 1 emissions (Figure 6).

Japan's exported scrap supply can support expansion of domestic EAF steel production

Japan is a significant producer of steel scrap, with supply totaling nearly 44 million metric tons in 2023. Steel producers are the dominant consumer of domestic scrap steel supply. In 2023, around 23 million metric tons went into EAFs. As Japan's EAF-based steel production capacity is smaller relative to the BF-BOF route, even with higher scrap ratios, the country has consistently generated more recoverable scrap than it can use in steel production.

Figure 14: Supply and demand of steel scrap in Japan



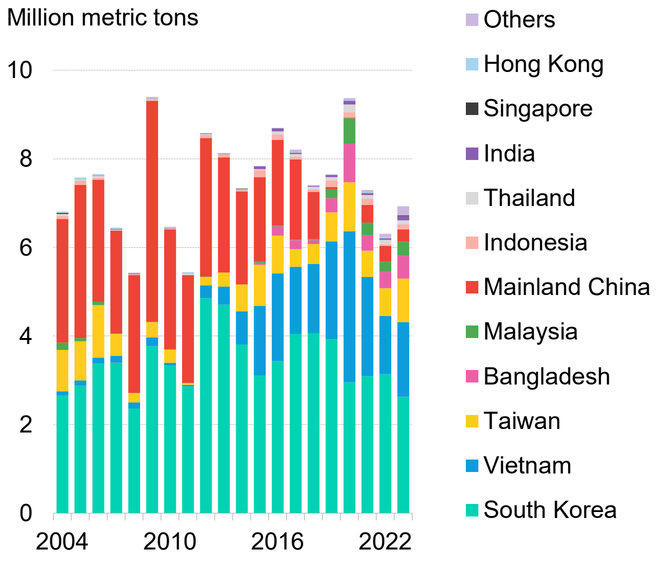
Source: Japan Ferrous Raw Materials Association, BloombergNEF. Note: EAF is electric arc furnace.

Domestic demand for scrap steel has shown a gradual decline in recent years, slipping to 35 million tons in 2024 from 46 million tons in 2010. This is driven by efficiency gains in steel production, a decline in overall steel production, and shifts in demand across different end-use sectors. Still, EAFs drive demand for domestic scrap even though BF-BOF also use this as partial feedstock.

Redirecting scrap exports to the domestic steel sector could reduce emissions by 10 $MtCO_2$ annually

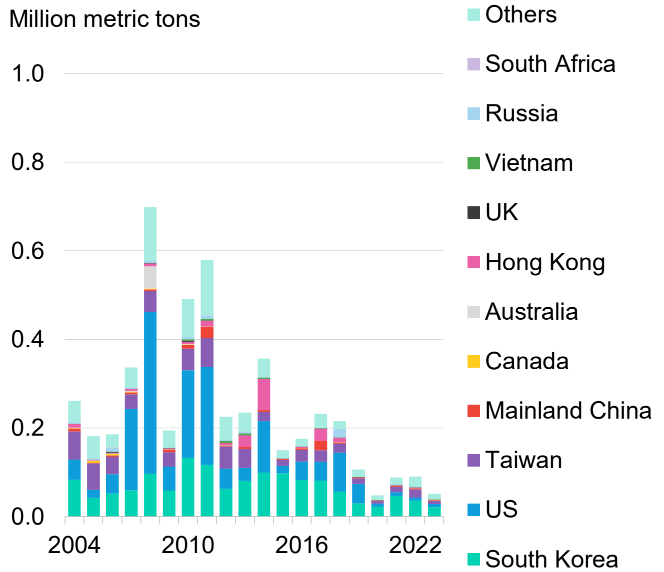
Japan has been a net exporter of scrap since the 1990s. In 2023, 6.9 million tons (or about 15% of domestic scrap supply) were exported. The export destinations have shifted noticeably over time. In the early 2000s, China was the dominant buyer of Japanese scrap, taking in large volumes as it built up its steelmaking base. Over the last decade, however, exports have tilted toward South Korea and Vietnam, which now account for around 60 percent of Japan's outbound scrap shipments (Figure 15).

Figure 15: Japan's steel scrap exports by market



Source: Japan Ferrous Raw Materials Association, BloombergNEF. Note: Data includes products under HS code 7204.

Figure 16: Japan's steel scrap imports by market



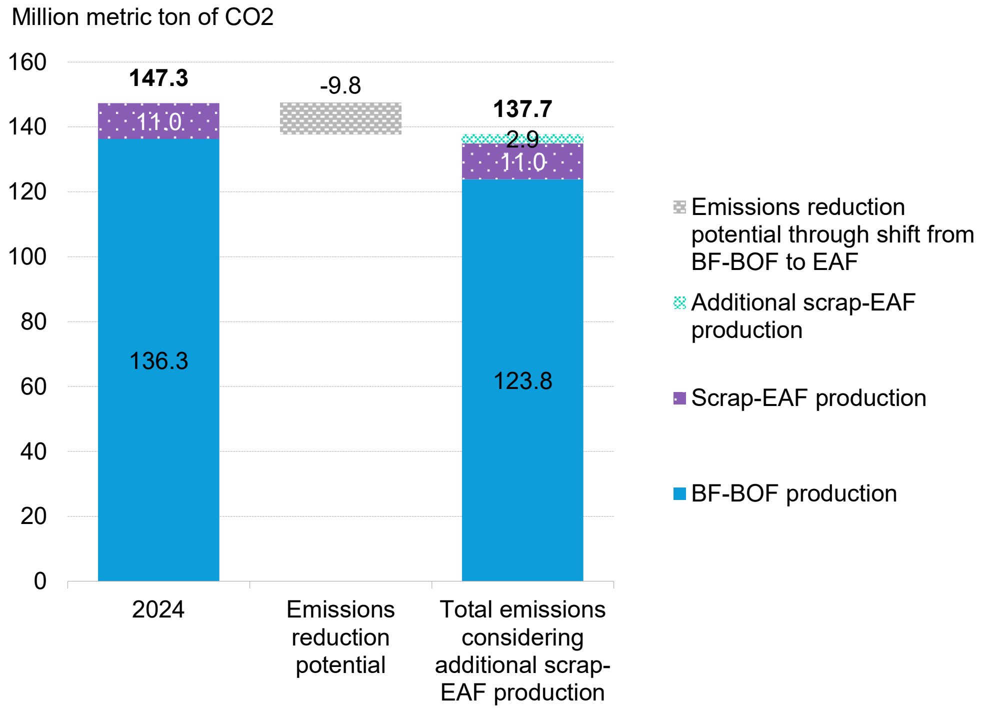
Source: Japan Ferrous Raw Materials Association, BloombergNEF. Note: Data includes products under HS code 7204.

While Japan does not have enough scrap to completely replace its BF-BOF fleet, redirecting its exported scrap volume toward domestic EAF production is the fastest and most economical pathway for Japan to lower emissions from its steel sector. The country already has an established EAF supply chain that can be scaled up. Based on recent project announcements, replacing a BF-BOF plant with an EAF usually takes about 4-5 years. In comparison, the timeline for other emerging low-emission steel technologies to be commercially available and reach cost parity is still uncertain.

The 6.9 million tons of scrap steel Japan exported in 2023 could enable production of 5.8 million tons of lower-carbon steel, assuming 1.2 tons of scrap are required per ton of output. Based on global emissions benchmark by production pathway, this helps Japan avoid 9.8 million tons of direct CO_2 emissions compared with BF-BOF production.

Once the steel production process is electrified, a shift from grid electricity to clean power allows for the full decarbonization of the pathway. When powered with zero-emissions electricity, there can be further abatement of up to 13.9 million tons of CO_2. This means that redirecting current scrap exports toward the domestic market to produce steel using EAFs and shifting from fossil fuel-based electricity to zero-emissions electricity can together lead to emissions reduction of up to 23.7 million tons of CO_2 according to calculations based on the global emissions benchmark (Figure 17).

Figure 17: Expected fuel-related emissions reduction in Japan's steel industry by shifting exported scrap toward EAF production



Source: BloombergNEF. Note: EAF is electric arc furnace. Assumes 5.8 million metric tons of steel produced by BF-BOF is displaced by scrap-EAF, based on 6.9 million metric ton of exported scrap supply redirected to the local market and 1.2 tons of scrap steel per ton of crude steel. Calculation based on emissions intensity of steel production pathway assumed at 2.2MtCO_2/ton of steel for BF-BOF and 0.5MtCO_2/ton of steel for scrap-EAF, and factoring in production volume of crude steel in Japan in 2024. Theoretical calculation based on global benchmarks; resulting total emissions are estimated emissions.

