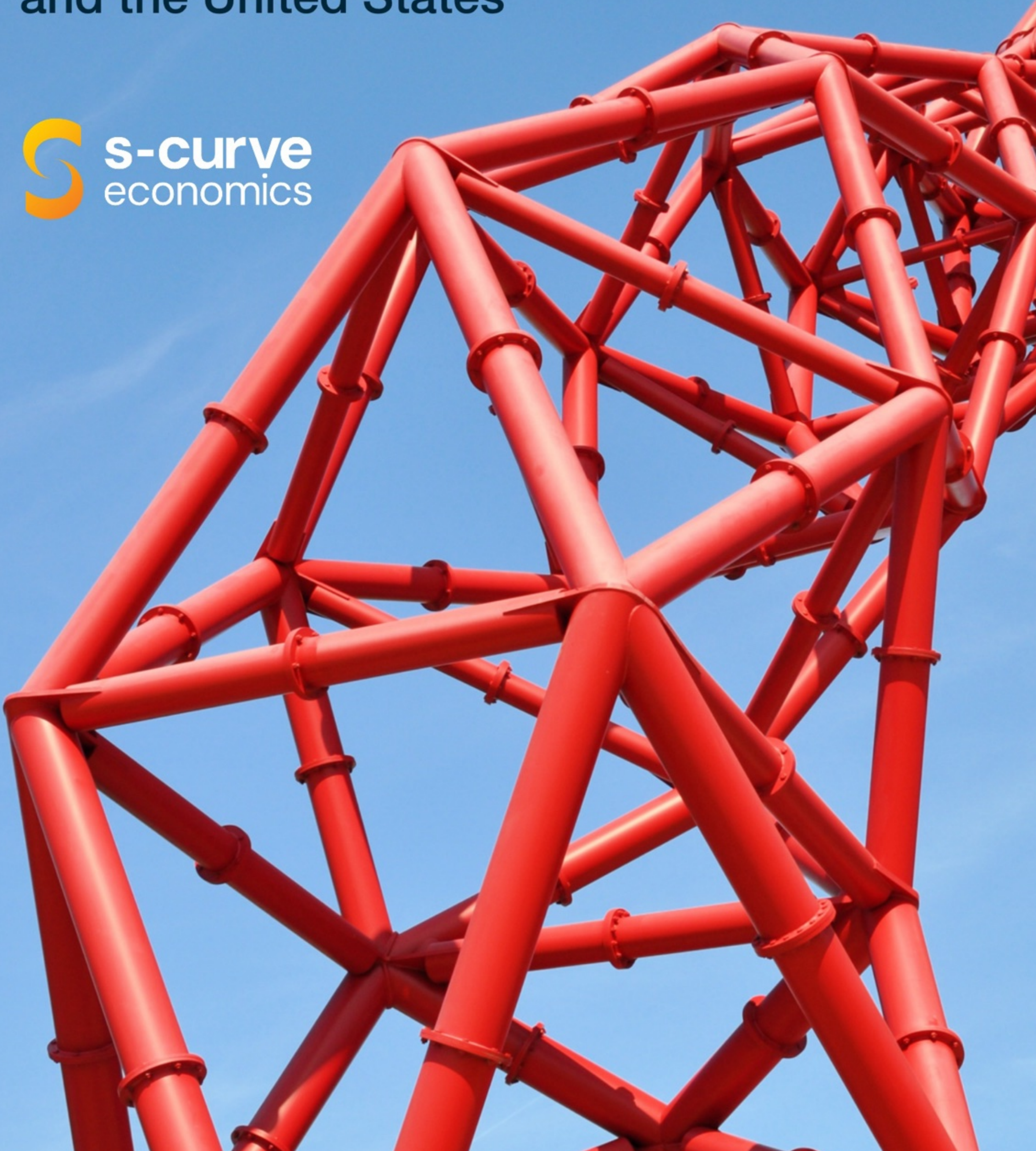
Scenarios for the Global Steel Transition

China, the European Union, and the United States

s-curve economics



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About us

S-Curve Economics CIC is a non-profit research organisation focused on advancing the understanding of the economics and diplomacy of the energy transition. Our analysis focuses on the power, road transport, and steel sectors, and cross-cutting issues of economics, policy appraisal, and diplomacy. Find out more at www.scurveeconomics.org.

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1 Executive summary

Executive Summary

The iron and steel sector, one of the most emissions-intensive and highly traded industries globally, faces dual challenges. Conventional steel production is undergoing significant disruption, as overcapacity cuts into profits and new tariffs reshape trade flows. At the same time, the sector is on the cusp of a wider transformation, as policymakers and industry seek to shift towards new technologies as part of efforts to address climate change.

In this context, policymakers and industry decision-makers face a complex challenge. They must steer their industries through the competitive pressures in the conventional steel markets, while simultaneously aiming to realise the opportunities and manage the risks of a technology transition.

This report summarises the findings of scenario exercises held among policymakers, researchers, industry representatives and other steel experts in each of China, the European Union and the United States, as well as a workshop involving experts from the three regions. These exercises explored different possible futures for national steel industries in the context of the global transition to near-zero emission steelmaking. The international workshop, facilitated using the Three Horizons framework, explored how international cooperation could shape this transition.

Diverse possible futures

The scenarios illustrated a diverse range of possible futures for each region's steel industry.

European stakeholders were uncertain about their industry's ability to access low-cost clean electricity and hydrogen, and unsure whether the EU could pursue a coherent industrial strategy. They could imagine European steelmakers succeeding in a *Green Multilateralism* scenario where the EU develops strategic partnerships to import green iron and cooperates with other major economies to create global markets for clean steel. But this was seen as less plausible than a *Fortress Europe* scenario where a protectionist EU achieves decarbonisation within its own borders but fails to shift the global market in line with its climate change goals. They could also envisage a *Managed Decline* scenario where producers in other regions such as China and the Middle East move more quickly to adopt the new technologies, leaving Europe behind.

Chinese participants were confident in their industry's technological capability to produce clean primary steel, but unsure how much demand for it would exist both domestically and internationally. They also faced uncertainties regarding conventional high-emission steel. These included how much growth in demand would be driven by other fast-developing economies, how open global markets would remain to China's output, and how long domestic overcapacity would persist. They saw a *Technological Foresight* scenario, where China develops a high capacity for clean steel production ahead of global demand, as the most plausible. At the same time, they considered a *Maximum Blast Furnaces* scenario to be the future most closely resembling the present, perhaps indicating a recognition that while China's carbon neutrality goals are clear, policies to deploy large-scale clean steel production capacity are yet to be established.

Steel experts in the US were uncertain whether domestic politics would in future support technological change in the steel industry. Instead, they focused on how much private demand for clean steel could incentivise industry investment in the absence of policy, or whether a breakthrough in a technology such as molten oxide electrolysis could change the game. They could imagine an *On The Fairway* scenario where America's desire to be at the forefront of innovation has driven long-term investment in clean technologies, resulting in growing exports of steelmaking technology as well as steel itself, but this most favourable scenario for US industry was also seen as the least plausible. The *Steel, the New Solar* scenario was seen as more likely, where China pursues clean steel as a strategic priority and the US, viewing the transition through the political lens of climate change, does not respond. Participants were unanimous in believing that policymakers were planning for a future in which China dominates clean steel production.

Participants from the three regions varied in their expectations and confidence in relation to the transition. Chinese participants were the most inclined to believe a fast global transition was likely, and the most confident about the future of the global steel sector being favourable for their national industry. US participants were the least confident in this respect. Chinese and European participants each saw a moderate level of overlap between the scenarios most favourable for their industries and the futures their governments were planning for, while US participants perceived little if any overlap.

International factors as determinants of country outcomes

While national starting points and contexts differ markedly, many of the uncertainties identified by participants in the project were international in nature, and common across the three regions. These included:

- the openness of trade in future
- the evolution of global standards
- the scale of global demand for low and near-zero emission steel
- the future costs of alternative clean steel production technologies
- the speed at which other countries move to deploy clean steel production technologies.

How governments respond to these uncertainties, through their domestic and international policy choices, will strongly influence whether their industries realise advantages or are exposed to risks as either first-movers or late-movers to clean steel technologies. Collectively, governments' actions will also shape the pace and costs of the global transition.

A clear implication is that **policymakers cannot plan effectively for the steel transition on the basis of domestic policy alone**. They must also consider the wider industry, trade, diplomacy and geopolitical environment.

Across the three regions, **scenarios involving a relatively high level of international cooperation were generally associated with better outcomes** for national steel industries, as well as with a faster global transition. The advantages arose from aligned policies in major steel-producing regions creating larger demand for clean steel, faster cost reduction, and reduced risks for first-movers to clean steel technologies.

Despite this, only around half of the exercise participants in China and the EU, and none of the US participants, saw these scenarios as closest to the future that their governments were planning for. This suggests a need for greater clarity in countries' international strategies for the transition.

Present, future, and pathway forward

In the international workshop, there was a high degree of consensus among experts from the three regions on the important factors that kept the global system of steel production and trade in its current state. The dominance of coal-based production, the high costs of clean steel technologies, the weakness of existing policies to support production or create demand for low and near-zero emission steel, the absence of agreed standards and the lack of differentiation between high- and low-emission steel in international trade all reinforce the status quo. Overcapacity, trade tensions, political sensitivity to job losses in the sector and subsidies to preserve existing industry were recognised as factors that further increase the difficulty of the transition in all regions.

Participants from the three regions did not have difficulty agreeing a vision of a desirable future system of steel production and trade. This involved a comprehensive shift towards electrified production routes for steelmaking (with and without hydrogen), a high rate of recycling, reduced adverse social and environmental impacts, a ban on trade in any steel failing to meet near-zero emission standards, and a more robust system of trade dispute management. Notably, the group had a strong collective preference for open global trade in the inputs to clean steel production (component technologies, green iron, and scrap steel), but a general ambivalence over the openness of trade in steel itself – acknowledging the importance of national interests other than accessing steel at the lowest possible cost. The group could agree this vision despite participants inevitably holding different views on their own countries' industries' desirable shares of the future global market.

Participants discussed whether a range of innovations in technology, industrial structure, policy and trade practices were 'transformative' – likely to lead towards the desired future state of the steel sector, or 'sustaining' – adaptations to a changing environment that tend to extend the lifetime of the current system. There was strong agreement that transformative change would be driven by investment in near-zero emission technologies that reshape the underlying energy system, such as hydrogen direct reduced iron and direct electrification, while technologies for marginal emissions reduction, such as blast furnace co-firing with hydrogen or biomass, were more likely to delay the necessary change. Technologies such as carbon capture and storage and natural gas direct reduced iron were seen as having an uncertain status as either transformative or sustaining innovations, depending strongly on the context of their use.

Actions identified as potentially transformative innovations in the fields of policy and trade included near-zero emission steel production subsidies, clean steel production mandates, public procurement of clean steel, green iron trade partnerships, and tariffs that differentiate between near-zero emission and conventional steel. Few such measures are yet being implemented. Instead, many of governments' current actions are those that participants considered to be either sustaining innovations, or of uncertain identity. These included carbon pricing at low levels, diplomacy through the UN Framework Convention on Climate Change, a proliferation of competing standards, and general increases in steel tariffs. Differences of opinion on these issues existed between individual participants but were not clearly apparent between the groups from the three regions, suggesting a shared understanding across countries of which actions are most likely to be transformative for the sector.

Opportunities for international collaboration

Participants in the international workshop identified options for international cooperation to strengthen the drivers of transformational change. The purpose was not to investigate these options in detail, but to generate an understanding of the range of possibilities. The scope included forms of cooperation that could plausibly be pursued by any major steel-producing countries, it was not assumed that the EU, US and China must all necessarily participate.

- **Interoperable standards** for low and near-zero emission steel, supported by common definitions, robust measurement, reporting and verification, and trusted governance arrangements, were seen as a necessary foundation of almost all other forms of cooperation. In future, an international organisation could be tasked with verifying claims of compliance with standards.

- **Coordinating carbon pricing** at a level sufficient to make clean steel competitive could be a game-changer, but was thought unlikely to be achieved in the near-term. Agreeing shared carbon accounting methodologies was a no-regrets option; a more creative action could be to use a share of revenues from developed countries' carbon border adjustment mechanisms to contribute to funding the deployment of clean steel technologies in developing countries.

- **An agreement on either the acceptable levels for clean steel production subsidies** or the process for awarding them was identified as a difficult but potentially high-impact option, which would also require commitments on transparency. Coordinated implementation of subsidies or regulatory policies to create demand for clean steel in end-use sectors was considered a creative approach with a potentially substantial impact.

- **Bilateral green iron offtake agreements** were seen as a high-potential pathway to reduce the costs of clean steel production, strengthening importers' comparative advantage and generating value for exporters. Agreeing a common definition of green iron would be a no-regrets preparatory step. An internationally funded platform using double-sided auctions to contract with suppliers and buyers of green iron could be a game-changer.

- **Tariff exemptions for clean steel** were identified as a game-changer option if agreed among a group of major steel-producing countries, even more so if made accessible to all countries in compliance with World Trade Organisation (WTO) rules. Creative options that could be more feasible in the near-term included differentiated tariffs for high- and low-emission steel being introduced into bilateral free trade agreements or trade and investment partnerships.

- The cost of producing clean steel through the hydrogen direct reduced iron (DRI) route depends heavily on the costs of clean power and low carbon hydrogen. **Liberalising trade in renewable energy systems components and electrolysers** could contribute to cost reduction, as could cooperation on research and development of next generation technologies. Exchange of knowledge on power sector reform was recognised as a no-regrets option.

The diversity of options identified suggests that there is scope for a more substantial discussion of cooperation on the steel transition than is currently taking place among major steel-producing countries. Any of these options would involve political difficulty, despite the shared diagnosis of the current state of the global steel industry and broad alignment on the direction of travel. However, countries could be motivated to attempt cooperation by interests in strengthening national steel industry competitiveness, increasing energy security, reducing the costs and risks of decarbonisation, and achieving internationally agreed global goals for avoiding dangerous climate change.

Participants consistently emphasised that substantive cooperation is unlikely to be agreed at this stage within comprehensive multilateral fora. Instead, it is more likely to occur through sector-specific dialogues either bilaterally or among small groups of countries, where there would be greater potential to find areas of alignment between a limited number of national interests. Overall, the scenarios suggest limits to what unilateral action can achieve, and underline the importance of trade diplomacy in the steel transition. Where countries act alone, markets for near-zero emission steel remain small, investment risks remain high, and global emissions fall too slowly. The strongest outcomes arise when governments combine decisive policy at home with selective and pragmatic cooperation abroad, aligning standards, shaping trade and investment incentives, and competing within a shared direction of travel. In this context, international cooperation is not an alternative to competition, but a means of shaping the conditions in which competition takes place so that it accelerates, rather than delays, the global steel transition.

2 Scenarios for the global steel transition

International uncertainties in the steel sector's transition

The iron and steel sector is deeply exposed to international dynamics. Iron and steel are among the world's most traded basic materials, and no country is fully insulated from the effects of competition and trade in the sector. In recent years, overcapacity in the steel sector – driven by falling demand in China – has correlated with falling steel prices and the squeezing of profits for producers in all regions of the world. New tariffs imposed by many countries in response to these conditions are reshaping trade patterns, with consequences for producers and exporters.