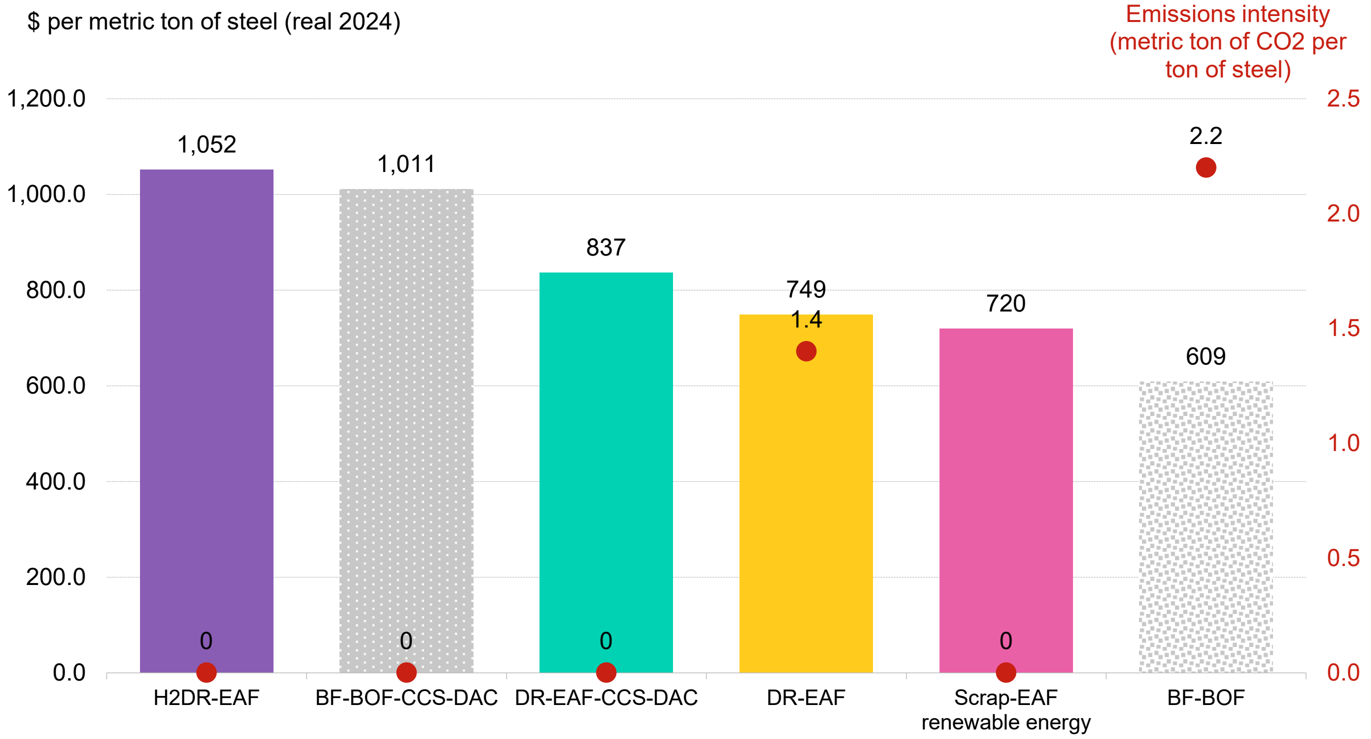
Carbon capture pathways

DR-EAFs with carbon capture can be a relatively cheap option, but may face feedstock supply constraints

Today, there is no operational DR-EAF plant in Japan. This technology also does not feature prominently in the country's steel decarbonization strategy. In 2030, such a DR-EAF-CCS-DAC plant in Japan theoretically would be the most economical choice for new emissions abated primary steel manufacturing capacity. The pathway allows steelmakers to produce cheaper and lower-carbon steel at $837/ton of steel in 2030 (Figure 18), 27% higher than the operational cost of an existing BF-BOF plant at $609/ton of steel but with none of the Scope 1 emissions.

However, this pathway is dependent on the materialization of CCS projects in Japan. Global supply chains for the higher-grade iron ores that the DR-EAF process require are also still nascent and emerging, presenting high uncertainty around availability and costs. Additionally, Japan is more reliant on imported gas, which creates added uncertainty.

Figure 18: Japan's levelized cost of steel in 2030 by production pathway



Source: BloombergNEF. Note: BF-BOF-CCS-DAC and BF-BOF represent retrofits while other represent new builds. Hydrogen based on cracking blue ammonia from Saudi Arabia. Carbon capture and storage (CCS) based on pipeline and offshore storage. Benchmarked against blast furnace-basic oxygen furnace (BF-BOF) emissions. DAC is direct air capture. DR is direct reduction.

Japan's steel sector may not largely rely on CCS due to high costs and weak policy framework

Japan's steel asset owners are keen to operate existing BF-BOF plants for as long as possible and CCS has gained attention as an enabler of that. Cost-competitive carbon capture and storage will determine if the technology is an economic decarbonization option for Japan's blast furnaces.

Japan introduced the CCS Business Act in 2024, establishing the first legal and licensing framework to facilitate private-sector participation in carbon capture and storage. While this represents a critical step, financing mechanisms remain underdeveloped. Instruments such as contracts-for-difference (CfD) or explicit price-gap support schemes are under discussion but have yet to be implemented.

METI is currently evaluating support frameworks through a dedicated committee. In the absence of robust policy incentives, many industry stakeholders view CCS as a last-resort abatement option, given its relatively weak competitiveness compared to alternatives. To date, CCS initiatives, such as the Tomakomai project, have been financed almost entirely with public funds.

Two main pathways are being considered to store captured CO_2 in Japan:

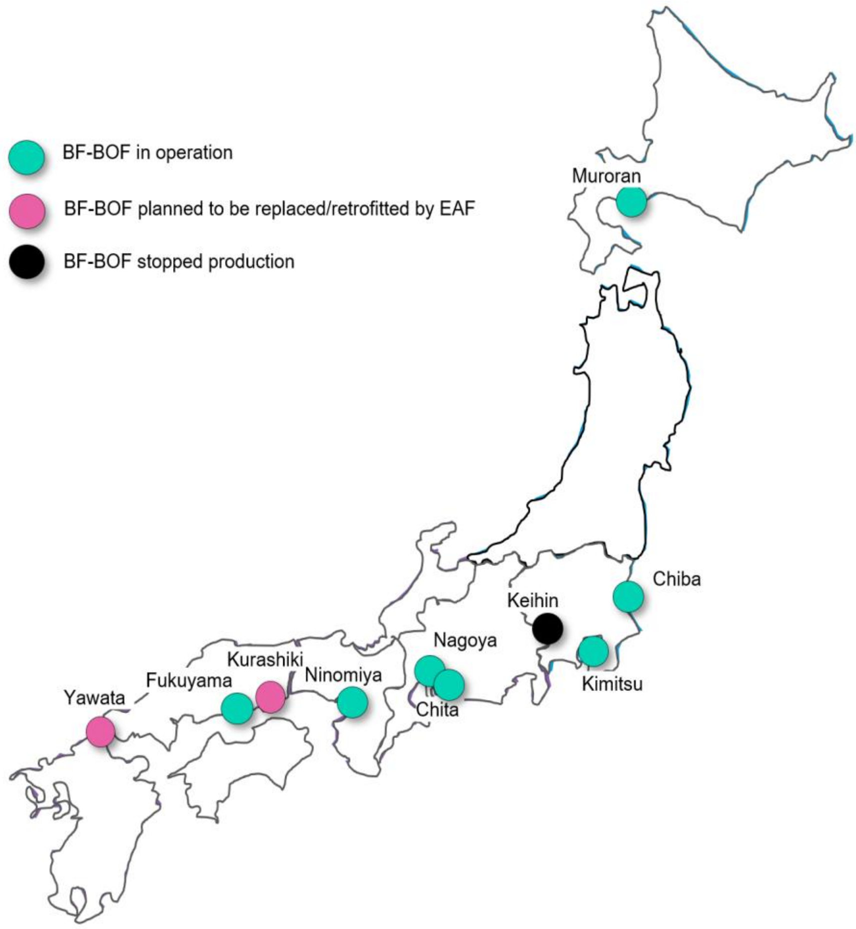
- Domestic offshore storage, involving the development of subsea sites off the Japanese coastline
- Overseas storage, requiring transportation using ships to partner countries such as Indonesia, Malaysia and Australia

The Japanese government has promoted overseas cooperation for carbon storage through the Asia Zero Emission Community (AZEC), emphasizing CCS as a regional decarbonization tool. However, cross-border storage faces unresolved issues around international liability, regulatory frameworks, and host country readiness. Onshore storage, while technically possible, faces significant opposition due to local concerns about impacts on groundwater resources, impact on agriculture, and seismic safety.

Japan's BF-BOF plants have access to near-shore carbon storage sites

Most BF-BOF steel plants are located nearshore rather than inland Japan, either on the Pacific Ocean side or Setouchi Inland sea (Figure 19).

Figure 19: Major BF-BOF-based steel production locations across Japan



Source: BloombergNEF, company websites. Note: Only includes major steel works locations. Map doesn't include Okinawa and other islands. BF-BOF is blast furnace basic oxygen furnace.

Projects selected under JOGMEC's Advanced CCS Program (Table 2) also concentrate on nearshore storage sites. Notably, the Tokyo project, covering Nippon Steel's Kimitsu Steel Works and other industrial emitters in the Chiba industrial complex, will capture CO_2 for transport via pipeline to offshore storage sites in the Pacific. METI has begun soliciting bids for storage well drilling rights at the proposed site.

The geographical proximity of the carbon storage sites and accessibility via pipeline reduces the carbon transportation infrastructure challenge faced by many CCS projects in other markets.

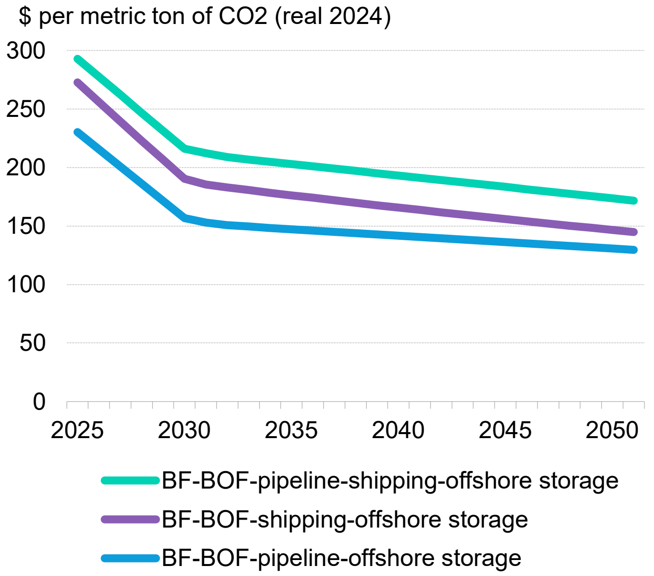
Table 3: Announced CCS projects in Japan by 2030, with the steel industry as emitting source

Project	Capture/storage capacity	Storage location	Expected FID decision	Major emitter	Transport type	Companies
Tohoku project	1.5~1.9MtCO_2/year	Offshore	FY2027	• Cement plants • Steel plants	Pipeline and shipping	ITOCHU, INPEX, NIPPON STEEL, MITSUBISHI HEAVY INDUSTRIES, TAIHEIYO CEMENT
Metropolitan Area CCS project	1.4MtCO_2/year	Offshore	FY2027	• Steel plants	Pipeline	INPEX, NIPPON STEEL
Oceania project	2MtCO_2/year	Offshore	FY2027	• Steel plants	Pipeline and shipping	NIPPON STEEL, Mitsubishi Corporation, ExxonMobil

Source: Japan Organization for Metals and Energy Security. Note: Details based on update by JOGMEC on July 9, 2025.

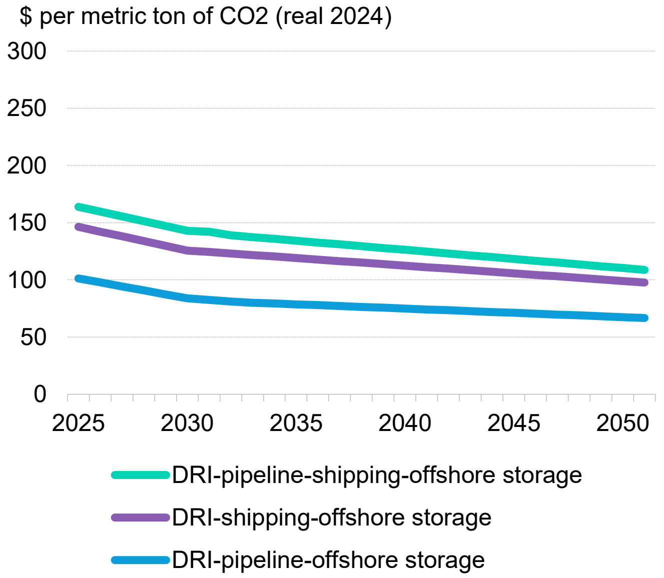
Storing CO_2 offshore in Japan via pipelines is currently the most economical option and is used as the benchmark in this analysis. Sending CO_2 to overseas storage sites, while technically feasible, adds significant costs due to shipping and still faces undecided regulatory requirements.

Figure 20: Total capture, transportation and storage costs for CO_2 from BF-BOFs, by pathway



Source: Research Institute of Economy, Trade and Industry, BloombergNEF. Note: BF-BOF is blast furnace-basic oxygen furnace. CCS is carbon capture and storage

Figure 21: Total capture, transportation and storage costs for CO_2 from DR-EAFs, by pathway



Source: Research Institute of Economy, Trade and Industry, BloombergNEF. Note: CCS is carbon capture and storage, DRI is direct reduced iron. DR-EAF is direct reduction-electric arc furnace.

Within the CCS value chain, carbon capture is usually the costliest component. In a BF-BOF plant, emissions come from multiple dilute gas streams, which makes carbon capture more technically challenging and costlier. This requires plants with larger capacity and higher energy demand and will also involve potential retrofits to several facilities within old steelmaking plants. In contrast, direct reduction with electric arc furnaces (DR–EAF) generates fewer, more concentrated CO_2 streams that are relatively cheaper to separate and easier to integrate into capture systems.

As no commercial-scale CCS projects have yet been built in Japan, first-of-a-kind (FOAK) projects could cost more. This reflects the higher upfront investment and additional complexity involved in integrating capture systems across diverse emission sources and managing the challenges of early deployment.

CCS will require a high carbon price or subsidies to be cost competitive

LCOS from an emissions-abated BF-BOF process in Japan could reach $1,011/ton (real 2024) in 2030 even with nearshore carbon storage sites. Abating emissions from a BF-BOF production process would raise the price of steel by 66% (Figure 18). CCS pathways will cost Japanese steelmakers more if they have to pipe and ship the captured carbon to an offshore site.

CCS abatement remains an expensive option out to 2050. Technological advancement and economies of scale are expected to drive the LCOS of a BF-BOF-CCS-DAC production down to $839/ton of steel in 2050. However, this remains the second-most expensive emissions abatement option for Japan, out-competing only hydrogen-based steel production by mid-century.

Hydrogen-based pathways

Significant reduction in cost is needed to make hydrogen-based steelmaking competitive in Japan

Japan is committed to developing its hydrogen industry to support its net-zero targets including decarbonization of hard-to-abate sectors such as steel production. BNEF's analysis shows that hydrogen-based steel production processes are expensive without subsidies or carbon pricing.

Like CCS, reducing the cost of hydrogen is critical to the scaling up of this decarbonization pathway. Further technological advancements for electrolyzers and maturation of the industry are still needed to help drive costs down for hydrogen-based steel production.

Steel producers in Japan face two primary options for procuring hydrogen: domestic production or imports. Domestically, hydrogen can be produced through green or blue pathways, using imported fuel, or ammonia, which is subsequently cracked back into hydrogen within Japan. For this study, we have assessed the costs of green and blue hydrogen produced in Japan, and ammonia imports from Australia, China, and Saudi Arabia, with conversion to hydrogen via ammonia cracking.

Japan remains a costly market for green hydrogen production, due to its high renewable electricity costs and electrolyzer equipment. BNEF's calculation estimates that by 2030 (in 2023 dollar terms), electrolyzer capital expenditures in Japan and Australia could be more than 3.5 times higher than in Saudi Arabia and China, and up to 4 times higher than in India. *See Electrolysis System Cost Forecast 2050: Higher for Longer (web | terminal).*

The total cost of hydrogen delivered to a steel plant in Japan is estimated by combining three components:

- Levelized cost of ammonia needed to yield 1 kilogram of hydrogen (8 kg × $/kg of ammonia)
- Transport costs

- A fixed ammonia cracking cost

For this analysis, we assume hydrogen produced within Japan is produced onsite at the steel facility with no transportation cost involved.