The transition from conventional fossil fuel-based forms of production to low and near-zero emission steel is sensitive to these international conditions. Today, low or near-zero emission steel products are virtually indistinguishable from conventional steel products. First-movers in the production of near-zero emission steel face significantly higher costs and weak demand. Even when domestic policies are in place to support the transition, the risks of being undercut by imported conventional steel or becoming uncompetitive in export markets undermine the case for investment. At the same time, the rates of innovation and cost reduction in clean steel technologies depend on global deployment. The success of governments' industrial and transition policies is therefore dependent on market conditions and actions outside their direct control.

These international dynamics limit the effectiveness of purely domestic policy approaches. Policymakers must consider not only national policy frameworks for the transition, but also the wider global industry, trade, diplomacy and geopolitical environment in which their industries operate. Equally, governments and steel companies cannot plan for future industrial competitiveness without considering the context of the global transition.

This project has examined how policymakers in three of the world's largest steel-producing countries and regions – China, the United States and the European Union – currently understand the trajectory of their countries' steel transitions within a global context. Leading experts from each region have explored the uncertainties they face, the assumptions that underpin their strategies, and the possible future scenarios that could materialise, all with the objective of considering strategies that are more resilient and likely to succeed.

A scenarios-based approach

The scenarios set out in this report are narrative scenarios – stories that allow decision-makers to explore alternative ways the world might develop and to consider how those developments might affect the success of their strategies. These differ from the quantitative scenarios constructed through modelling. Narrative scenarios are subjective and are not predictions or forecasts. They are a strategic foresight tool that can be used to generate diverse and challenging pictures of the future.

The underlying principle of scenario thinking is uncertainty. The scenario process is designed to identify the range of uncertainties facing an organisation or a sector, and from those uncertainties to imagine different possible futures. What is uncertain depends on whose perspective is adopted. In the steel transition, many important factors, such as government policy, the availability of infrastructure, and international trade conditions, are outside the control of the steel industry. Governments have control over policy and legislative frameworks, but to them, steel companies' investment choices and strategic decision-making are uncertain, as are the actions of the governments of other countries. The scenarios in this report are constructed primarily from the perspective of government policymakers.

Because scenarios are not predictions, none of them are intended to be ‘right’ or to reflect the trajectory of current policy or strategy. Rather, they provide an opportunity for stakeholders to explore the dynamics of change together; to develop a shared understanding of the opportunities and challenges that the steel industry in different countries might face in the future; and to rehearse the strategic choices and decisions they may have to make – individually or collectively – to achieve success.

Structure of this report

To produce the scenarios contained in this report, the project began by interviewing experts and policymakers to identify the major uncertainties and strategic risks shaping each region’s transition to near-zero emission steel. These uncertainties formed the inputs to scenario workshops, where participants examined how these uncertainties might evolve over the next decade and prioritised those most important to explore. These resulted in a 2x2 scenario matrix for each country. Participants then developed a narrative scenario for each of the four different future conditions. These were further elaborated by the authors after the workshops, and then validated with participants before being finalised. The scenario workshops were held in Brussels, Beijing and Washington, DC, in May, June and July 2025 respectively.

Section 2 of this report presents the uncertainties, scenarios and expectations of the policymakers and experts in each region, based on the individual interviews and the scenario workshops. The full narrative scenarios are contained in the Appendix.

Section 3 of this report explores potential areas for international cooperation to advance the global transition to near-zero emission steelmaking in a context of competitive trade. This is based on a workshop in which experts from Europe, China and the United States came together, held in London in October 2025.

The European Union’s steel transition

Context

Europe is at a crossroads in its steel transition. The EU is leading the way, with the highest number of near-zero emission steel projects announced of any region.[1] Political commitment to addressing climate change has been largely consistent over time. Its policy regime is well developed in some respects: the Emissions Trading Scheme and the Carbon Border Adjustment Mechanism (CBAM) are the most advanced schemes of their kind.

On the other hand, the EU faces substantial difficulties. Several flagship clean steel projects have been stalled or cancelled due to high costs, policy uncertainty, and lack of confidence to invest.[2] The EU and its industry are deeply concerned about competitiveness. These concerns stem largely from the effect of its own carbon pricing policy, and the risk that the CBAM may not sufficiently protect European industry from being undercut by cheaper, more emissions intensive production in other countries.[3]

The steel market is changing too, driven by external factors. Global overcapacity – driven primarily by China – continues to depress prices and put pressure on European steel profits.[4] US trade restrictions on European steel further compound this pressure and are reshaping trade flows between the two regions.[5] Geopolitically, opposition to the EU CBAM continues, especially amongst the largest emerging economies – China, India and Brazil.[6]

Recent EU policy proposals such as the Clean Industry Deal and the European Steel and Metals Action plan reflect growing political recognition that competitiveness, decarbonisation, and economic security must be pursued together.[7] New announcements have included a €100bn Clean Industrial Bank and proposed amendments to the CBAM, tariffs and steel safeguards. At the same time, debates continue on whether to extend ‘free allowances’ under the EU’s ETS, effectively exempting most production from paying the carbon price.[8] The path forward for the EU is in question, with competing visions of how to preserve the EU’s interests while making progress towards clean steel technologies

Critical uncertainties

Ahead of the EU steel scenarios workshop in Brussels, interviews were conducted with European experts and policymakers to identify a set of uncertainties – both domestic and international in nature – important to the EU’s steel sector transition.

Domestic uncertainties

1. ***Political support for the transition.*** Participants highlighted uncertainty over whether senior decision-makers would remain committed to the steel sector’s transition, and to specific

[1] LeadIT (2025). *Green Steel Tracker.*
[2] BankTrack (2025). *EU State Aid at a Crossroads: Green Steel Projects are Stalling Despite Public Subsidies Worth Billions*
[3] Eurofer (2025). *CBAM proposals single out key loopholes but fall short of ensuring comprehensive and structural solutions, warns Eurofer.*
[4] Mattera, G., Pazos, R., & Takada, Y. (2025). *Steel trade and trade policy developments (Jan-Oct 2024).* OECD.
[5] Directorate-General for Trade and Economic Security. (2025). *Joint Statement on a United States-European Union framework on an agreement on reciprocal, fair and balanced trade.*
[6] Politico (2025). *EU strains to defend carbon levy as trade tensions engulf COP30.*
[7] European Commission (2025). *Clean Industrial Deal.* and European Commission (2025) *A clean steel and metals action plan*.
[8] Carbon Market Watch (2025). *Climate hypocrisy: EU industry cools on carbon levy with freebie phase out on horizon.*

policies such as the phaseout of free allowances in the EU ETS, and the extent of public investment that would be made available for near-zero emission steel technologies. There were also questions about whether the EU's steel transition would continue to be supported by labour organisations.

2. ***EU industrial policy coherence.*** The ability of the EU and Members States to develop a coherent industrial strategy was a key uncertainty. Underlying this debate was a larger question: to what extent would the EU and its Member States seek to preserve the European steel industry's existing structure? For example, it was uncertain whether Member States would agree to measures that could improve competitiveness, such as relocating parts of the steel value chain to countries (including within the EU) where conditions were more favourable for production. Respondents also questioned whether the EU would invest in innovation in steelmaking technologies, and whether it would succeed in developing more flexible and innovative production processes.

3. ***Cost and availability of clean power.*** Participants highlighted questions around whether Europe would be able to provide enough low-cost clean power to be able to compete in low and near-zero emission steel production. Respondents also questioned the security of supply of renewable energy in Europe, and the quantity of green hydrogen that could be produced domestically. Participants were uncertain whether the cost of power could make steelmaking competitive using hydrogen direct reduced iron or electric arc furnaces.

International uncertainties

4. ***Diplomatic cooperation to create markets for low or near-zero emission steel.*** At the international level, a major uncertainty was the extent to which demand for clean steel would grow globally. Related to this was uncertainty over how far the EU and other major economies would work together to create a market in clean steel. Cooperation or aligned policies between countries could increase demand for low and near-zero emission steel, and increase industry's confidence to invest. There was also uncertainty over whether the EU's steel standards would be consistent with those of its major trading partners.

5. ***Openness of the international trade environment.*** The extent to which the EU would remain open in its trading arrangements, or implement more protectionist trade measures in response to factors such as global overcapacity and US tariffs, was a key uncertainty.

6. ***The EU's cost competitiveness for near-zero emission production relative to other countries.*** Participants were uncertain about the long-term competitiveness of hydrogen direct reduced iron steelmaking in Europe, relative to other countries and to other innovative methods of clean steel production such as molten oxide electrolysis. Whether the EU would seek to build its own hydrogen direct reduction iron furnaces, or purse strategic partnerships to import green hydrogen or green iron (for example, from South Africa, where production could be much lower cost) was seen as likely to influence how competitive the EU could be.

7. ***The speed of other countries' steel transitions.*** The speed at which other countries would move towards low or near-zero emission steelmaking was identified as an important unknown. How quickly other countries – from China to the Middle East and North Africa – would move to invest in near-zero emission steel technologies, and how competitive they would be relative to Europe, were seen as major uncertainties.

Axes of uncertainty

At the workshop in Brussels, participants started with a long list of the uncertainties that they had identified individually, and prioritised these through a participatory process to create two strategic axes. These axes represented the uncertainties collectively considered most important, and formed the basis of the scenarios.

The first axis describes uncertainty in the future global trade environment and, specifically, whether it will be open or protectionist:

Open global trade environment ⟷ Protectionist global trade environment

At one end of the axis, the global trade environment is open. Countries engage in international trade with minimal restrictions and there is a free flow of goods, services, capital and labour across international borders. Tariffs and quotas are minimal. Supply chains are efficient and pricing is competitive. Innovation is high and new technologies spread quickly, fuelling continued economic growth for those with an advantage in the global market.

At the other end of the axis, the global trade environment is protectionist. Tariffs mean imported goods and materials are more expensive than domestic products. Quotas restrict the level of imports. Innovation is constrained locally, efficiency is lower and prices remain high. Economic growth is uneven between nations and intergovernmental relationships are fragile at best and volatile at worst.

The second axis describes uncertainty around the speed at which Europe and other steel producing countries or regions transition to low carbon steel production:

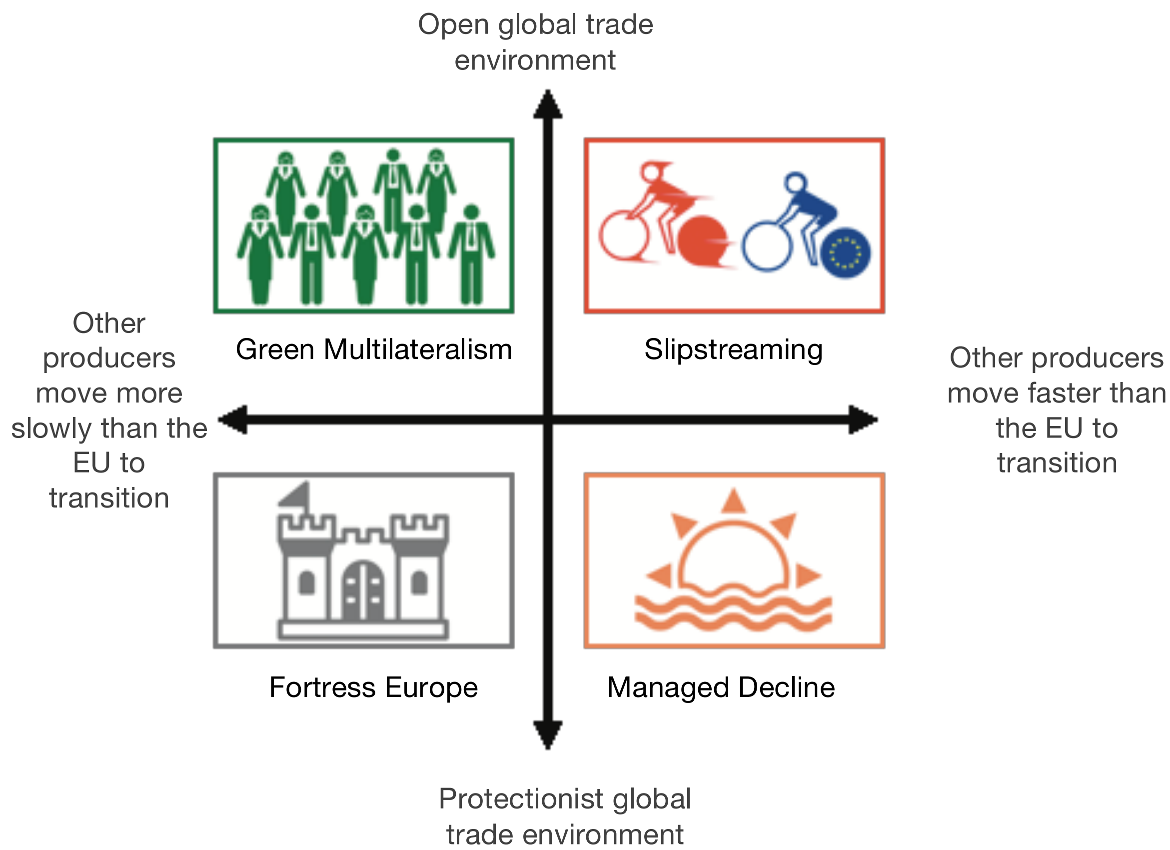
Other producers move more slowly than the EU to transition ⟷ Other producers move faster than the EU to transition

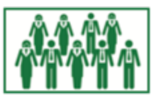
At one end of the axis, other producers move more slowly than the EU to transition to low carbon steel production. This could be interpreted as the result of stronger policies for the transition in Europe than in other regions.

At the other end of the axis, other producers move faster than the EU to transition to low carbon steel production. This could be understood as resulting from the European steel industry encountering difficulties, while producers in countries with access to abundant low-cost renewable power move early to establish a competitive advantage in clean steel.

Scenarios of the European Union's steel transition

The two axes create a scenario framework that describes four alternative outcomes for the European steel industry in 2035.





Green Multilateralism describes a future where global trade is open and other steel-producing countries move more slowly than the EU to transition to low carbon steel production. Europe's steel industry has emerged as a market leader in low-carbon production, driven by strong and aligned climate and industrial policy which has brought the cost of clean power down, and by major investments in new steelmaking technologies. The EU has reached agreements with other major countries to ensure a level playing field and interoperable standards for clean steel in international trade. It has also struck bilateral agreements to import green hot briquetted iron at lower cost than producing it domestically, to further enhance competitiveness. The EU's steel producers have become premium suppliers in a global market that increasingly values emissions credentials, traceability and regulatory certainty. Demand for clean steel is spreading globally. Europe plays a key role in meeting it.

Fortress Europe describes a future where global trade is protectionist and other producers move more slowly than the EU to transition to low carbon steel production. Europe has not abandoned decarbonisation — but it has narrowed its focus within its own borders. Faced with rising geopolitical volatility and uneven global willingness to address climate change, EU policymakers have chosen to defend the integrity of their domestic industry and its transition to clean steel rather than gamble on global alignment. High tariffs and scrap export restrictions protect the European industry while it undergoes the transition. Steelmaking in Europe has transitioned to low carbon production, powered by clean energy, but output has fallen and demand is concentrated in the EU's domestic market. Progress on decarbonising the steel industry outside Europe is slow, and relationships with other countries are strained.

Managed Decline describes a future where the global trade environment is protectionist and other producers move faster than the EU to achieve low carbon steel production. Other regions have taken advantage of abundant low-cost renewable power to stake out leadership positions in clean steel, and have put up their own trade barriers to prevent imports of high-emission steel. Europe has struggled to follow due to a lack of political support for climate objectives, limited investment and fragmented industrial policy – which has failed to address competitiveness concerns, including power costs, and so left the sector strategically vulnerable. Europe still has a steel industry, but largely due to political intervention rather than industrial competitiveness. Most understand that the sector is in long-term decline.