Over time, green hydrogen costs are expected to decline as electrolyzer performance and unit economics improve (Figure 22). In contrast, blue hydrogen, usually produced via methane reforming, is unlikely to see significant cost reductions. However, blue hydrogen, particularly in the form of imported blue ammonia from Saudi Arabia, is cheaper than green hydrogen through the late 2040s, and forms the base case for our analysis. Green hydrogen, while strategically important, is not expected to achieve cost competitiveness compared to blue hydrogen from imported blue ammonia at scale in the Japanese steel sector within the forecast horizon.

Figure 22: Delivered cost of hydrogen in Japan, by type

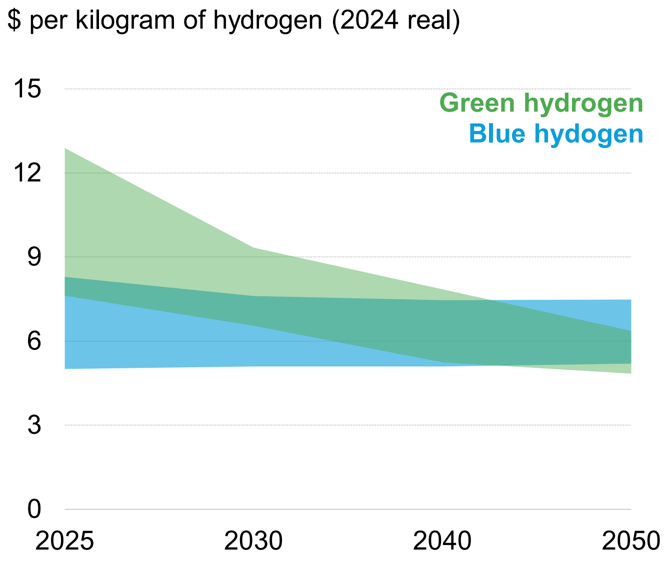
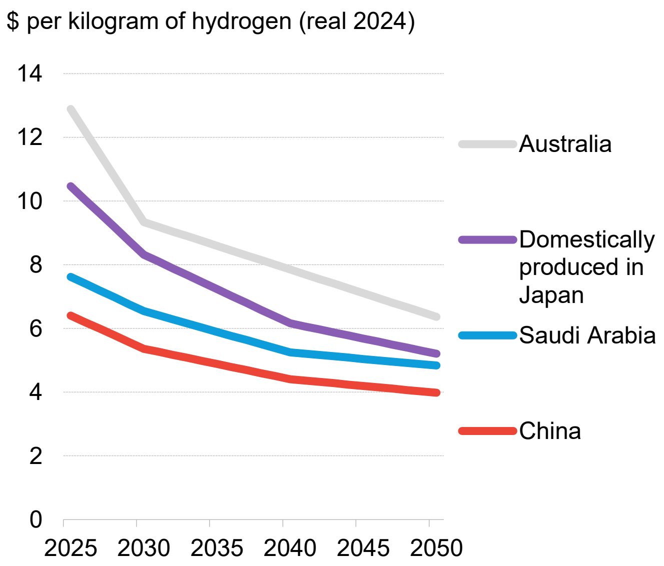


Figure 23: Delivered cost of green hydrogen in Japan, by production country

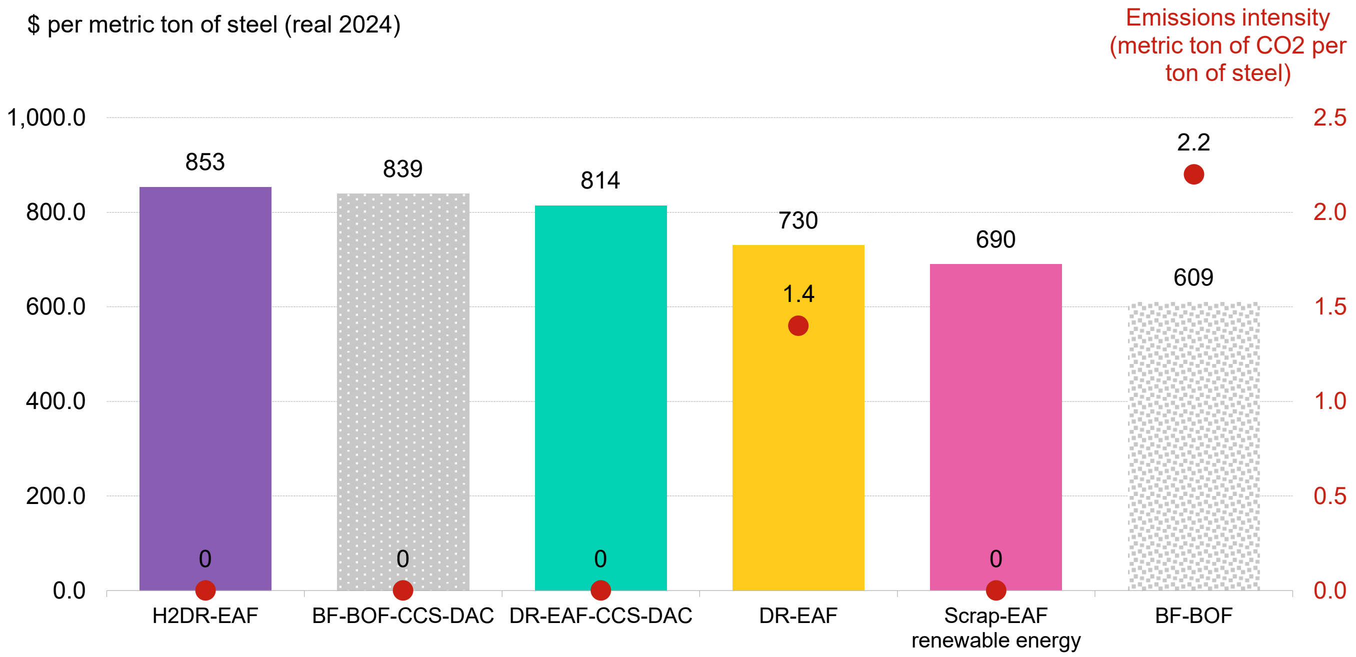


Source: BloombergNEF. Note: Total hydrogen delivery cost is calculated by summing the cost of green ammonia required to produce 1 kilogram of hydrogen (8kg × $/kg of ammonia), the transport cost per kg of hydrogen (based on the per-ton ammonia transport rate), and the fixed ammonia cracking cost of is $0.60 per kg of hydrogen. For Japan, the calculation assumes onsite production.

Hydrogen-based steelmaking is expected to remain costly through 2050.

In 2030, the LCOS of a H2DR-EAF steel plant is expected to be $1,052/ton of steel (real 2024). This is 1.7x more expensive than the operational cost of steel production from an existing BF-BOF, and 1.4x more expensive than an existing scrap-EAF steel production plant. This falls to $853/ton of steel (real 2024) by 2050 (Figure 24) but remains the most expensive decarbonization option for Japan’s steel sector.

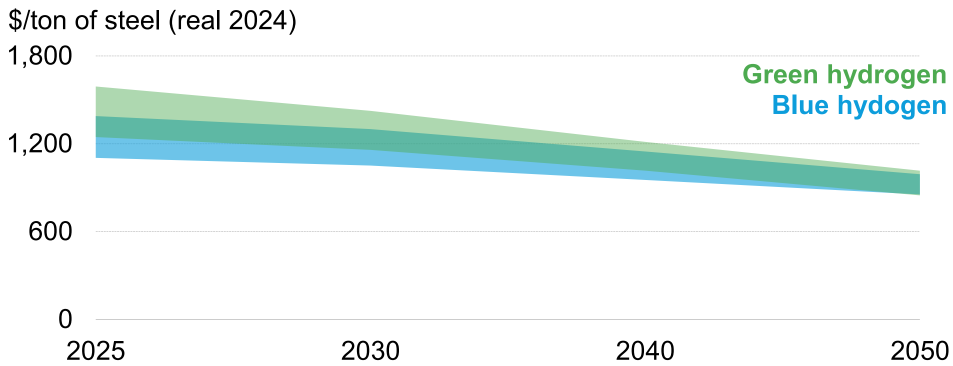
Figure 24: Japan's levelized cost of steel in 2050 by production pathway



Source: BloombergNEF. Note: BF-BOF-CCS-DAC and BF-BOF represent retrofits while others represent new builds. Hydrogen based on cracking blue ammonia from Saudi Arabia. Carbon capture and storage (CCS) based on pipeline and offshore storage. Benchmarked against blast furnace-basic oxygen furnace (BF-BOF) emissions. DAC is direct air capture. DRI is direct reduced iron. DAC is direct air capture.