Slipstreaming describes a future where the global trade environment is open and other producers move faster than the EU to achieve low carbon steel production. The global steel industry is in the midst of structural transformation driven by rapid innovation, reorganisation of iron and steel value chains and cost declines in clean steel technologies as investment rises to meet growing demand for green steel. Europe, long a regulatory leader, should have been at the forefront but has fallen behind; held back by strategic hesitation, a lack of political alignment on climate and industrial policy, disjointed national policies and slow execution. European governments have decided to prioritise low-cost steel imports and overall economic productivity over maintaining national steel industries, influenced in part by stubbornly high electricity prices. What remains of the sector has made the bold strategic decision to enter a licensing partnership with China to access the technological systems and services that it needs to remain competitive in niche markets. Questions hang over the remainder of Europe's industrial ecosystem, with some parts thriving from cheap imports from abroad and other parts in decline.

The Europe scenarios are described in full in **Appendix A.**

Likelihood of scenario outcomes

Following the workshop, participants were invited to vote on which scenarios felt most credible, favourable, or aligned with current plans. The results are set out in the table on the following page.

The votes indicated that:

- Respondents felt that *Fortress Europe* was seen as the most plausible, followed by *Green Multilateralism.*
- *Green Multilateralism* was seen as the most preferable for the EU's steel industry.
- *Green Multilateralism and Slipstreaming were* seen as equally favourable for achieving the global transition.
- *Fortress Europe* was seen as the scenario closest to the present moment.
- Respondents were divided on which future policymakers were planning for, *Green Multilateralism* or *Fortress Europe.* But they were clear that *Green Multilateralism* would demand the greatest change.

Table 1: Votes on scenario likelihood and desirability in the European Union.

	Most plausible	Most favourable for the EU Steel industry	Most favourable for achieving the global transition to net zero	Closest to now	Closest to the future that policy makers are planning for	Closest to the future that demands the greatest change
Green Multilateralism	25%	75%	50%	25%	50%	50%
Fortress Europe	75%	25%	0	50%	50%	25%
Managed Decline	0	0	0	25%	0	0
Slipstreaming	0	0	50%	0	0	25%

Conclusions

At the level of EU domestic policy, uncertainties affecting the EU's steel sector transition included its ability to produce low-cost clean power and hydrogen, the durability of political support, the extent of investment in low and near-zero emission steel production, and the coherence of the EU's industrial and innovation strategy.

At the international level, the EU's diplomatic coordination with other major economies to create demand for low-emission steel, the openness of international trade, the extent to which the EU invests in green iron partnerships, and the speed of other countries' steel transitions were seen as key uncertainties influencing the transition.

Based on these uncertainties, experts and policymakers involved with the EU's steel transition see opportunities to pursue a scenario – *Green Multilateralism* – where global markets for clean steel are created through diplomatic cooperation with other major steel-producing countries, and where the EU has developed competitive clean steel production, supported by strategic partnerships to import green iron. This vision was seen as beneficial both for European steel producers and for the global transition to a net zero emissions economy, but also as requiring the greatest change.

This favourable scenario was, however, considered less plausible than the *Fortress Europe* scenario, where the EU prioritises the transition within its own borders and protects its industry through trade defences and scrap export restrictions. While *Fortress Europe* was seen as avoiding strongly negative outcomes from European steel producers, it was considered less beneficial for the transition globally. If only European industry is decarbonised, the policy objective of reducing climate change risks is not met.

Taken together, the results indicate only moderate confidence in meeting Europe's goals for industrial competitiveness and limiting the risks of climate change. Experts and policymakers could also see scenarios where the EU's steel transition stalled entirely – driven by populist anti-transition political movements – or where other countries such as China moved faster than the EU to establish clean steel technological expertise, leaving the EU as a follower rather than leader in the transition. Some of the group saw *Managed Decline* as the scenario 'closest to now'.

China's steel transition

Context

As the world's largest steel producer, responsible for more than half of global steel output, China is in a powerful position to compete in and shape the transition.

China's steel transition is picking up pace. Projects by state-owned enterprises HBIS Group and Baowu Steel are deploying near-zero emission capable technologies.[9] The government is developing enabling infrastructure, such as a 400km hydrogen pipeline from Inner Mongolia to the Beijing-Tianjin-Hebei region.[10] Policy signals are strengthening. The government has withdrawn permits for new coal-fired steelmaking facilities, tightened its capacity-swap rules requiring firms to remove an equal amount of older existing steel capacity when adding new capacity, and set targets for electric arc furnace (EAF) steel production.[11] [12]

At the same time, all is not well in the Chinese steel sector. Domestic steel demand has fallen, driven by a downturn in construction.[13] This is perceived to mark a broader turning point in China's rapid economic development and consumption of steel. As a result, overcapacity persists, depressing prices and profits. Large increases in exports have created trade tensions, with rising tariffs and steel safeguards being increasingly applied.[14] For provincial governments and steelworkers, the shift away from the relatively labour-intensive coal-based blast furnace-basic oxygen furnace production route presents social and political challenges.

Critical uncertainties

Prior to the China steel scenarios workshop in Beijing, interviews were conducted with experts to identify a set of uncertainties, both domestic and international in nature. The following uncertainties were identified as important to China's steel sector transition.

Domestic uncertainties

1. ***Domestic demand for steel in China.*** Experts highlighted uncertainty over the degree and speed of China's structural slowdown in steel demand. Around 90% of China's steel is consumed domestically at present. However, demand has already fallen by 16% compared to the same period in 2021 when construction activity in China's property sector peaked.[15] There is uncertainty around how far these trends will continue, as well as around how much they may be offset by new demand emerging from clean energy manufacturing (e.g. wind turbines, electric vehicles, and grid infrastructure).

2. ***Extent of overcapacity.*** Overcapacity is one of the core challenges facing China's steel sector, and is depressing margins and affecting profits. Reducing excess capacity is difficult due to the relatively young BF-BOF fleet. Local governments in areas that are heavily reliant

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[9] Centre for Research on Energy and Clean Air (2025). *China's greener steelmakers spread overseas.*
[10] The State Council of the People's Republic of China. (2023). *China plans to build 400-km hydrogen pipeline.*
[11] Centre for Research on Energy and Clean Air (2024). *Turning point: China permitted no new coal-based steel projects in H1 2024 as policies drive decarbonisation.*
[12] Reuters (2025). *China proposes tougher steel capacity swap plan to curb overcapacity*.
[13] S&P Global (2025). *China's domestic steel demand falls further, exports hit another high in May.*
[14] OECD (2025). *OECD Steel Outlook 2025.*
[15] S&P Global (2025). *China's domestic steel demand falls further, exports hit another high in May.*

on the steel sector for employment tend to be reluctant to take measures to address this problem. How long this situation will persist is a key uncertainty for the sector.

3. ***Industry willingness to invest in new technologies.*** Another uncertainty is the pace at which state owned enterprises (SOEs) and the private sector in China will invest in near-zero emission steel technologies. SOEs have established several commercial-scale hydrogen-based steel projects, but the cost of hydrogen is a barrier to wider deployment. Since no sector-wide policies are yet in place to create demand for clean steel or support its production, the industry's response to policy is untested. A wave of blast furnace relinings will be due in the 2030s; whether firms choose to reinvest in BF-BOF assets or shift to near-zero emission technologies will shape the future industrial landscape.

4. ***Technological pathways***. China is exploring multiple decarbonisation pathways: hydrogen injection into blast furnaces, hydrogen direct reduced iron, carbon capture, use and storage, and increased use of scrap recycling and the electric arc furnace (EAF) route. Which pathways will be preferred by industry and prove most successful is an uncertainty. Hydrogen direct reduced iron appears promising, but its costs are high. EAFs are expected to play an important role, but their production costs are higher than those of BF-BOF, and future scrap steel supply is uncertain. Whether carbon capture, utilisation and storage or hydrogen injection will have a role in a fully decarbonised sector is unclear.

International uncertainties

5. ***Openness of international trade.*** Weak domestic demand for steel is driving increased exports, but Chinese products face growing trade defence measures including tariffs, anti-dumping measures, and carbon border adjustment mechanisms. The future access of Chinese steel – both conventional and low-emission – to foreign markets is highly uncertain. Trade defences or CBAM-type barriers could place greater pressure on BF-BOF capacity or redirect exports to different markets.

6. ***Future global demand for steel.*** Global steel demand is growing in emerging economies, and this could potentially absorb some of China's excess production capacity. The extent of future demand growth is uncertain. An additional uncertainty is whether developing countries choose to import Chinese steel, or to prioritise building their own domestic steel industries.

7. ***Future demand for low or near-zero emission steel.*** Demand for low or near-zero emission steel could be driven by major markets such as the EU or created within China through domestic policies. Alternatively, demand may remain weak and price sensitive. The international element of demand is an uncertainty for Chinese policymakers. Whether China can deploy clean steel only in the domestic market or as a strategic export sector will depend on how global standards and markets evolve.

Axes of uncertainty

Two strategic axes emerged from the uncertainties identified in interviews with Chinese experts. These represented the uncertainties collectively considered most important, and were the starting point for scenarios developed at the workshop in Beijing.

The first axis describes uncertainty around the level of green steel production capacity in China in future. Participants considered China's technological capability for near-zero emission steel production to be already proven, but the scale of its future production capacity – which would depend on both policy and industry investment decisions – was highly uncertain.

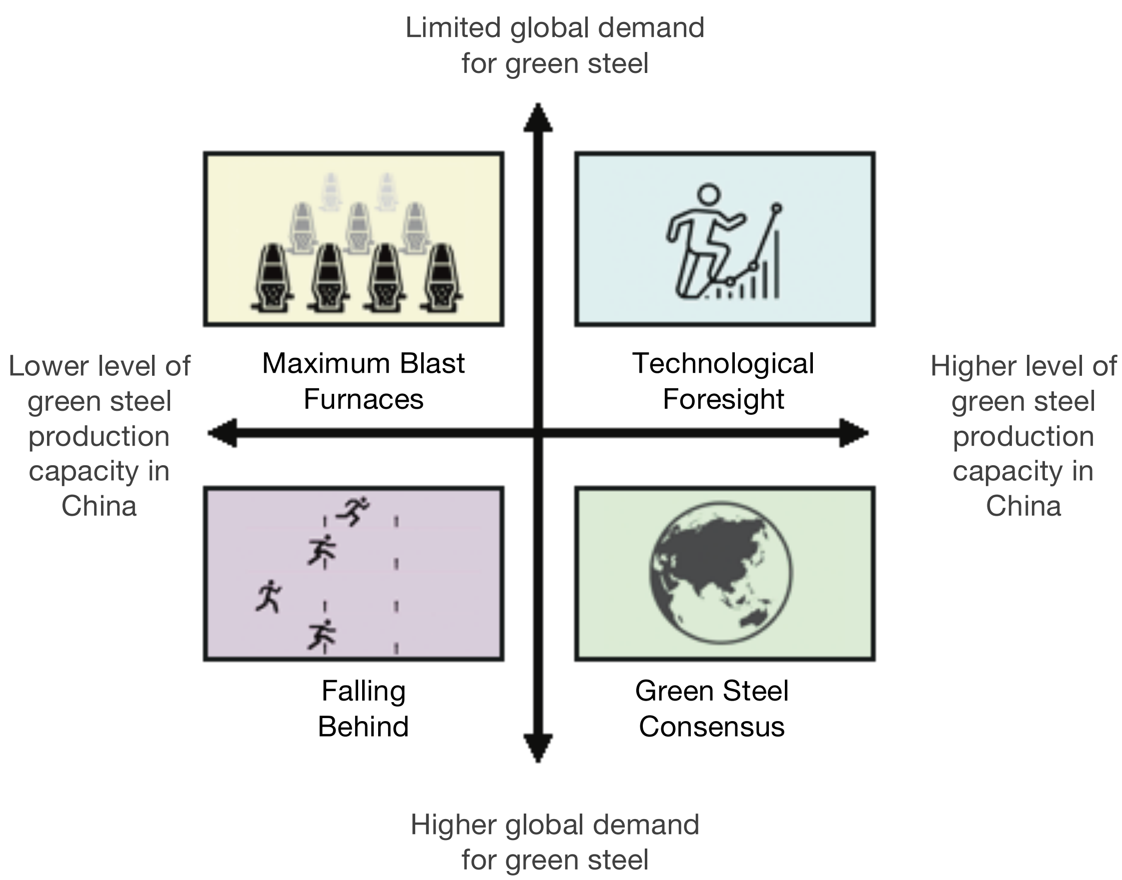
Lower level of green steel production capacity in China ↔ Higher level of green steel production capacity in China

The second axis describes uncertainty around the level of global demand for green steel – whether demand will be limited or high.

Limited global demand for green steel ↔ Higher global demand for green steel.

Scenarios of China's steel transition

The two axes combine to create four scenarios for China's steel industry in 2035.



Technological Foresight describes a future where there is limited global demand for green steel, but where China has a higher level of green steel production capacity. The global effort to decarbonise energy-intensive industries has gained little momentum over the last decade. Political instability and economic uncertainty have increased risk aversion, reducing investment and encouraging reactive planning. Protectionism has increased. China's steel industry suffers from the pressures of falling domestic demand and increased barriers to its exports. The government invests in clean primary steel as an industrial strategy. Global demand for green steel remains low at present but that is not a threat to China's producers who can serve the domestic market and wait until the current turbulence in foreign markets has settled down. The state's capacity to hedge against weak global demand for green steel while building its future capability has secured China's continued dominance in the industry.

Green Steel Consensus describes a future where demand for low carbon steel is high and where green steel production in China is high. The global transition to low carbon steel has moved ahead at pace over the last decade. Governments in first-mover countries have implemented mandatory green public procurement policies and green steel subsidies. Together with growing green iron production in countries with abundant renewable energy resources, this has prompted other countries to follow, wary of the risks to long-term competitiveness if they do not. China has secured competitive advantage in the global market by investing strongly in clean power and in green hydrogen production. The direction of travel is clear: green steel is not only the future — it is the present. Having deployed the new technologies on an unrivalled scale, China is well positioned to maintain its dominance of the sector for years to come.

Falling Behind describes a future where demand for low carbon steel is high and green steel production in China is low. Demand for green steel has been slow to take off but is accelerating as western nations push hard to decarbonise, and other countries take advantage of rapid technological progress. The global steel industry has undergone a dramatic transformation in the last decade, shaped by strong policies, market forces, and surprisingly fast technological progress, sparking a decade-long race to capture the green iron and steel value chain. China has strong capabilities in clean steel technology but has been caught out by the pace of the transition. The scale of change it must now make domestically to regain its global position is significant, allowing other, more nimble, producers to capture significant market share.

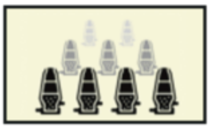
Maximum Blast Furnaces describes a future where demand for low carbon steel is limited and green steel production in China is low. Unresolved geopolitical tensions continue to hamper efforts to establish collaborative technology and trade frameworks that support decarbonisation. Policies relating to steel production are focussed on keeping energy costs low rather than on pursuing low carbon strategies. China, like most other major producers, avoids the economic risks of producing higher-cost green steel in an underdeveloped global market. Its strategy is to maximise profits from blast furnace production and exports, while building small scale clean steel pilot projects to hedge against the long-term risk of the transition. As other countries also hold back, progress in the transition is slow across all industrial sectors, and higher global emissions worsen the outlook for long-term climate change risks.