Green hydrogen commands a premium to blue hydrogen today. According to BNEF estimates, producing steel with green hydrogen may become cheaper than from blue hydrogen in the late 2040s (Figure 25). The cost reduction expected from green hydrogen, however, is insufficient to change the relative economic competitiveness of a hydrogen-based steel production pathway compared to other low-emission steel options.

Figure 25: Levelized cost of steel in Japan using the H2DR-EAF production pathway, by range of hydrogen cost and color



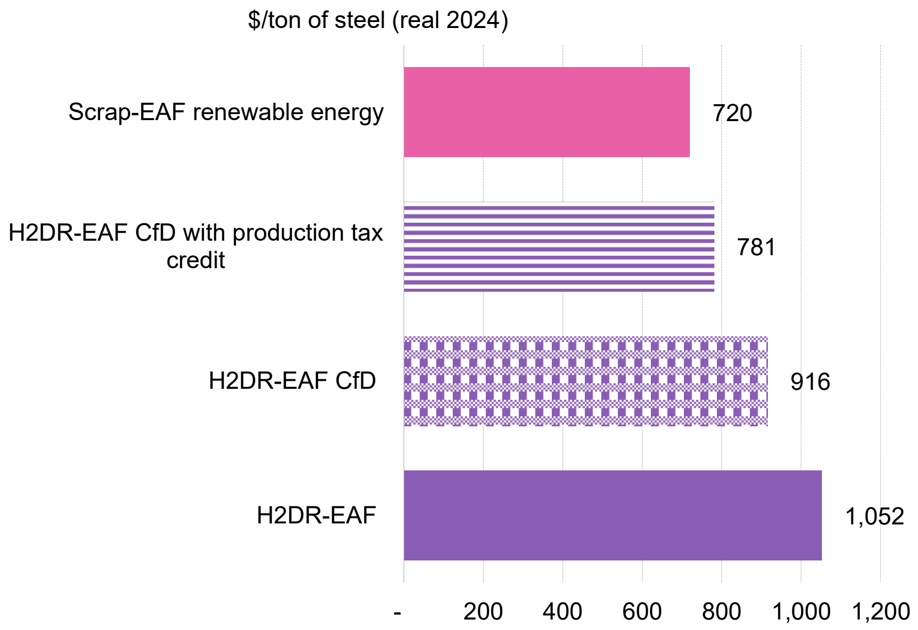
Source: BloombergNEF. Note: H2DR-EAF is hydrogen-based direct reduction integrated with electric arc furnace.

H2DR-EAF-based steelmaking may get help from current subsidies, but is unviable without a significant decrease in unsubsidized hydrogen costs

Hydrogen suppliers in Japan are eligible for a CfD scheme for replacing other carbon intensive fuels with hydrogen. Such subsidized hydrogen can then be used by steelmakers to produce H2DR-EAF-based steel. Additionally, if the full subsidies awarded to a hydrogen supplier are passed through to Japan's steel manufacturers, it could help lower the levelized cost of producing steel (LCOS) through the H2DR-EAF pathway by 13% to $916/ton of steel (real 2024) in 2030, down from $1,052/ton of steel without the subsidy (Figure 26).

Japan also allows double dipping of its hydrogen CfD with a production tax credit. When combined with the production tax credit for green steel, the levelized cost of steel is further reduced to $781/ton of steel (real 2024). This is still more expensive than scrap-EAF running on renewable energy but narrows the premium. However, there is uncertainty over whether the tax credit and subsidy will be extended.

Figure 26: Levelized cost of steel by production pathway and subsidy scenario in 2030



Source: BloombergNEF. Note: H2DR-EAF is hydrogen-based direct reduction integrated with electric arc furnace. CfD is contract for difference. Calculation assumes projects beginning in 2030, supported by a 15-year contract for difference. After the CfD expires in 2045, hydrogen providers must operate without subsidy for an additional 10 years. After 2045, the model applies the forecasted levelized cost of hydrogen derived from blue ammonia imported from Saudi Arabia.

Bio-based pathways

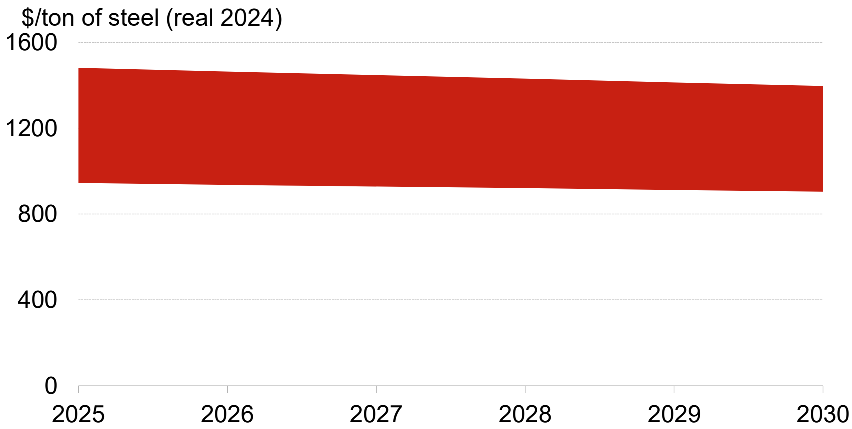
Suitable and cheap biomass supply chain as a coal substitute is needed for the BF-BOF-biomass route; most projects are at feasibility study stage

One potential pathway to reduce coal use in BF–BOF steelmaking is its partial replacement with biomass, but identifying biomass with an energy density comparable to coal remains a major challenge. Different biomass derivatives are being explored, each with unique advantages and limitations. Raw forms such as wood chips and white pellets typically suffer from low calorific value, high moisture content, and inconsistent ash composition, making them unsuitable for direct large-scale use.

Biochar, produced through pyrolysis, is viewed as a more viable alternative due to its higher energy density and improved handling properties. However, cost remains a critical barrier. Replacing coal with biochar is estimated to increase steel production costs by approximately $904 to $1,396 per ton of steel (Figure 27) in 2030, largely reflecting the high cost of biochar, which ranges between $200 and $500 per ton.

Kobe Steel has launched a feasibility study for replacing coal with biomass. However, biochar is not yet proven for full coal substitution in blast furnaces. Current trials and studies focus only on partial replacement, highlighting significant technical, economic, and supply-related uncertainties. Further research, demonstration projects, and supply chain development will be required to validate performance and lower costs before biochar can play a more substantial role in BF–BOF decarbonization.

Figure 27: Levelized cost of steel in BF-BOF-biomass production pathway 2025-2030



Source: BloombergNEF.

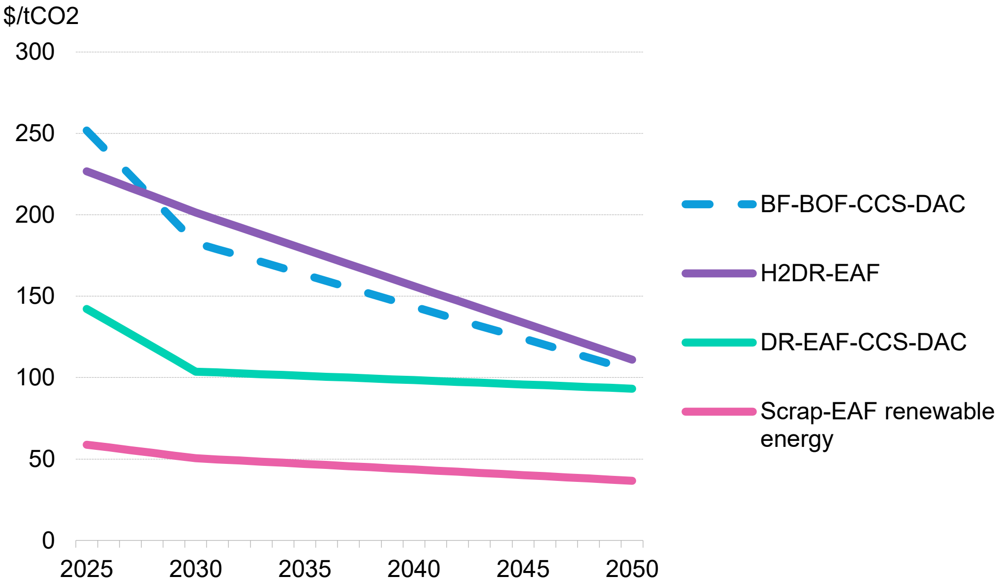
3.2. Marginal cost of abatement

Unlike the power and transport sectors where net-zero options can compete economically with conventional technologies, decarbonized steel production will always be more expensive than unabated production. That makes either subsidies or some form of carbon pricing crucial to reduce emissions in this industry based on economics.