The China scenarios are described in full in **Appendix B.**

Likelihood of scenario outcomes

In the final part of the workshop, participants voted on a number of strategic questions related to the likelihood, desirability, and alignment with current plans of the different scenarios. The results are set out in the table below.

Table 2: Votes on scenario likelihood and desirability in China.

	Most plausible	Most favourable for China’s Steel industry	Most favourable for achieving the global transition to net zero	Closest to now	Closest to the future that policy makers are planning for	Closest to the future that demands the greatest change
 Technological Foresight	53%	53%	0	32%	47%	0
 Green Steel Consensus	47%	42%	100%	26%	53%	100%
 Falling Behind	0	0	0	0	0	0
 Maximum Blast Furnace	0	5%	0	42%	0	0

The votes indicated that:

- The group was evenly divided on which of two scenarios – *Technological Foresight* or *Green Steel Consensus* – was most plausible. These are both scenarios in which China develops a high level of clean steel production capacity. The same two scenarios were seen as most favourable for China’s steel industry.
- The group was unanimous that *Green Steel Consensus* was the most favourable scenario for the global transition to a net zero emissions economy.
- The group was divided about which scenario was ‘closest to now’, indicating differing interpretations of the current situation. Around a quarter of the group thought it was *Green*

Steel Consensus; a similar number thought it was *Technological Foresight*; while more of the group felt that *Maximum Blast Furnaces* was closest to now.
- The group was agreed that *Maximum Blast Furnaces* was not the future that policymakers were planning for, which may explain why none saw it as the most plausible scenario. The group was divided on whether policymakers were planning for *Technological Foresight* or *Green Steel Consensus.*
- While *Green Steel Consensus* was seen as the most favourable scenario for achieving the global transition to net zero as well as being favourable for Chinese industry, it was also unanimously seen as the future that demands the greatest change.

Conclusions

Within China, the steel transition is affected by uncertainties including the future demand for steel, the persistence of overcapacity, and industry's willingness to invest in low or near-zero emission technologies in different policy contexts.

At the international level, China's steel transition is affected by uncertainties including the openness of global markets to Chinese steel, the evolution of green steel demand in other major economies, and future demand for conventional Chinese BF-BOF steel in other fast developing economies.

Participants felt the scenarios in which China has high levels of clean steel capacity were the most likely. However, they were divided on whether this would take the form of a *Technological Foresight* scenario – where China develops this capacity without clear global demand for low or near-zero emission steel existing – or a *Green Steel Consensus* scenario, with greater cooperation between countries to grow markets for clean steel. The latter was unanimously recognised as the most beneficial for the policy objective of reducing the risks of climate change through the global energy transition, but participants were unsure whether this was the future that policymakers were planning for. The unanimous identification of *Green Steel Consensus* as the scenario requiring the greatest change, despite this scenario sharing domestic policy characteristics with *Technological Foresight*, suggests a change in China's diplomatic or trade policies may be needed to bring this scenario into being.

Participants viewed the scenarios where China either falls behind others in the steel transition (*Falling Behind*), or chooses to maximise its existing BF-BOF fleet without investing in new technologies (*Maximum Blast Furnaces*) as less plausible, and none thought these were closest to the future that policymakers were planning for. However, these judgments were in tension with the view of almost half the participants that *Maximum Blast Furnaces* was 'closest to now'. This suggests a recognition that while the strategic goals of carbon peaking and neutrality in the steel sector are clearly established, developing large-scale clean steel production capacity will require market-wide policies to support production or create demand.

The United States' steel transition

Context

The United States is starting its steel transition in a very different place to most other major steel producers. As the fourth largest steel producing country, 72% of its steel already produced with electric arc furnaces – a far higher share than the average globally. This means its industry has much lower emissions than those of most other countries.[16] A small number of integrated blast furnace-basic oxygen furnace (BF-BOF) plants are still important, responsible for producing the higher grade and higher value steels generally required for the aerospace, defence and automotive sectors.

Under the Biden administration, policies were put in place to support the steel sector transition. These included production tax credits for investment in renewable energy, carbon capture and storage and hydrogen, together providing a broad range of incentives for investment in infrastructure and energy sources that could support near-zero emission steel production.[17] In parallel, the Federal Government had started to implement 'Buy Clean' initiatives which would see public procurement commitments to stimulate demand for low- and near-zero emission steel.[18]

Internationally, the US Government was seeking to negotiate climate and trade agreements with other countries. This included attempting to agree clean steel provisions in a deal with the EU known as the Global Arrangement on Sustainable Steel and Aluminium.[19]

These policies had begun to influence steel company decision-making. Cleveland-Cliffs was one of the first companies to announce it would replace its coal-based blast furnace-basic oxygen furnace plants with hydrogen direct reduced iron. In recent years, however, transition policies have been reversed by the current US administration, reducing confidence in near-zero emission production routes. Cleveland-Cliffs has since announced the abandonment of its planned hydrogen direct reduced iron projects.[20] This situation leaves industry decisions on whether to invest in cleaner steel production technologies much more to market forces than before.

Critical uncertainties

Domestic uncertainties

1. ***Political and policy support for the steel transition.*** A key uncertainty flagged by multiple respondents was the question of whether steel decarbonisation would be a political priority for the US in the next decade. Since climate change is a polarising and partisan issue, it was seen as highly uncertain whether policy would be put in place to help the industry invest in near-zero emission production. As the United States already has a significant proportion of production that is electrified and cleaner than the global average, it was unclear whether the steel transition would attract much political attention even for reasons beyond climate change, such as technological change and competitiveness.

[16] World Steel. (2025). *World Steel in Figures 2025.*
[17] United States Department of Energy. (2025). *Inflation Reduction Act of 2022.*
[18] Office of the Federal Chief Sustainability Officer. (2023) *Federal Buy Clean Initiative [Archived].*
[19] Rimini, M et al. (2023) *The EU-US global arrangement on sustainable steel and aluminium.*
[20] GMK Center (2025). *Cleveland-Cliffs cancels hydrogen-based steel project.*

2. ***Private sector voluntary demand.*** In the absence of policy, respondents questioned whether private sector voluntary demand for low or near-zero emission steel might grow. It was uncertain whether businesses in certain sectors (for example, technology companies commissioning the construction of new buildings) might create a premium market for clean steel in the US, and if so, how large this market would be.

3. ***Steelmaker investments in clean steel technologies.*** Interviewees questioned whether the industry would invest in new clean steel technologies, beyond electric arc furnaces, particularly as blast furnaces came up for relining. If so, there was also uncertainty around the technologies that might be prioritised – whether these would be state-of-the-art electric arc furnaces, or plants using hydrogen direct reduction, carbon capture and storage or molten oxide electrolysis technologies.

International uncertainties

4. ***Global market demand for clean steel.*** The extent to which there would be demand for low and near-zero emission steel globally, and the speed at which this market would develop, was identified as a key uncertainty that would influence the development of the steel sector in the United States.

5. ***Relative competitiveness with China (and others).*** If global demand did exist for clean steel, participants were uncertain whether the United States would be able to compete successfully against China to fulfil this demand. This was seen as dependent on other uncertain factors including power sector decarbonisation, technological development and cost reduction, and industry investment.

6. ***The effects of US climate and trade diplomacy.*** The extent to which the US would use its trade policy to influence the energy transition globally was recognised as uncertain. The US might use its trade policy to weaken the climate change and energy transition policies of other countries (as already seen in negotiations at the International Maritime Organisation), but how much this would affect the steel transition was unclear. On the other hand, the US might introduce trade policies where carbon emissions were used in tariffs or standards as a way to create an advantage for US industry. How US tariffs targeting Chinese overcapacity, as well as other countries' steel products, would evolve in future, and how these would shape the industry globally, were also uncertain.

7. ***Other countries' climate and trade policies.*** How other countries' climate and trade policies would influence the United States market was uncertain. One example was the uncertainty around the effect of the European Union's carbon border adjustment mechanism. Would it succeed, and would this policy approach spread to other countries? If so, would that have a positive or negative impact on the United States' steel industry?

8. ***Technological breakthroughs and opportunities.*** Participants questioned whether the US would have technological successes that it could harness to drive new growth in its steel industry. Specifically, technological breakthroughs in molten oxide electrolysis, where firms in the United States are currently leading innovation, were seen as a potential driver of export opportunities and growth for the industry.

Axes of uncertainty

At the workshop in Washington DC, participants started with a long list of the uncertainties that they had identified individually, and prioritised these through a participatory process to create two strategic axes. These axes represented the uncertainties collectively considered most important, and formed the basis of the scenarios.

The first axis describes uncertainty around the cost competitiveness of clean steel technologies.

Clean steel technologies are cost competitive	⟷	Clean steel technologies are not cost competitive

At one end of the axis, clean primary steel technologies are cost competitive. By 2035, technological breakthroughs and falling renewable energy and hydrogen prices make hydrogen-based direct reduced iron, electric arc furnace and molten oxide electrolysis steel production as affordable as conventional blast furnace-basic oxygen furnace steelmaking.

At the other end of the axis, clean steel technologies are not cost competitive. Clean primary steel technologies remain significantly higher cost than coal-based blast furnaces. The exception is recycling steel in electric arc furnaces, a route that is already cost competitive in the US at present.

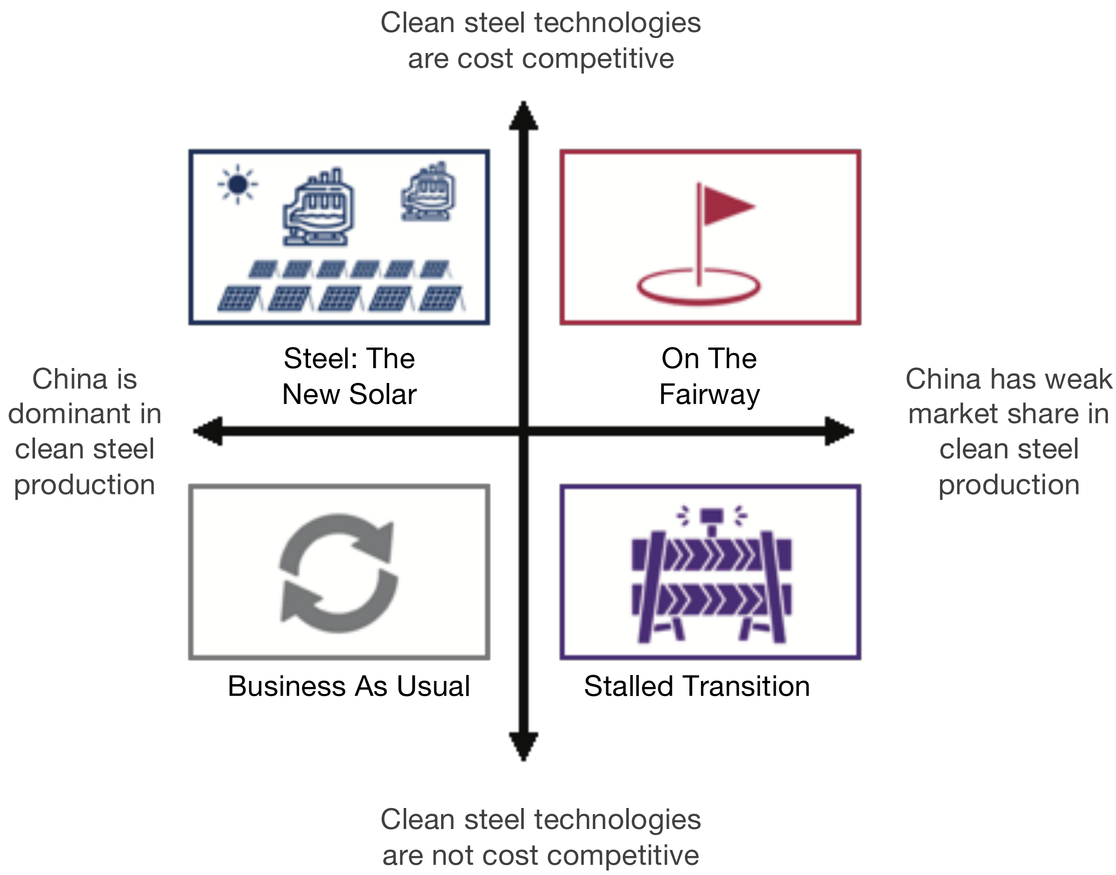
The second axis describes uncertainty around the extent of China's dominance of the global market for clean steel:

China is dominant in clean steel production	⟷	China has low market share in clean steel production

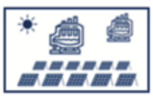
At one end of the axis, China is dominant in clean steel production. Participants imagined this resulting from China leveraging its existing industrial scale and capabilities, policy coordination and investment in renewables and hydrogen. At the other end of the axis, China has a low market share in clean steel production.

Scenarios of the United States' steel transition

The two axes create a scenario framework that describes four alternative outcomes for the US steel industry in 2035.



On The Fairway describes a future where clean steel technologies are cost competitive and China has weak market share in clean steel production. America's desire to be at the forefront of innovation has driven long term investment in clean technologies. Hydrogen DRI and molten oxide electrolysis have achieved cost parity with BF-BOF for high-grade steel production, driven by technology breakthroughs, and incumbents race to retrofit plant. Washington has forged a coalition with other producers to align carbon accounting rules, to agree new standards for low and near-zero emission steel and to impose tariffs on high-emission imports. Paying a premium for clean steel is disappearing in advanced markets. China remains the world's largest steel producer but has not invested in clean steel technologies or standards and is locked out of the trade flows shaping the high-value global economy. The US steel industry enjoys first-mover advantage but competitors are already scaling up their own clean steel capacity. The US has no intention of letting its advantage slip.



Steel: The New Solar describes a future where clean steel technologies are cost competitive and China is dominant in clean steel production. Despite being well-positioned to compete in the global transition to clean steel, America hesitates and China pulls ahead. China's leadership classifies clean steel technology as a strategic national priority. State-owned enterprises begin simultaneous deployment of hydrogen DRI plants and large-scale upgrades of electric arc furnaces running on high-quality scrap and clean power. The US, primarily viewing clean steel through the lens of climate change, fails to respond. As China pulls ahead, it secures agreements to export green steel widely. Its technical norms and certification schemes set global standards. US steelmakers still do well domestically but are under pressure from overseas suppliers. For US policymakers, the choice now is whether to accept this weaker position or to launch a second push.

Business As Usual describes a future where clean steel technologies are not cost competitive and where China is dominant in clean steel production. Rather than invest in unproven technologies, US steel producers focus on their strengths in EAF production and retain existing BF-BOFs. China sees clean steel as a low-risk gamble and mobilises a small number of state-owned mills to develop commercial-scale technologies. The market is small but China dominates it. Efforts to build up the US clean steel sector fail to gain traction as producers argue that being a 'fast follower' makes more sense than risking first-mover disadvantage in a high-cost, low-demand segment. As China strengthens its position, and other producers move into clean steel, there are growing concerns that US industry will fail to keep pace.

Stalled Transition describes a future where clean steel technologies are not cost competitive and China has a weak market share in clean steel production. The cost gap between clean steel technology and BF-BOF is wide and the transition is effectively stuck. Europe strikes out on its own, pairing subsidies for clean primary steel with a rising carbon price and a fully implemented CBAM. As Europe's strength grows, its framework for measuring and certifying carbon intensity in steel is adopted as the gold standard by some producers outside the EU. The US chooses not to follow, sticking with conventional EAF and BF-BOF in its domestic market. As Europe becomes stronger in clean steel and China doubles down on conventional steel, the US risks losing out in both markets. However, it remains unclear whether the real race has begun and whether the US can strengthen its position before it does. For now, the technological future of the sector remains uncertain.

The US scenarios are described in full in **Appendix C.**

Likelihood of scenario outcomes

In the final part of the workshop, participants voted on a number of strategic questions related to the scenarios' plausibility, desirability, and alignment with current plans. The exercise was designed to explore participants' perspectives on the range of possible outcomes and strategic choices defined by the scenario set. The votes are set out in the table below:

The vote indicates that:

- The scenario that almost all of the group believed to be most favourable for the US steel industry – *On The Fairway* – was seen as the least plausible. It was also seen as the future that demands the greatest change.
- The scenario that the majority of the group believed to be most plausible was *Business As Usual*. No participants believed this scenario to be the most favourable for the US steel industry or for achieving the global transition to net zero. It was, however, the scenario that most of the group believed was closest to the future that policy makers are planning for.
- Almost half of the group disagreed that *Business As Usual* is the most plausible scenario. Their vote was split equally between *Steel: The New Solar* and *Stalled Transition* – two

scenarios that are diametrically opposed on the scenario matrix. This suggests significant uncertainty among US experts around the global steel industry's future direction of travel.

- Most of the group voted *Steel: The New Solar* as the most favourable scenario for achieving the global transition to net zero. Despite China's dominance in this scenario, around a third of the group believed it to be closest to the future that US policymakers are planning for.

The group was unanimous that policymakers are planning for a future on the left side of the scenario matrix – that is, one where China is dominant in clean steel production.

Table 3: Votes on scenario likelihood and desirability in the United States.

	Most plausible	Most favourable for the US' Steel industry	Most favourable for achieving the global transition to net zero	Closest to now	Closest to the future that policy makers are planning for	Closest to the future that demands the greatest change
On The Fairway	0	86%	31%	0	0	92%
Steel: The New Solar	22%	0	69%	0	38%	8%
Business As Usual	57%	0	0	0	62%	0
Stalled Transition	22%	14%	0	100%	0	0

Conclusions

Within the United States, uncertainties affecting the steel sector's future include whether the transition to clean steel will again become a political and policy priority; in the absence of policies, how much voluntary private demand for low and near-zero emission steel will emerge; and whether steelmakers will invest in new clean steel technologies without policy support. The commercialisation of new technologies, such as molten oxide electrolysis, is also an important uncertainty.

At the international level, uncertainties relate to the pace and scale of demand for low and near-zero emission steel, the US industry's competitiveness with China in future clean steel markets, and the effects of trade and climate policies implemented by the US and by other countries.

Experts and policymakers could envisage a successful transition, described in the *On The Fairway* scenario, where US innovation, markets and policy made primary clean steel technologies cost competitive. In this scenario, the United States used alliances and trade policy to build a coalition around common standards and protected markets for near-zero emission steel. This future was viewed as highly favourable for the US steel industry and positive for the global transition, but was considered the future requiring the greatest change, and none saw it as the most plausible or as closest to the future that policymakers were planning for.

It was striking that all participants thought the scenario closest to the future that US policymakers were planning for was either *Steel: The New Solar* or *Business As Usual*, and no participants saw either of these scenarios as most favourable for the US steel industry. Both these scenarios involve Chinese dominance in clean steel production: US policy support stays limited and fragmented, and US producers rely on existing EAF strengths, while China and others shape emerging clean steel markets. This suggests that the US steel sector could benefit from wider discussion about whether Chinese dominance of clean steel is an inevitability, or whether there are policy options that might increase the likelihood of scenarios more favourable to the US industry's future competitive position.

Comparisons across the three regions

Uncertainties

Experts in the three regions identified a common set of underlying challenges relating to the steel sector's transition, such as the higher costs of near-zero emission steel production, the lack of demand for clean steel, and the steel industry's consequent lack of willingness to invest. However, the nature of uncertainties differed across countries, reflecting their distinct political economies and market structures, as well as different starting points. In contrast, the international uncertainties were more similar across regions. These included the extent of global demand for low and near-zero emission steel, the openness of other countries' trade policy, the speed of other countries' transitions, and the approach of other countries to trade and diplomacy. At the same time, there were some noticeable differences in emphasis.

US participants put the most emphasis on the uncertainties around voluntary private sector demand for clean steel, and innovation in clean steel technologies, reflecting low expectations of steel transition policies being in place. European participants put greater emphasis on the uncertainties around the political support for, coherence of, and effectiveness of steel transition policies. Chinese participants were more focused on the effectiveness of transition policies in response to structural changes in demand for steel.

Chinese participants were the most confident about their industry's capability to be competitive in clean steel technologies. European participants were uncertain, while US participants were highly doubtful. The participants from the three regions differed in the relative importance they ascribed to other countries in defining the future for their own industries. US participants identified China's position as a critical uncertainty. European participants were concerned with China but also with a wider range of potential competitors, including Middle Eastern producers. Chinese participants gave greater emphasis to the uncertainty in global demand, in which other developing countries were the decisive actors.

Scenarios

The differences in emphasis regarding uncertainties translated into differences in the scenarios that participants developed.

Axes of uncertainty

For the EU, the scenarios focused strongly on the extent to which the global trade environment is open or closed over the course of the transition, and the strength and pace of competitors in the transition. These axes reflect perceived opportunities of the EU's current leadership position in the steel sector's transition, and the competitiveness risks that European industry is exposed to in both conventional and clean steel production.

For China, the focus of the scenarios was on the scale of low and near-zero emission steel production capacity that China could develop in the next ten years, and the scale of global demand for these products. These scenarios reflect opportunities provided by China's technological capability and extensive industrial capacity, as well as the risks of managing excess blast furnace-basic oxygen furnace production.

Comparison of domestic uncertainties

European Union	China	United States
Political support for the transition	Demand for steel in China	Political support for the transition
Industrial policy coherence	Extent of excess production capacity	Extent of private voluntary demand for low and near-zero emission steel
Cost and availability of clean power	Industry willingness to invest in new technologies	Industry willingness to invest in new technologies

Comparison of international uncertainties

European Union	China	United States
Extent of diplomatic cooperation to create markets for low or near-zero emission steel	Extent of global market demand for low and near-zero emission steel	Extent of global market demand for low and near-zero emission steel
Openness of international trade	Openness of international trade	Climate and trade diplomacy
EU cost competitiveness compared to other countries	Future global demand for steel	Relative competitiveness with China (and others)
Speed of other countries' transitions	Technology pathways	Technological breakthroughs and opportunities

For the United States, the scenarios largely focused on the extent to which market forces would bring down the cost of clean steel production, along with the extent of Chinese dominance in clean steel technologies. These scenarios reflected perceptions of the US economy's strengths as a market-led system for investment and innovation, alongside the unpredictability of its politics and policy and the uncertainties of its economic and geopolitical competition with China.

Risks and opportunities

Across the three regions, some broad scenario types emerged that highlighted similar risks and opportunities presented by the steel transition.

A '**first-mover advantage**' scenario appeared in all three scenario sets. Generally, this was characterised by effective domestic policy support for the transition. In some cases there was also strong international policy alignment or cooperation, resulting in robust competition for global demand for green steel. In this world, countries that move decisively to leverage their competitive strengths — whether technology, resources, or policy leadership — capture market share in emerging clean steel markets.

The details of this scenario differ in each region:

- In the EU's *Green Multilateralism* scenario, the success of its coherent industrial policy, development of green iron partnerships that allow lower-cost and competitive clean steel production, and diplomatic engagement on standards and regulations, all allow it to lead competitively in the global transition.
- In China's *Green Steel Consensus* scenario, its comparative advantages in clean power and hydrogen production, lower cost electrolysers, and deep technological capabilities and industrial capacity in steel production allow it to develop and dominate emerging green steel markets.
- In the United States' *On The Fairway* scenario, market- and policy-driven innovation leads to technology breakthroughs, both in the power sector and in steel production, that give its industry an advantage. This, along with proactive diplomacy to create clean steel markets that favour the United States and its allies, allows US industry to compete in growing clean steel markets.

A '**late-mover risk'** scenario was another scenario-type that appeared in all regions. This was generally characterised by costs for clean steel production falling faster, and demand for clean steel growing more quickly, than anticipated. In these scenarios, the late-moving country is typically seen as having been constrained by domestic politics. Its industry is left unprepared, while other countries capitalise on their competitive advantages and configure international trade around clean steel to gain market share.

- In the EU's *Slipstreaming* scenario, weak and misaligned policy has seen European industry lose its leadership position in the transition. As a result, China has harnessed its strengths and dominated the market. Europe is now increasingly dependent on cheaper near-zero emission steel and production technologies from China.
- In China's *Falling Behind* scenario, China's political constraints in transitioning away from BF-BOFs and its adoption of relatively weak policies mean it moves more slowly to build clean steel capacity. Meanwhile, other regions (including Europe and the United States) move faster than expected to create and enforce international markets for clean steel.
- In the United States' *Steel: The New Solar* scenario, weak policy domestically and lack of political prioritisation has left it further behind China in its ability to meet market demand for low and near-zero emission steel.

A '**stalled transition'** scenario of some kind features in the scenario set of each region. Features of these scenarios include low domestic political support for the transition or policy incoherence, geopolitical tensions and a lack of international collaboration, and negligible green steel demand globally. In these circumstances, competition and investment in clean steel stalls.

- In the EU's *Managed Decline* scenario, populism leads to decline in support for the transition, industrial policy is fragmented, geopolitical tensions are numerous, and the focus is on preserving existing industry. As a result, there is limited progress on steel decarbonisation.
- In China's *Maximum Blast Furnaces* scenario, geopolitical tensions limit green steel demand, China's internal politics leads to prioritisation of preserving BF-BOFs, and climate risks worsen.
- In the United States' *Stalled Transition* scenario, the cost-gap between clean and conventional steel remains wide, the EU prioritises its own climate framework, and the US and China double down on conventional steel production without growing new clean steel markets.

A ’**go-it-alone’** scenario, in which a single country moves decisively ahead while others hesitate or are constrained by their own domestic political contexts, was defined in both China and Europe. In each of these cases, unilateral action achieves only a limited effect on the global transition due to the small scale of the clean steel market. Whether this becomes a **‘first-mover risk’** scenario depends on national circumstances.

- In China’s *Technological* Foresight scenario, China is proactive in developing green steel technologies. The lack of global demand means that this capability generates relatively little value at first, but Chinese clean steel producers sell to the domestic market and are well positioned to dominate global markets when the transition eventually takes place.
- The EU’s *Fortress Europe* scenario is strongly characterised by the need to manage first-mover risk. To protect its industry while decarbonising, the EU adopts a more protectionist stance in trade. The EU industry contracts, as progress on decarbonisation outside the EU is slow, and European producers only serve their own internal market.

Expectations

The results of the voting highlight significant differences in expectations between participants in the three regions. A selection of comparative results is presented in the table below.

Share of the group rating…	EU	China	US
...a fast global transition scenario as the most plausible	25%	47%	21%
...the 'most plausible' scenario* as the most favourable for its own industry	25%	53%	0%
…the most favourable scenario for its own industry* as the most plausible	25%	53%	0%
…the scenario closest to the future that policymakers are planning for* as the most favourable for its own industry	50%	42%	0%
…the scenario most favourable to the global transition* as the closest to the future that its policymakers are planning for	25%	53%	38%

**As chosen by a plurality of the group. Where the vote was evenly split, an average is used.*

Chinese participants were the most confident about the future of the global steel industry being favourable for their country’s industry, and US participants were the least confident. Chinese and European participants both saw a moderate level of overlap between the scenarios most favourable for their industries and the futures their policymakers were planning for, while US participants perceived little if any overlap.

In none of the three regions was the scenario identified as most favourable for the global transition also seen as the most plausible scenario by a plurality of the group. The share of the group that did see the most favourable global transition scenario as also the most plausible was highest in China, and lowest in the US. As well as being the most optimistic about the pace of the global steel transition, Chinese participants were more likely than European or US participants to believe that their government was planning for the scenario most favourable for the global transition.

3 A shared vision of the global steel transition

A shared vision of the global steel transition

The scenario exercises conducted in the United States, China and the European Union revealed that while domestic uncertainties differ, a common set of uncertain international factors shapes the direction of the steel sector transition. These relate to technology, trade, and the effect of other countries' policies on the demand for clean steel and conventional steel in global markets. How countries navigate these uncertainties could determine whether their industries are more exposed to first-mover or late-mover risks.

Across the three regions, scenarios involving a high level of international collaboration were associated with a faster global transition. In the second part of this project, we explored the potential for collaboration between major steel producing countries to advance the transition. Collaboration in this context is not considered to be an alternative to competition, but a means to set the direction of industrial competition to align with a common goal.

China, the United States and the European Union remained the focus in this part of the project. While these are far from being the only countries and regions that are important in the sector's global transition, their different political, economic and technological contexts make a useful case study in how collaboration could be progressed amongst a group of countries with strong but different interests in the transition.

To explore these issues, twenty policy experts from Europe, China, and the United States met in London in October 2025.

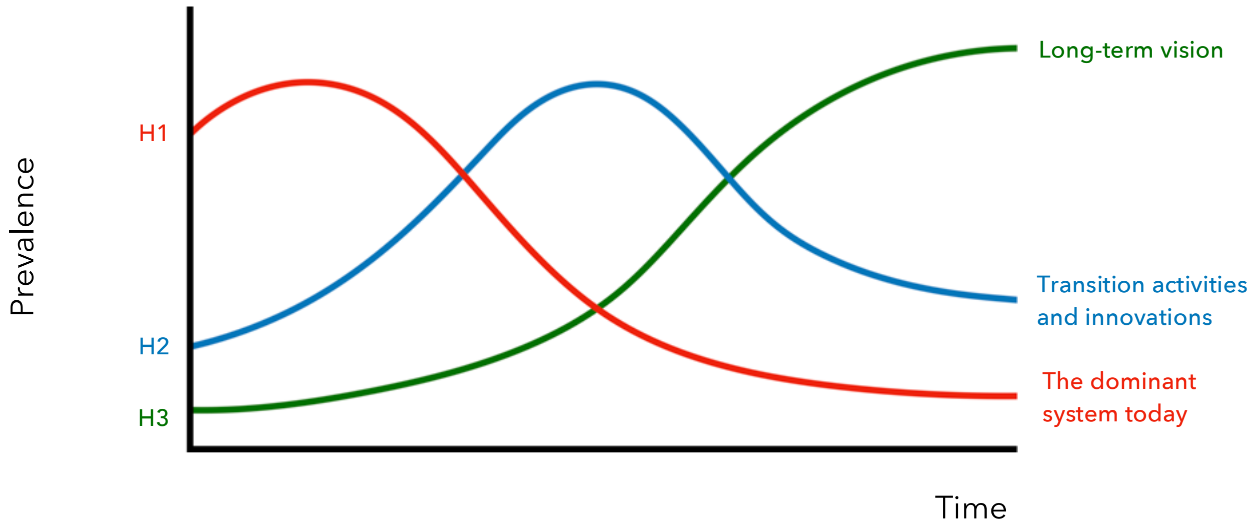
The Three Horizons framework

The discussion was facilitated using Three Horizons, a framework that maps the shift from established patterns of the present to the emergence of new stable patterns in the future. Whereas scenarios are useful for exploring uncertainties over which actors have limited influence, the Three Horizons framework is suited to situations where there is high uncertainty but also a high degree of agency. A few major economies working together could exert strong influence over the global steel transition, so Three Horizons can provide an appropriate framework for a discussion about international cooperation.