Compared to other decarbonization pathways, scrap-EAF when coupled with renewable energy remains one of the cheapest pathways to decarbonize (Figure 28). In 2030, a $50/tCO_2$ carbon price would allow a scrap-EAF pathway powered by renewable power to be cost-competitive against an existing fully depreciated BF-BOF plant.

BNEF estimates that a carbon price of \$183/tCO_2 and \$202/tCO_2 is needed to make BF-BOF-CCS-DAC and H2DR-EAF production pathways cost-competitive against BF-BOF in 2030, respectively. We expect costs decrease over time, reducing the carbon price support to \$104/tCO_2 and \$111/tCO_2 for the same two technologies respectively by 2050, almost three times the marginal abatement cost for scrap-EAF of \$37/tCO_2.

Figure 28: Marginal cost of abatement by decarbonization pathway in Japan



Source: BloombergNEF. Note: Dotted lines represent retrofitted existing plants while solid lines represent new build. Hydrogen based on cracking blue ammonia from Saudi Arabia. Carbon capture and storage (CCS) based on pipeline and offshore storage. Benchmarked against blast furnace-basic oxygen furnace (BF-BOF) emissions. DRI is direct reduced iron. DAC is direct air capture.

While decarbonization is a public priority in many markets, even under supportive policy frameworks, the premium remains far above the industry’s usual margins per ton of steel. This highlights the need for either significantly higher carbon prices or broader cost reductions across the hydrogen and CCS value chain.

Section 4. Path forward

Japan's national decarbonization goal is closely intertwined with its industrial decarbonization policies. Achieving Japan's 2050 carbon neutrality goal requires action now accompanied by coordinated and stringent measures to drive tangible emissions reduction in the country's steel sector while maintaining the sector's global competitiveness.

BNEF has identified four potential steps to accelerate decarbonization of Japan's steel sector:

- Establishing low-emissions steel standards and benchmarks
- Maximizing EAF utilization and increasing electric steel production
- Strengthening the carbon market to drive decarbonization
- Scaling demand for low-carbon steel

4.1. Establishing low-emissions steel standards and benchmarks

Laying out low-emissions steel standards and benchmarks has the potential to provide a strong signal to domestic steel manufacturers on the need for decarbonization. It also gives manufacturers clarity on the end-goal and a pathway to make the necessary plans and investments.

A green steel standard that recognizes all available pathways

Japan currently lacks an official green steel or low-emissions steel standard, leaving manufacturers and buyers to rely on self-declared standards and voluntary frameworks (Table 4). Without a unified standard, each manufacturer defines its own criteria for what qualifies as "low emissions," leading to limited comparability across products.

Table 4: Currently marketed low-emission steel products by Japan's manufacturers

Manufacturer	Advertised product	Emissions reduction method example	Marketed CO_2 reduction versus usual products	Accounting method for emission
Nippon Steel	NSCarbolex® Neutral	Conversion of scrap melter to an electric arc furnace	Up to 100%	Mass balance
JFE Steel	JGreeX™	Expanded use of cold iron sources (such as scrap)	Up to 100%	Mass balance
Kobe Steel	Kobenable® Steel	Eliminating annealing and tempering in the production process	Up to 100%	Mass balance
Tokyo Steel	enso®; Near Zero / ほぼゼロ	EAF (scrap-based) and using renewable energy certificate	~ 75% for near zero products	Physical EAF and non-fossil power certificate

Source: BloombergNEF, company website. Note: BF-BOF is blast furnace-basic oxygen furnace. EAF is electric arc furnace.

The development of a green steel standard agreed across industry, which prevents carbon leakage, is based on a physical reduction in emissions and promotes investment into low-emissions steel production, would greatly support the development of Japan's green steel market.

Globally, no universally agreed definition exists either. The European Union is moving toward a common approach under its Carbon Border Adjustment Mechanism (CBAM), while initiatives such as the Low Emission Steel Standard (LESS) provide voluntary classification systems that differ in thresholds and coverage.

India's 2024 green steel taxonomy is currently the only government-endorsed standard, setting an intensity threshold of 2.2 tons of CO_2 per ton of finished steel, a starting point but not enough to drive global alignment. For more, please refer to *India's New Green Steel Thresholds Aid 2030 Emissions Goal* (web | terminal).

Leading the formulation of a global green steel standard

Japan, as one of the world's largest steel producers and exporters, is better positioned to take an active role in facilitating the development of a global green steel framework that is credible and technology-neutral. By establishing transparent, third-party verifiable and internationally consistent standards in partnership with other steel-producing markets and multilateral organizations, Japan can bring credibility to a fragmented market and shape a clear, net-zero–aligned framework for green steel. This also provides a clear direction and pathway for Japanese steelmakers to stay relevant in future global steel supply chains.

Green steel standards may need to evolve over time and recognize all decarbonization technologies and efforts

Japan is responding to rising global demand for lower-carbon steel and enabling its domestic steelmakers to stay relevant in global supply chains with a green steel framework. The Japan Iron and Steel Federation (JISF) published its green steel guidelines as part of the country's Green Transformation strategy. JISF's green steel standards primarily adopt the "mass balance" and "allocation" approaches to enable steelmakers to offer lower-emission products.

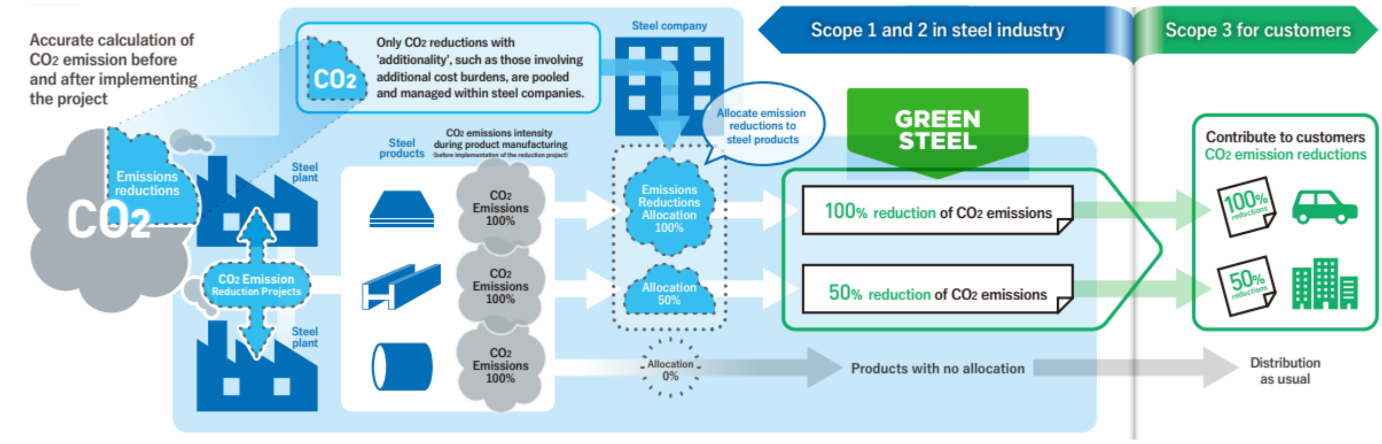
Under the mass balance approach, emissions reduction achieved from the organization's Scope 1 and 2 emissions, termed as Achieved Amount of Reduction (AAR), can be aggregated and allocated to its products, enabling them to offset up to 100% of their embodied emissions (Figure 29). The product sold is accompanied by a carbon reduction certificate which can be applied to the purchaser's Scope 3 emissions even if the production process underlying the marketed "green" or "lower-emissions" steel remained largely unchanged. This offers little transparency for buyers and policymakers and few incentives for manufacturers to invest in production process decarbonization technologies in the near term.

JISF has also introduced an "allocation" approach allowing verified greenhouse gas (GHG) reductions made at the company level to be directly reflected in the product's carbon footprint (CFP).

Such approaches have been tapped by many markets, including Europe, at a time when decarbonization options are still limited. They are effective in spotlighting the need for emissions reduction and pushing steelmakers to optimize their operational emissions to the extent possible through available technologies such as improved processes and energy efficiency.

Nonetheless, Japan's green steel standards and definition may need to evolve and tighten over time. As decarbonization rules and policies tighten in Japan's steel export markets, steel purchasers may start to require or be willing to pay a premium for greater traceability and products that "physically" embody lower carbon.