Participants in a Three Horizons workshop explore change from three perspectives:

- The first horizon (H1), which is the dominant system at present. It represents 'business as usual'. We rely on these systems being stable and reliable but, as the world changes, aspects of business as usual begin to feel out of place or no longer fit for purpose. Eventually 'business as usual' will always be superseded by new patterns of activity.
- The third horizon (H3) is the long-term successor to business as usual. It grows from emerging practices in the present that introduce new ways of doing things. These are unfamiliar at first, but turn out to be better fitted to the world that is emerging than the dominant H1 systems.
- The second horizon (H2) describes the innovative products and processes that are emerging in the market, as people try out new approaches in response to changing conditions. Some of these innovations will sustain the dominant system (H1), adapting it to prolong its life. These are described in the approach as 'H2 minus' innovations. Some will drive towards the emergence of qualitatively different systems (H3). These are described as transformative innovations or 'H2 plus'.

The three horizons co-exist but their dominance changes with time. H1 patterns of activity decline as H3 practices gain traction:

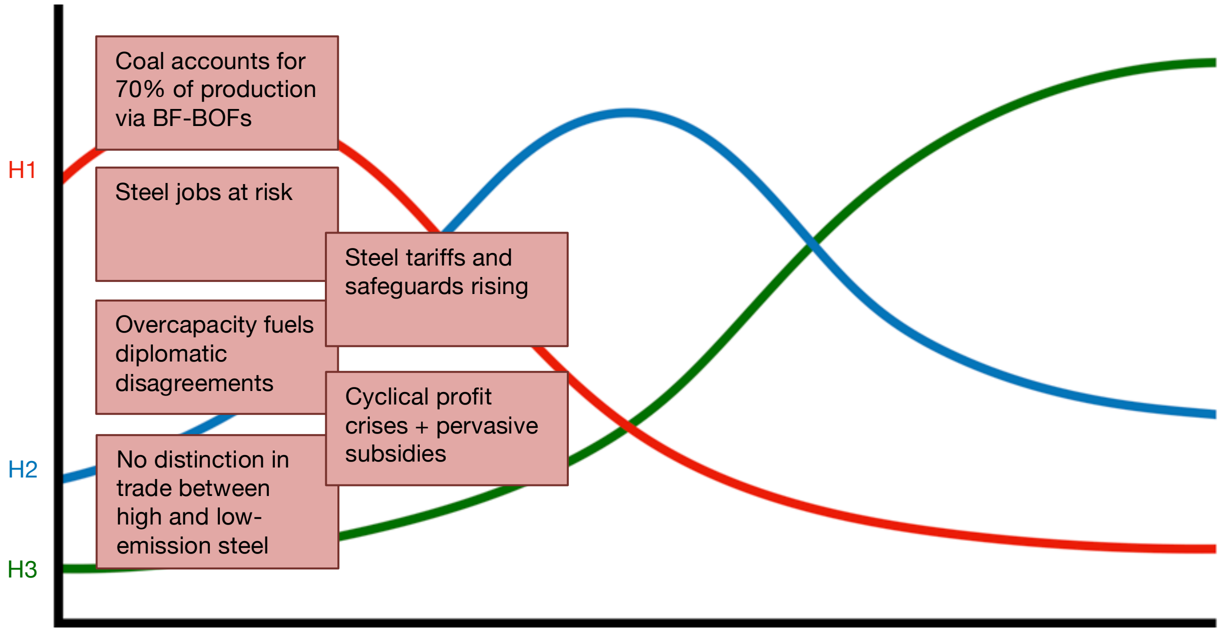


Applying this framework to the global steel transition, the discussions among experts from the three regions were structured as follows:

- First, participants discussed the characteristics of the dominant global system of steel production and trade, (H1). They focused on four elements – technologies, policies, trade and industry structures.
- Second, participants described the key characteristics of the future system of global steel production and trade that they saw as desirable (H3). They focused on the same four elements of the global system as the H1 conversation – technologies, policies, trade and industry structures.
- Third, participants identified innovations that were taking place (H2), and discussed whether these should be characterised as sustaining innovations (H2-) extending the life of H1, or transformative innovations (H2+) driving the industry towards H3.
- Finally, participants focused on the H2+ actions and discussed the potential for countries to work together to strengthen these transformative innovations and so develop the H3 system of global steel production and trade that they had envisioned.

This section of the report summarises those discussions.

Characterising the current system of steel production and trade (Horizon 1)



Summary of the H1 section of the Three Horizons map produced by Chinese, US and European steel experts in the London workshop.

Participants from the three regions described the currently dominant system of steel production and trade as follows.

Technologies

Blast furnace-basic oxygen furnace technologies account for over 70% of global steel production, and rely on coal as a reductant and energy source. Around 20% of steel is produced using electric arc furnaces, but coal continues to play an indirect role through its presence in many countries' electricity generation.

The structure of the industry

The steel industry is made up of many large companies, with over a quarter of steel produced globally by 10 companies, and over half by the top 50 companies.[21] The largest steel companies are transnational with cross-border ownership of plants and complex corporate structures. Many of the largest steel companies are state-owned enterprises or have historically been so. In 2016 approximately a third of steel production globally was from state-owned enterprises (SOEs).

Despite global ownership structures, most of iron and steel production takes place close to local demand. Iron ore and metallurgical coal are highly traded commodities, but a large proportion of steel is produced in the markets in which it is consumed. The geographical concentration of the steel industry reflects where conditions have historically been most favourable: access to cheap coal and iron ore, lower cost labour, and strong domestic demand.

The labour-intensive nature of steel production processes has meant that workers have

[21] World Steel in Figures, 2025.

traditionally had significant voice and bargaining power in the steel industry. As a result, steel jobs have become deeply embedded in the political economy of many countries.

As countries have rapidly industrialised and then experienced slower growth, patterns of steel production and consumption have changed, at times leading to a surplus of production capacity globally. For advanced economies such as the EU and United States, steel consumption has plateaued. In China, demand is falling after sustained growth in previous decades. In other emerging and developing countries, such as India, demand is growing rapidly. In some regions, such as sub-Saharan Africa, steel consumption per capita remains critically insufficient to meet basic needs.

Trade

Despite most steel being consumed locally, around a quarter of steel is traded internationally. The current period of overcapacity, caused by excess investment in new production capacity at the same time as falling demand in China, has led to a resurgence of tariffs and steel safeguards in the EU, US and globally. These have led to bitter disagreements between countries over who is responsible for falling steel prices and the period of unprofitability experienced across many countries' steel industries.

In most international trade arrangements there is no distinction between high- and low-emission steel. An exception is the EU's carbon border adjustment mechanism, introduced to ensure that imported steel is subject to the same carbon price as domestically produced steel. This has been criticised by other countries, including the United States and China. No internationally agreed standards yet exist to define low-emission, near-zero emission or green steel.

Policies

The steel sector experiences cyclical periods of profitability and crisis. In many countries, steelmaking companies are long-term recipients of government support, as subsidies are used to protect companies' solvency and profitability and to insulate workers from downturns.

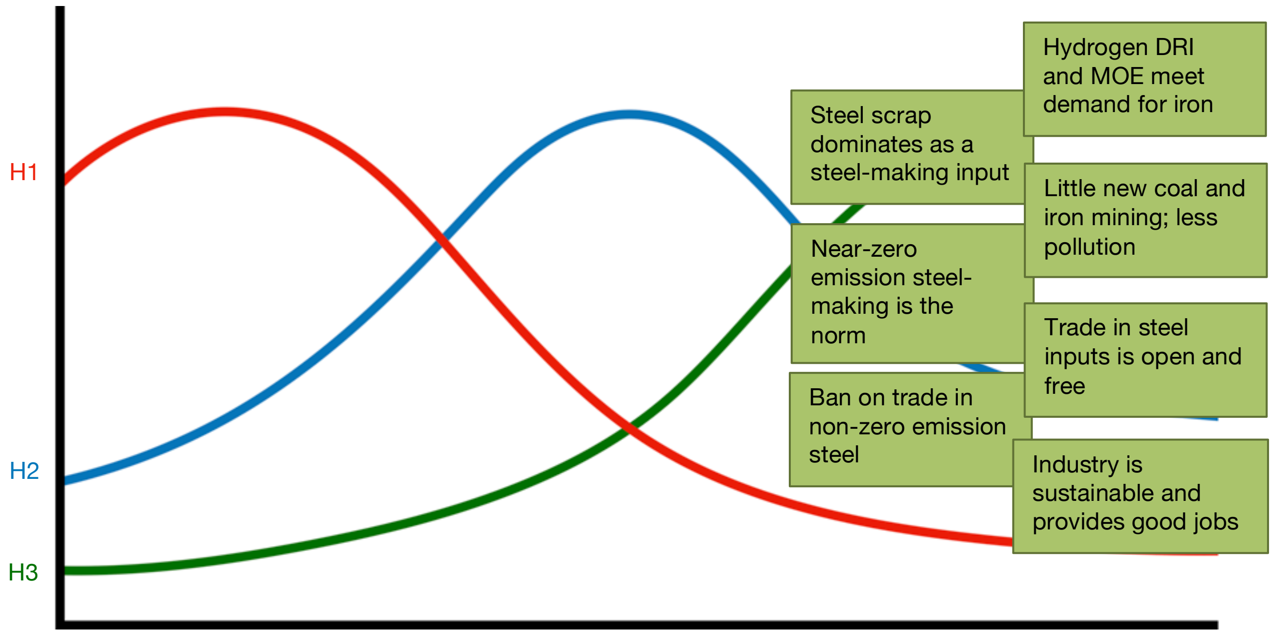
Other forms of state intervention in the sector are common. The US, for example, uses local content requirements in public procurement for federal infrastructure under 'Buy America' provisions. In China, the central government plays an orchestrating role in managing capacity through granting or withholding permits for new plants. In the EU, many countries provide energy-intensive industries with relief from high electricity prices. Increasingly, arguments are made in favour of protecting the steel industry and its supply chains on the basis of national security interests. In most countries that have steel industries, there is a view that steel is, or should be, a national political priority.

Policies to support the steel sector's transition are not well developed in any region. Those most prevalent include carbon pricing and incentives to increase energy efficiency and recycling.

A shared view of challenges

There was a high degree of consensus among experts from the three regions on the important factors that keep the global system of steel production and trade in its current state. These included the higher cost of clean steel technologies; the weakness of existing policies to support the transition; and the lack of differentiation between high and low-emission steel in international trade. Overcapacity and political sensitivity to job losses in the sector were recognised as factors that increased the difficulty in all regions.

Envisaging a desirable future system (Horizon 3)



Summary of the H3 section of the Three Horizons map produced by Chinese, US and European steel experts in the London workshop.

Participants discussed what a desirable future system of steel production and trade would look like from the perspectives of their national and regional interests. They described the main characteristics of this future system as follows.

The structure of the industry

In the long-term vision of the future, the global steel sector looks significantly different to today. Primary steel is no longer a major part of the industry. 95% of scrap steel globally is recycled or reused, and global stocks of scrap have increased significantly. As a result, a much smaller share of steel needs to be produced from iron ore than at present. The sector continues to underpin the global economy, providing essential materials for infrastructure, housing, and transport, but smart design and engineering has led to far more circular and efficient use of steel than before. The business of steel is now considered as much to do with services as to do with goods. Companies provide advice on how to integrate high-strength and recyclable materials into designs to maximise efficient use.

There is little new iron ore mining, resulting in fewer environmental problems and allowing former mining areas to be ecologically regenerated. The health and social costs of polluting production methods are no longer a concern in cities or towns; smog no longer exists. There are fewer workers in the industry than before, but the sector is more stable and provides good quality, skilled jobs. In some regions, the sector is highly consolidated for economies of scale, but in other places it is decentralised allowing for small, distributed steelmaking facilities close to local demand.

Technologies

Near-zero emission steelmaking is the norm, with the industry powered almost entirely by clean electricity. Hydrogen direct-reduction iron is the dominant production route for primary steel. Abundant low-cost renewable power is used to produce green hydrogen, eliminating the roles of coal and gas.

Other technologies have emerged as important. Molten oxide electrolysis (MOE) has become a commercially viable and highly efficient way to produce green iron using electricity and iron ore alone. This process has become competitive through its high efficiency compared to hydrogen direct reduced iron, its modular nature, and its ability to process lower-grade iron ores. In some regions with severe constraints on electricity and hydrogen systems, carbon capture and storage has been used in plants with natural gas or biomass as inputs, although this technology has not experienced the cost reduction seen in routes relying on electrification.

The majority of production takes place in electric arc furnaces (EAFs) with inputs of scrap steel and renewable power. EAFs have proven more flexible, efficient and lower cost than fossil-fuel-powered alternatives. Innovation has made new EAFs even lower emission and more efficient than previous designs, allowing them to be used for making almost all kinds of steel.

Policies

Now that almost all steelmaking is near-zero emission, few policies to support the transition are needed beyond regulation to prevent any return to high-emitting technologies. The focus of policy has shifted towards improving circularity, strength and efficiency.

Trade

Standards for near-zero emission steel have been agreed and have become globally accepted norms. There is now a global ban on trade in any steel that does not meet the near-zero emission standard. Digital carbon-tracking systems ensure accountability throughout value chains.

Trade in steel inputs (scrap steel, green iron, and iron ores) is open, free from export restrictions or significant tariffs. This allows countries to access the inputs they need for clean steel production without unnecessary costs. Trade, finance and intellectual property structures have been used to facilitate developing countries' access to low-cost clean steel technologies.

Trade in steel itself is not entirely open. Countries still use tariffs to maintain domestic steel production capacity and supply chains in line with national interests. Trade disputes still occur, but a functioning multilateral regime now exists to resolve disputes and enforce rules. The stability of the steel sector globally has led to a far less diplomatically contentious sector than seen in the many previous decades.

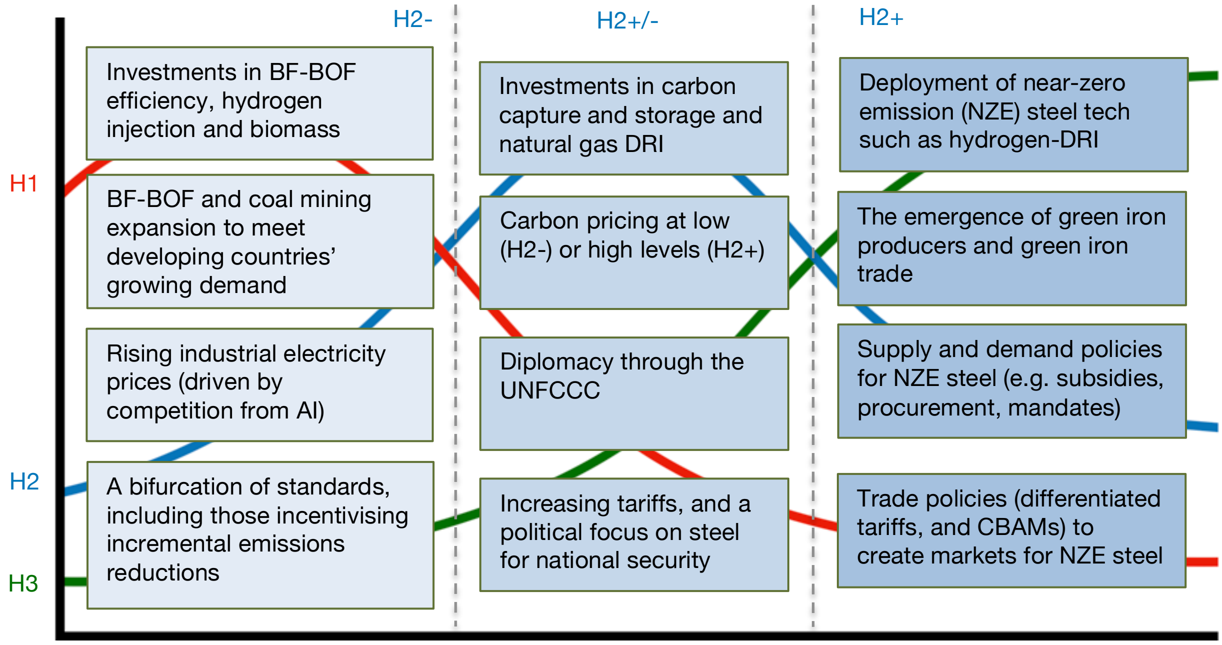
A shared vision

Apart from the obvious difference in national interests with respect to countries' relative shares of the global steel market, the vision of a desirable future system of steel production and trade was largely shared by participants from the US, China and Europe. Participants largely agreed on the relative importance of different technologies, and need for a large share of demand to be met through recycling. It was notable that the group had a strong collective preference for open global trade in the inputs to clean steel production, but a general ambivalence or some disagreements over the desirability of openness of trade in steel itself – reflecting an acknowledgement that some national interests may be more important than accessing steel at the lowest possible cost.

Identifying the levers for transformative change (Horizon 2)

In this section, we discuss innovations and activities identified by the group as having the potential to either sustain the dominant system of steel production previously discussed (known as ‘H2-’ or sustaining innovations) or drive towards the shared future vision (known as ‘H2+’ or transformative innovations). We also highlight those that were not conclusively decided upon as either H2+ or H2-.

Sustaining innovations (H2-) are not necessarily ‘bad’. They may be useful for reducing near-term emissions, or to advance other policy objectives. The distinction between sustaining and transformative innovations relates only to the policy objective of achieving the transition. In that context, it can be understood as a guide to prioritisation.



Summary of the H2 section of the Three Horizons map produced by Chinese, US and European steel experts in the London workshop.

Technologies

Actions and innovations that would drive transformative change towards the shared vision (H2+) were identified as:

- **Deployment of hydrogen direct reduced iron as a steel production technology.** As this is scaled up and replaces coal and gas-fuelled primary steel production, it can eliminate emissions from the process – consistent with the desired H3 future. The commercial scale demonstration of this technology in Europe and China is already beginning.
- **Reduction in the costs of renewable power, electrolysers and hydrogen.** These costs are falling due to growing economies of scale and learning, as the technologies diffuse globally. As they fall further, the competitiveness of near-zero emission electricity-based steel production routes will improve.

Innovations that were seen as sustaining the dominant system of steel production (H2-) included:

- **Investments to improve the efficiency of blast furnace-basic oxygen furnace plants.** These can only marginally improve emissions, which may be beneficial but does not lead to the desired H3 future.
- **Hydrogen injection and biomass substitution in blast furnaces.** [22] These were seen as likely to achieve only partial emissions reductions, whilst sustaining ongoing use of coal and the blast furnace industry. Examples of these projects being trialled or developed exist in India, China and Europe.

Innovations that the group debated as either H2+ or H2- included:

- **Carbon capture and storage used with BF-BOF or DRI plants.** This could be near-zero emission (with development) and deployed in appropriate locations (H2+). Alternatively, the technology could be positioned as a wide-scale solution but fail to receive investment by steel companies or to prove its viability at scale, delaying action in other areas and sustaining the use of blast furnace-basic oxygen furnaces (H2-).
- **Investment in natural gas direct reduced iron furnaces.** These could reduce emissions compared to blast furnaces and switch easily to hydrogen once it is available at a sufficiently low cost (H2+). Alternatively, use of this technology could incentivise further investment into expensive gas infrastructure, leading to continued political pressure to maintain gas demand (H2-). If natural gas steel plants are built in locations not suited to hydrogen production, this will reduce the likelihood that future fuel switching occurs (H2-).

Industry structures

Actions and innovations that would drive towards the shared vision (H2+) were identified as:

- **Trade in green iron.** This could be introduced into international markets by new entrants or existing producers. As the cost of green hydrogen depends on the cost of renewable electricity, countries with good iron ore reserves and the cheapest renewable power could export green iron at more competitive prices. This could support early investment in near-zero emission steel production.
- **Aggregation of voluntary private sector demand** for near-zero emission steel. This can be driven by companies willing to pay the premium, such as European automakers or large US-based technology companies building data centres. For example, the United States steel companies Electra and Nucor are in the early stages of partnering with technology firm Meta.[23]
- **Workers' advocacy for investment in clean steel technologies.** This can help provide political backing for investment in these technologies. Examples of this exist today, such as the activities of workers for ThyssenKrupp in Lower Saxony who have advocated for switching to clean steel technologies.[24]

Innovations identified as likely to sustain the dominant system of steel production (H2-) included:

- **The emergence of artificial intelligence and rapid construction of new data centres.** While not an innovation taking place in the steel sector itself, this is placing major additional demand on electricity systems, which could drive up prices for industrial electricity users, making the transition more difficult.

These could combine with forces pushing directly for further growth of the existing system (H1):

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[22] Where biomass is more readily available to use at low cost (e.g. Brazil), it may be a H2+/H2- innovation depending on how it affects investment in near-zero emission technologies.
[23] Canary Media (2025). *Electra announces deals with Meta, Nucor to scale its clean iron tech.*
[24] TUC (n.d.). *German steelworkers win a green steel transition.*

- **Continuing investment in new blast furnace-basic oxygen furnace steel plants,** particularly in India and Southeast Asia, supported by investment from China, Japan and South Korea.
- **New investments in coal mining supply chains**, underpinning the dominant system of steel production. At present, 850 new mines and mine expansion projects have been announced or are under development.[25]

Innovations that were seen by the group as having potential to be either H2+ or H2- included:

- **Growth in the global market share of steel producers in the Middle East and North Africa region,** using hydrogen direct reduced iron. This could drive the transition by harnessing renewable energy resources in these regions for low-cost clean steel production, and by channelling investment into electrolysis and DRI technologies (H2+). It could also be H2- if using hydrogen produced with gas, with CCS being used for enhanced oil recovery, which would further support the fossil fuel industry.

Trade

Innovations that the group identified as likely to drive towards the shared vision (H2+) included:

- **Differentiated tariffs for near-zero emission steel,** compared to high-emission steel. This could incentivise investment in production using near-zero emission methods, by giving clean steel an advantage in international trade.
- **Carbon border adjustment measures (CBAMs).** A CBAM prevents producers who pay a carbon price from being undercut by producers who do not. This can contribute to creating lead markets for near-zero emission steel, in combination with other policies.
- **Interoperable standards** to differentiate between clean and high-emission steel, which could be agreed through diplomacy. These could create common markets for, and facilitate trade in, near-zero emission and low-emission steel.
- **Green iron trade deals,** which could be agreed between steel companies and iron producers, supported by governments. Steel producers could benefit from the lower cost iron production in other countries to make their own near-zero emission steel more competitive. Examples of these kinds of agreements today include those between Fortescue and Baowu Steel[26], and HyIron in Namibia and the German Government.[27]

Innovations that the group saw as likely to sustain the dominant system of steel production and trade (H2-) included:

- **A proliferation of competing standards**, or lack of agreement on common standards for low and near-zero emission steel. This could slow the emergence of a joined-up market for clean steel, and so hold back demand. A division is already evident between ‘sliding scale’ standards endorsed by an increasing number of countries, and standards that adopt approaches with greater emphasis on scrap recycling.
- **Credit systems based on the mass balancing approach**, whereby producers re-allocate incremental avoided emissions to claim low or near-zero emission steel. By rewarding investments in incremental efficiencies in BF-BOF steel production, this could delay the necessary investment in new clean steel production plants.

Innovations that the group saw as having potential to be either H2+ or H2- included:

- **Increasing tariffs on steel,** which could be either a targeted sectoral policy or part of a more geopolitically-driven trade agenda. If applied in an unpredictable way, increased tariffs could reduce international steel trade, create uncertainty, reduce competition, and

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[25] Global Energy Monitor. (2025). Still digging 2025: Tracking global coal mine proposals.
[26] Fortescue. (2025). Fortescue and TISCO join forces on green ironmaking technology trial.
[27] Federal Ministry of Economic Affairs and Energy. (2023). Commencement of construction of the first green iron plant in Africa.

impact profitability, reducing industry confidence in investment in new steel facilities (H2-). Alternatively, tariffs applied fairly and transparently could insulate producers from the economic effects of global excess capacity and support the business case for investment in new technologies (H2+).

Policies

Actions and innovations identified by the group as likely to drive towards the shared vision (H2+) included:

- Investment and other policies to **expand electricity grids**, reduce the cost of clean power, and speed up new grid connections. These can improve the competitiveness of electricity-based steelmaking technologies.
- **Public procurement policies** to create guaranteed demand for low and near-zero emission steel in public construction and infrastructure projects.
- **Long-term clean steel production subsidies,** to level the cost of near-zero emission primary steel production and conventional production methods. Early examples of this include the carbon contracts for difference scheme in Germany, and the loans, grants and tax credits provided by the previous US government under the Inflation Reduction Act.
- **Near-zero emission production mandates and credit schemes,** to require and enable production of low-emission and near-zero emission steel and increasingly restrict the production of higher emission steel. A mandate could be complemented with a credit swapping or purchasing scheme, where producers who do not produce enough low-emission steel must buy permits from those who do.
- Government support for **demonstration and commercialisation projects**, alongside funding for **research and development**. This can help to bring the next wave of near-zero emission steel technologies to the market.
- **Preferential permitting for clean steel projects,** to accelerate their development. This could include exemptions from local restrictions on steel production capacity additions where these exist (as in China).

Innovations that the group saw as likely to sustain the dominant system of steel production (H2-) included any policy incentives for the use of the technologies identified above as H2-, such as hydrogen or biomass injection into blast furnaces. The group also noted the possibility (and in the US, current reality) of policies deliberately designed to oppose the transition. These include reversing policies that support the steel transition, cuts to innovation spending on industry decarbonisation, and policies and subsidies to promote fossil fuels use, such as assigning metallurgical coal with critical mineral status and providing subsidies for its production.

Actions and innovations whose H2+ or H2- status was debated by the group included:

- **Carbon pricing.** High carbon prices could raise the cost of high-emission steel, create long-term signals on future costs of emitting, and when complemented with other policies, contribute to enabling the deployment of near-zero emission steel technologies (H2+). Alternatively, low carbon prices could create the perception of policy action while incentivising only marginal change, delaying the introduction of other policies needed to enable investment in near-zero emission technologies.
- **Diplomacy through the United Nations Framework Convention on Climate Change.** This process plays a role in reinforcing international commitment to act on climate change, which may translate into mobilising government, industry and civil society efforts to accelerate the steel sector's transition (H2+). Alternatively, by absorbing political capital without focusing on the practical problems of implementation, the existing process of negotiations can be seen as a distraction from the kind of diplomacy that is needed in the steel sector (H2-).

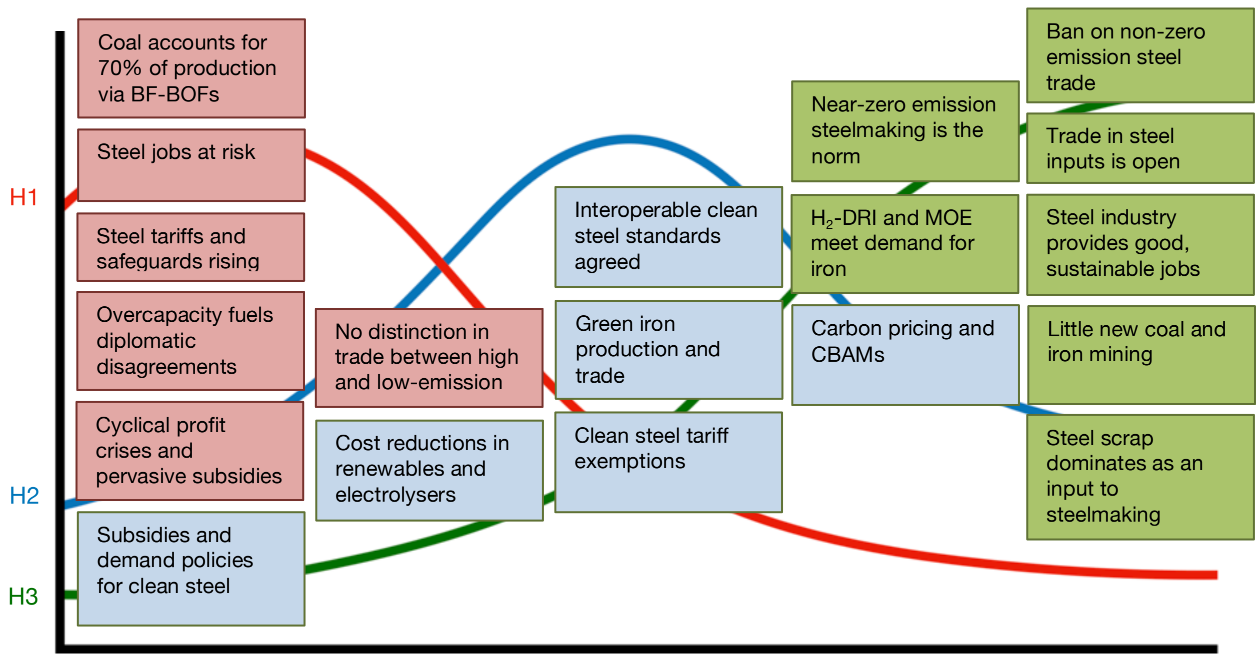
- **Prioritisation of national security concerns in policymaking on the steel industry.** This could drive government interest in maintaining a strong and sustainable steel industry, and a proactive approach to international partnership (H2+) or could lead to the shoring up of less efficient industry and an overly conservative approach to diplomacy (H2-).

Shared perspectives on the potential for change

The classification of actions and innovations as either H2+ or H2- involved more uncertainty and debate than the descriptions of the H1 and H3 systems. However, as in the previous sessions, differences of opinion existed between individual participants but were not clearly apparent between the groups from the three regions.

In relation to technology and industrial structure, participants were most aligned in their views of the strongest forms of transformative innovation. The deployment of near-zero emission technologies would change the underlying structure of the energy system rather than achieve marginal efficiencies in the existing system. Similarly, the rise of new green-iron producers in regions with abundant renewable energy resources could disrupt the structure of the global industry, and accelerate the transition. In contrast, the potential for technologies such as CCS and natural gas DRI to be either transformative or sustaining innovations was seen as uncertain, and as depending strongly on the context of their use. There was also a shared concern that the expansion of blast furnace capacity and metallurgical coal mining to meet demand in rapidly industrialising countries could reinforce the incumbent system.

On policy and trade, it was notable that many of governments' current actions are those considered by participants either as H2- or as uncertain (H2+/-). These include carbon pricing at low levels, diplomacy through the UNFCCC, a proliferation of competing standards, and general increases in steel tariffs. Much less activity is currently focused on some of the actions participants identified as having transformative innovation potential (H2+), such as near-zero emission steel production subsidies, production mandates and credit schemes, public procurement of near-zero emission steel, differentiated tariffs for clean steel, and green iron trade.