Figure 29: Japan's "mass balance" approach for green steel



Source: Japan Iron and Steel Federation

Decarbonizing Japan's steel sector will require the country to explore all available low-carbon steel pathways. Accordingly, any green steel standard can adopt an inclusive framework or have varying frameworks that recognize the diverse approaches that all contribute to emissions reduction in the steel sector.

4.2. Maximizing EAF utilization

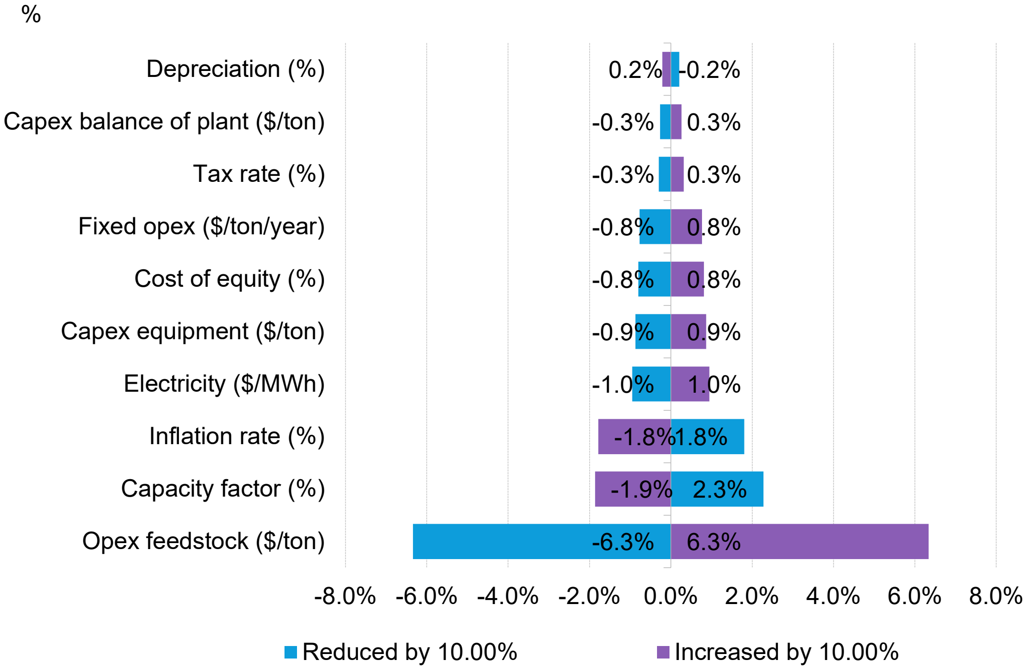
Shifting steel production from the coal dependent BF-BOF route to EAF is at the center of Japan's current steel decarbonization strategy. Domestic steel manufacturers such as JFE Steel and Nippon Steel have announced plans to replace their BF-BOF assets with EAFs. It is critical that Japan ensure the build-out of required infrastructure to support increasing EAF production, both from new and existing assets, to avoid potential bottlenecks.

Building out long-term clean power and grid infrastructure

EAF steel production is highly power-intensive, consuming between 400 and 600 kilowatt-hours of electricity per ton of crude steel. A stable and affordable supply of zero-emission electricity is crucial for Japan's steel decarbonization strategy. Given these high energy needs, both power price and emission intensity of the power are major determinants of the cost-competitiveness of low-emissions steel produced in Japan through the EAF route. BNEF estimates that a 10% variance in electricity prices results in a 1% change in the levelized cost of steel (LCOS) for EAF-based production (Figure 30).

Japan's power prices are facing increasing volatility due to its high dependency on imported fuel, growing volatility in the global commodities market, tight domestic supply of firm power capacity and grid infrastructure constraints. This creates uncertainty for energy-intensive industries. For more on Japan's power, please refer to *Japan Power Market Outlook 2H 2025: Bumpy Descent to 2030 (web | terminal)*.

Figure 30: Sensitivity analysis of the levelized cost of producing steel (LCOS) for scrap-EAF, new plant in 2025, production pathway, by variable



Source: BloombergNEF.

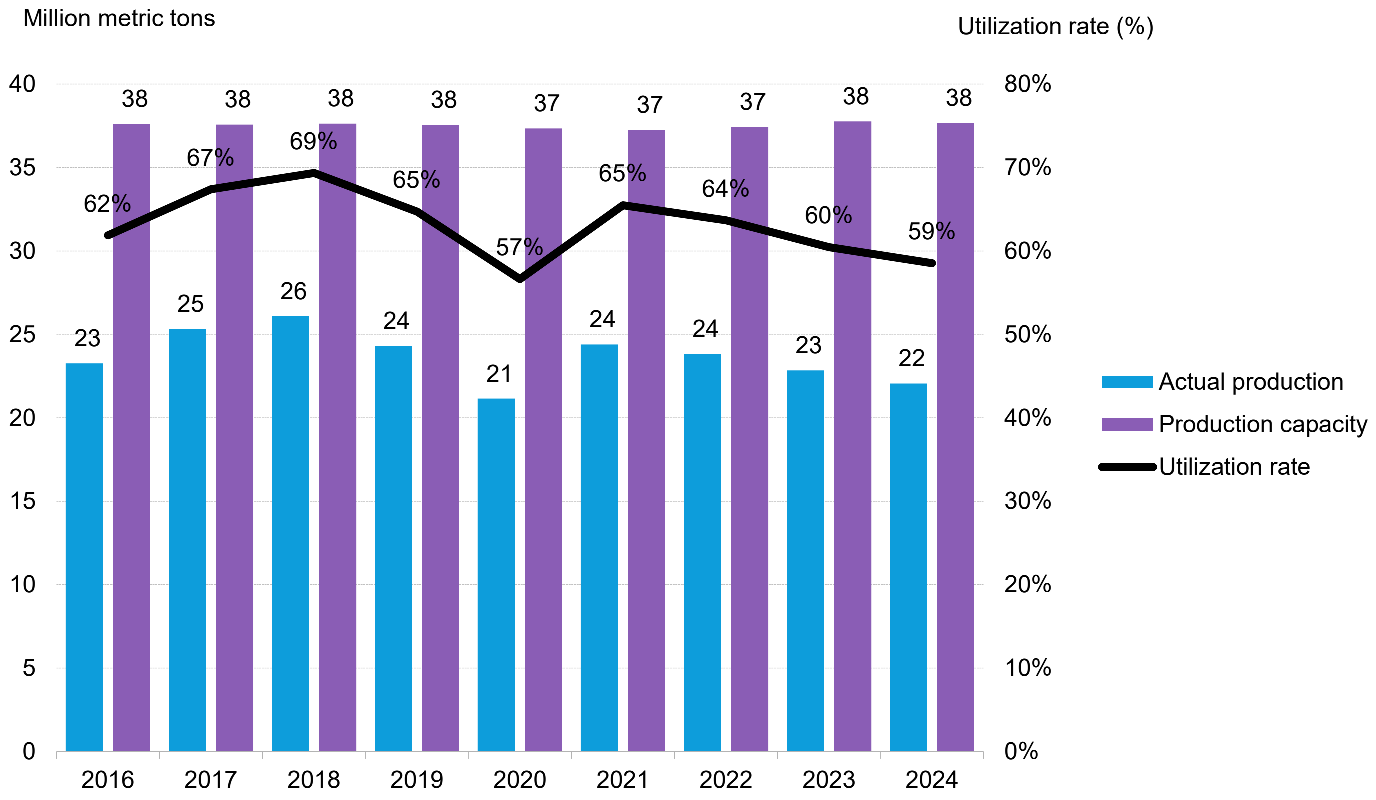
To mitigate price volatility and reduce carbon emissions, energy-intensive industries, particularly in the materials, industrial, and manufacturing sectors, are increasingly entering long-term clean power purchase agreements (PPAs) globally. In 2024 alone, the materials industry accounted for 10GW of clean PPA capacity, representing 17% of global deals. Since BNEF began tracking clean PPAs, materials firms have consistently been the largest off-taker group across 27 major markets worldwide. For more information regarding corporate power procurement, please refer to *1H 2025 Corporate Energy Market Outlook: Enter Nuclear* (web | terminal).

Steelmakers in Japan can take an active role in securing long-term, low-cost, zero-emission electricity through clean PPAs. Government policy has a key role in facilitating this shift. Renewable power expansion faces challenges such as grid congestion, lengthy approval processes for grid connections, and land procurement challenges, all of which hinder a reliable zero-emission supply. Government action, through grid expansion, and streamlined land-use regulations, is crucial to unlock greater renewable integration. Policies supporting expansion of renewables and nuclear power sources can further ensure stable, affordable electricity for industries. Expanding renewable and nuclear generation capacity, strengthening transmission networks, and promoting energy storage will collectively enhance the stability of zero-emission power supply.

Bolstering scrap steel supply and quality for domestic steel producers

Japan's EAFs tend to operate below their potential capacity (Figure 31) due to several structural and operational challenges. Logistical constraints in material handling are key factors that restrict continuous operation. High electricity costs in Japan further limit cost-effective furnace utilization, while product-mix constraints, such as the difficulty of producing high-grade steels with variable scrap quality, also reduce the overall utilization rate.

Figure 31: Electric arc furnace production capacity and utilization rate in Japan, by year



Source: Ministry of Economy, Trade and Industry, Japan Iron and Steel Federation. Note: Utilization rate is calculated by dividing actual production by production capacity.

As Japan's EAF fleet expands, demand for scrap will rise. Ensuring steelmakers have access to a stable supply of scrap steel will allow Japan to maximize production of lower-carbon steel locally. As global decarbonization and resource sufficiency efforts intensify, scrap supply is increasingly viewed as a strategic resource with a growing number of markets implementing either a partial or full ban on scrap exports. Likewise, Japan needs to prioritize domestic utilization of available scrap through regulatory or fiscal measures that discourage exports and ensure stable feedstock for domestic EAFs.

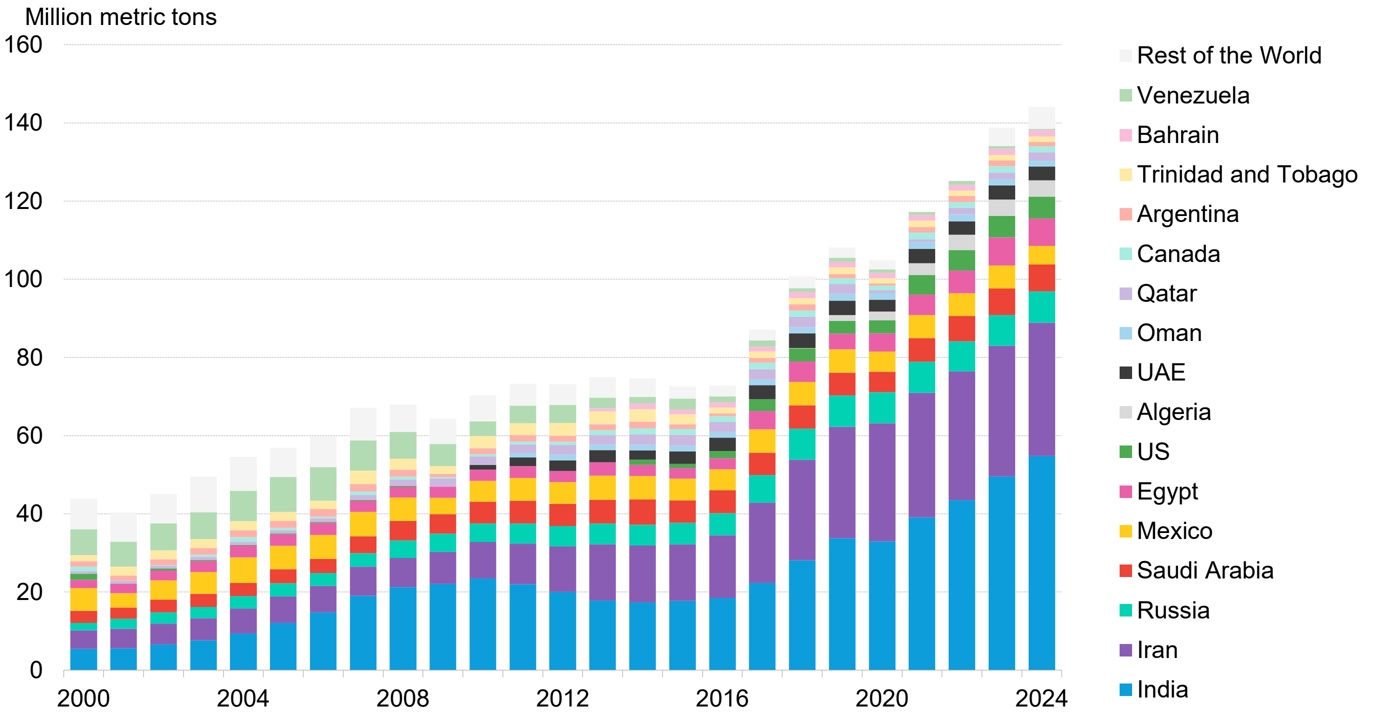
Japan produced about 43 million tons of scrap in 2024, 7 million tons of which were exported. This suggests current domestic scrap supply is nearing demand. Strengthening recycling mandates for higher recovery rates and enhancing scrap sorting infrastructure and processes could aid in improving the availability and quality of domestic scrap to support steel production.

Establishing supply chains for new low-carbon iron feedstocks through technological and trade partnerships

Most pathways to low-emission steel will require a shift in long-established trade dynamics. As Japan's steel production asset base moves from one dominated by BF-BOFs to EAFs to be compatible with its 2050 carbon neutrality goal, new feedstock supply chains need to be established. Japan's current exported scrap volume is only sufficient to support an additional 5.8 million tons of steel production, just sufficient to displace 9% of steel produced domestically through BF-BOFs in 2024. Developing and securing access to other low-carbon iron feedstocks, such as direct reduced iron (DRI), can provide certainty for Japanese steelmakers looking to boost low-emissions steel production through EAFs.

High-quality iron ore reserves are scarce, and miners and governments globally are committing to increasing the supply of DR-grade products to capture this high-value market and meet the growing demand from steelmaking companies (Figure 32). Early engagement by Japan and its steelmakers with markets looking to produce DRI could help advance the availability of and ensure Japanese steelmakers' access to required feedstocks.

Figure 32: Direct reduced iron production, by country



Source: BloombergNEF, World Steel Association.

4.3. Strengthening the carbon market to drive decarbonization

Japan's carbon pricing system is entering a pivotal stage as METI introduces a proposal for new benchmark-based allocations under the GX-ETS for the steel sector. The proposed framework, still under review, sets process-specific emissions benchmarks for blast furnace, scrap EAF, and special steel EAF routes. Japan looks to establish the benchmarks based on emissions intensity levels based on the top-performing assets of each category (2.3).

An effective carbon pricing scheme needs a sufficiently high carbon price that incentivizes decarbonization. In the compulsory GX-ETS market starting next year, Japan will need per ton of CO_2 costs to be more than \$59 for the least-cost zero-emission (scrap-EAF) pathway to compete with BF-BOF (Figure 28). This is relatively higher than the historical weightage average domestic voluntary credit market price of less than $20 per ton of CO_2.

To ensure long-term decarbonization efforts, Japan's carbon program needs to establish a clear pathway for progressive tightening of benchmarks aligned with net-zero objectives. Free carbon credit allocations need to decline predictably, helping to shift production toward pathways that drive decarbonization. The program also needs to integrate transparent verification of emissions data, allowing fair comparison across producers and maintaining comparability with international carbon border measures so that Japanese low-emissions steel products are competitive in the markets with carbon border tariffs as well.

4.4. Scaling demand for low-carbon steel

Expanding eligibility for green public procurement programs

Governments can drive green steel market formation and encourage necessary investments into steel decarbonization technologies through green procurement. Japan could accelerate the development of its local green steel industry through stronger demand signals.

Japan's Act on Promoting Green Procurement already provides a foundation for environmentally responsible purchasing and can evolve into a key driver of industrial decarbonization. The government's ongoing plan to include green steel within the law's framework represents a major opportunity to align public spending with emission reduction and industrial competitiveness goals. To make this effective, the framework should establish clear, verifiable thresholds for embodied emissions in steel used for public projects, prioritizing products that demonstrate substantial and measurable physical reductions in carbon intensity (4.1).

Government-led demand will also help de-risk further investment in low-emission technologies such as DRI, EAF upgrades, and other low-emission technologies. For more, please refer to *Scaling Technologies for Greening Heavy Industry* (web | terminal).

As with Japan's green steel standards, its green public procurement program and other demand side programs must acknowledge the diverse portfolio of available steel decarbonization technologies and allow a level playing field and access to support for all domestic steel producers based on physical emissions, regardless of the decarbonization pathway.

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