Summary of the Three horizons map produced by Chinese, US and European steel experts, showing H1, H2+ and H3 factors.

International cooperation to accelerate the transition

In the final section of the workshop, participants discussed the scope for international collaboration to strengthen the transformative innovations (H2+) that they felt had most potential to accelerate the transition. Six areas of transformative innovation were discussed: carbon pricing and carbon border adjustment mechanisms; clean steel subsidies; green iron trade agreements; tariff exemptions for clean steel; and cost reductions in renewable power and electrolysers. In each of these areas, participants identified options for international cooperation and categorised those options as either ‘no-brainers’ (low risk, but limited impact), ‘creative actions’ (more difficult, but higher impact), or ‘game-changers’ (highly difficult but potentially consistent with the international community’s stated goals for avoiding dangerous climate change).

The purpose was not to investigate these options in detail, but to generate an understanding of the range of possibilities, which could inform the development of an agenda for an intergovernmental dialogue on the global steel transition.

This section summarises these discussions and the ideas and actions explored.

Carbon pricing and carbon border adjustment mechanisms

Carbon pricing and carbon border adjustment mechanisms were considered as potentially transformative policies to support the transition, although, as noted above, there was debate among the group on this point. Views differed on the effectiveness of these policies, which would depend on the level of carbon pricing set. Participants questioned the political feasibility of raising carbon prices to the level needed to close the cost gap between conventional and near-zero emission production routes in the near-term. The EU’s delayed phasing-out of free allowances (which exempt producers from the carbon price) due to industry lobbying was given as an example of this.

Participants also found it difficult to identify how international coordination of carbon prices and CBAMs would work in practice, given divergent national approaches. The United States was seen as very unlikely to adopt carbon pricing in the foreseeable future, while China‘s carbon price was expected to be set at a level much lower than the EU’s for some time. Participants were unclear how interoperability could be achieved given differences in system design. While the EU CBAM was the first of its kind, it was not designed collaboratively with international partners. It has also been criticised by emerging and developing economies on equity grounds. Participants agreed that while establishing a common carbon price at a sufficient level to make clean steel competitive would be a ‘game-changer’, it was unlikely to be achieved in the near-term.

In this context, participants instead discussed what practical steps countries could take to enhance cooperation on the interoperability and effectiveness of countries’ national carbon pricing systems. Several ‘no brainer’ options were identified. These included:

- Establishing an international dialogue to align on carbon accounting methodologies. This was seen as potentially relevant even for countries that are sceptical of the transition, as there could be value in benchmarking their industries’ emissions against others.

- Improving countries' understanding and recognition of each other's national carbon pricing systems. This could streamline administrative burdens for industry and could be supported by businesses.
- Developing an open platform for measuring, reporting and verifying emissions data, learning from initiatives such as open banking[28]. This could be backed by a system of independent collection and verification of data.

Using a share of CBAM revenues from developed countries to contribute to funding the deployment of near-zero emission steel technologies in developing countries was identified as a 'creative action'. This could be coordinated through a collective investment fund, and could build trust by addressing equity concerns, as well as having direct practical benefits. Another 'creative action' identified was the agreement of principles for effective carbon pricing, addressing issues such as the potential need for an appropriate carbon floor price.

Clean steel subsidies

Subsidies were identified as a transformative policy because they can directly support the deployment of near-zero emission steel production technologies and bring down their costs, making near-zero emission steel competitive with conventional steel. Participants agreed that subsidies would be likely to be necessary in most countries, at least early in the transition. However, experience in other sectors has shown that clean technology subsidies can generate trade tensions and disputes. Zero emission vehicles were given as one example of this, where 'buy local' provisions in the United States have been disputed by the EU and others, while China has faced increased tariffs from the EU and US in response to what those governments perceive as its unfair subsidies.[29]

Participants suggested that an international agreement on the acceptable levels of subsidies for clean steel technologies or the process for awarding them could reduce the risks of trade disputes and support the transition. This was seen as a 'game-changer' option. An alternative 'game-changer' proposal was for countries to agree a peace clause on clean steel subsidies within the World Trade Organisation (an arrangement where WTO members agree to a time-limited and conditional moratorium on the use of dispute settlement procedures on a particular issue). This could include a time-limit or a cap on the amount of near-zero emission steel eligible to be subsidised. Either of these game-changer options would need to be accompanied by commitments on transparency. Participants proposed joint discussions between industry, trade and finance ministries to explore these options. Discussions could start with a consideration of the first commercial-scale near-zero emission steel projects being launched in China and the EU, the levels of support required to make those projects commercially viable, and the question of which technologies would qualify for support.

The main political barriers to an agreement on clean steel subsidies were identified as differences of view on the scale of subsidies that would be acceptable, and reluctance to provide full transparency around the subsidies given. Evidence suggests that non-OECD countries already provide subsidies for conventional steel production at much higher levels than OECD countries[30], making agreement difficult. Transparency was seen as particularly difficult in less open political systems. Disagreements could also arise over which technologies qualify for subsidies, including scrap recycling versus primary steel production technologies.

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[28] https://www.openbanking.org.uk/
[29] European Commission. (2024). EU Commission imposes countervailing duties on imports of battery electric vehicles (BEVs) from China.
[30] OECD. (2023). Subsidies to the steel industry.

Participants identified ‘no-brainer’ options including an agreement among governments to phase out fossil fuel subsidies along the steelmaking value chain and repurpose these for clean steel technologies; an agreement on which production routes qualified as near-zero emission; and the increased provision of development finance for industrial decarbonisation. ‘Creative actions’ identified included coordinated implementation of subsidies or regulatory policies in steel-using sectors such as automotive manufacturing or construction, to create demand for near-zero emission steel.

Green iron trade agreements

Participants agreed that green iron trade was a key area of opportunity for international cooperation. A ‘game-changer’ option would be an internationally funded platform that used double-sided auctions to match suppliers and buyers of green iron, establishing long-term contracts at agreed prices. This could help mobilise investment in green iron production by closing the cost gap to conventional iron production, and by aggregating demand.

As a more practical and near-term ‘creative action’, participants proposed an international producer and consumer dialogue on green iron trade, including countries such as Australia, Brazil, the EU, and China. This could focus on agreeing a common definition of ‘green iron’ along with interoperable standards and emissions measurement and verification systems, and on exploring the potential for bilateral or plurilateral green iron offtake agreements. Bilateral green iron offtake agreements were themselves identified as a ‘creative action’, with participants noting that the first such agreements would be particularly valuable to build confidence and demonstrate proof of concept. A dialogue on green iron trade could also address related barriers, such as obstacles to the licensing of technologies needed for green iron production in developing countries.

Participants noted that the difficulties involved in establishing a dialogue on green iron agreements could include security concerns as well as competitiveness concerns, given that steel is considered a strategic and foundational industry in many countries.

A ‘no-brainer’ option identified was that major donor countries to the multilateral development banks could provide greater support for investment in green hydrogen and steelmaking technologies and associated infrastructure, to support sustainable development and encourage new producers of green iron to enter the market.

Interoperable standards

All participants identified interoperable standards as important to advancing the transition. Common definitions of ‘low-emission’ or ‘near-zero emission’ steel, along with agreed measurement standards and reporting processes, will be essential to differentiate these products from conventional steel. While domestic approaches can differ, cross-border trade will depend on interoperability.

Participants agreed that advancing discussions among a group of countries willing to adopt mutually recognised standards was a key priority. The need for these discussions was a ‘no-brainer’; the achievement of mutual recognition among countries collectively accounting for a large share of the global market would be a ‘game-changer’. The group could be new, or formed within an existing initiative. The EU and China were seen as likely to be central to such discussions. Already, progress on interoperability is being made by industry associations and civil society in these regions, as reflected in recent agreements involving the Chinese Iron and Steel Association, ResponsibleSteel and LESS (supported by the German Government).[31]

Participants agreed that a dialogue would need to address both high-level principles of definitions, and detailed technical measurement methodologies. It could assess the viability of different standards, considering their scope, stringency and treatment of scrap. In the medium term, an international body that can verify and investigate claims of compliance with standards would also be needed.

The main political challenge likely to arise was disagreement on what qualifies as near-zero emission or low-emission steel, including emissions boundaries and scrap thresholds. Countries with high levels of scrap-EAF steel production are likely to advocate measures that give preference to scrap-recycling over primary near-zero emission production. Others might advocate measures that reward marginal efficiency improvements, to avoid the more difficult challenge of deploying new technologies.

Tariff exemptions

Tariff exemptions for low or near-zero emission steel were seen by the group as a potentially transformative innovation. Differentiating tariffs based on the emissions or technology used in production could give near-zero emission steel an advantage in international trade if used together with appropriate domestic deployment policies.

Participants agreed that applying a plurilaterally agreed tariff exemption to near-zero emission steel globally in compliance with World Trade Organisation rules would be a ‘game-changer’. This would mean the tariff exemption being agreed among a group of countries, but made available to all countries. Alternatively, ‘creative options’ could include clean steel tariff exemptions being written into free trade agreements or explored in relation to bilateral trade and investment partnerships. An alternative to differentiating tariff levels would be a shift to differentiated tariff rate quotas based on emissions performance. Any such arrangements could be underpinned by a joint monitoring, reporting and verification system.

Participants saw considerable political challenges in this approach. How to tackle overcapacity in the steel industry is a key area of disagreement among countries at present, with diplomacy on this issue between China and OECD countries being particularly difficult. Tariffs and steel safeguard measures are increasingly being applied by many countries, some of which specifically target Chinese steel products. While agreements on clean steel tariff exemptions could be discussed separately to the issue of overcapacity in conventional steel production, some countries may seek to link these issues.

Renewable power and electrolyser cost reductions

Scaling up the deployment of renewable power and electrolysers was seen as an important area for international cooperation. The costs of these technologies are central to the business case for steel produced using hydrogen direct reduction of iron, and scaling up their deployment drives learning and cost reduction.

Participants agreed on the value of trade liberalisation for renewable energy systems components and electrolysers. Lower tariff and non-tariff barriers could enable cheaper and faster deployment.

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[31] ResponsibleSteel. (2025). *Landmark agreements link majority of world’s steel production under global and regional standards for low-emission steel.*

Disputes around local content requirements, overproduction and subsidies currently exist between China, Europe, the US and India.[32] An agreement in which China relaxes controls on the export of critical minerals while the EU and US relaxes restrictions on relevant inward Chinese investment was seen as a potential 'game-changer', but would involve obvious political difficulties.

Participants identified cooperation between major economies such as the EU and China on investment in developing countries' clean energy infrastructure, manufacturing and supply chains as an area of 'creative action'. This could include clean power systems and electrolyser manufacturing. Participants also discussed the potential for constructive approaches to managing intellectual property for critical technologies, for example by considering compulsory licensing in developing countries (where local firms are permitted to produce a patented technology in exchange for a fee).

'No-brainer' options identified included cooperation on research, development and demonstration of clean technologies, cooperation on renewable energy component recycling, and knowledge exchange between countries on energy system planning and the integration of energy and demand side management (a form of cooperation that is already common).

Scope for more constructive international dialogue

The diverse array of options identified by participants suggests that there is considerable scope for a more substantial discussion of international cooperation on the steel transition than is currently being held between major steel-producing countries in any international forum. Diplomacy could usefully focus on the range of H2+ actions, since these are most aligned with the shared goal of achieving a global transition to a near-zero emission steel sector. This can complement diplomatic efforts that are concerned with managing the problems of the H1 system, such as overcapacity in conventional steel production.

The classification of options into three categories gives a rough indication of how diplomacy on the transition could progress. It would not be realistic to expect any 'game-changing' options to be agreed quickly, but neither would it be helpful to limit dialogue only to options that are uncontroversial but low-impact. Engagement on 'no-brainer' options can be used to build trust, and on several of these options, international talks are already taking place. Discussion of 'creative actions' could be a useful focus of diplomacy in the near-term. 'Game-changer' options could benefit from serious consideration and research, and could be introduced into dialogue among small groups of countries initially to better understand the challenges to their achievability.

[32] Reuters. (2025). China files WTO case against Indian tariffs, subsidies.

4 Conclusions and implications for policy

Conclusions and implications for policy

This project set out to explore how policymakers in China, the European Union, and the United States see the iron and steel sector's transition unfolding, to highlight uncertainties and the possibility of different futures, and to assess the scope for international collaboration. This section of the report summarises conclusions following interviews, regional scenario exercises, and a three-way country dialogue with policymakers in London.

The speed and success of the steel sector's transition in any country depends not only on domestic policy, but also on trade policy and diplomacy. Interviews with policymakers show that while each country faces a range of different uncertainties domestically in its steel transition, a common set of uncertainties emerges at the international level. The openness of future trade in iron and steel, global demand for low and near-zero emission steel, the interoperability of standards, trade and diplomatic relations between countries, and the speed at which others move to new technologies all have a bearing on a country's transition. This implies that trade policy and diplomacy should be central elements of national steel transition strategies.

High international collaboration scenarios are likely to deliver preferable outcomes for industry and a faster transition. Scenario exercises conducted with policymakers in each region suggest that international cooperation could significantly influence how the transition plays out, particularly by creating larger demand for near-zero emission steel, incentivising investment, and reducing first-mover risks. As a result, most participants in the EU and US and about half the participants in China saw scenarios involving greater international cooperation as the best for their country's industry, and participants in all three regions saw these scenarios as most beneficial for the global transition. This did not necessarily mean multilateral cooperation; plurilateral cooperation and strategic alliances were also imagined. In contrast, scenarios with a low level of international cooperation see the transition progress more slowly, and countries attempting to decarbonise their steel industries face higher costs and risks.

There is a need for greater clarity in countries' international strategies for the transition. The scenarios currently being planned for by policymakers are not clearly those that involve a high degree of international cooperation. Despite the perceived benefits of scenarios with high levels of international cooperation, only around half the participants in China and the EU saw these scenarios as closest to the future that policymakers were planning for. The other half of participants in those regions believed their governments were planning for scenarios in which they attempt the transition in a context of minimal cooperation. In the US, the transition was largely expected to stall due to a lack of domestic policy, and no participants saw a scenario in which the US engaged in international cooperation as the most likely.

Policymakers from the three regions largely share a common diagnosis of the problems with today's steel industry. Industry in all three regions faces higher costs of clean steel technologies, insufficient existing policies to support the transition, and no differentiation between high and low-emission steel in international trade. Overcapacity, subsidies for the existing industry, and political sensitivity to job losses in the sector were also recognised as factors that increased the difficulty of the transition in all regions. This suggests common interests in overcoming these challenges exist, alongside countries' competing interests in maximising their respective market shares.

The long-term vision for the steel sector is remarkably similar across countries. Many of the characteristics of the future vision for the steel industry outlined in this project were shared by participants from different regions. Steel production would be dominated by scrap recycling, with the remaining share of demand met by primary steel produced through technologies such as hydrogen direct reduced iron or molten oxide electrolysis. Trade would be made up entirely of near-zero emission steel, with inputs to the steel production process traded openly. Tariffs would still be used on steel itself, in line with national interests, but managed by a robust system of trade dispute resolution. This suggests there is little need for diplomacy to focus on debating the goal, and greater value in focusing on the practical steps to enable change in this direction.

The policies and pathways needed to achieve this long-term vision involve systems change, rather than incremental emissions reduction. Participants viewed the move to near-zero emission technologies, particularly hydrogen direct reduction, as the central route for the global transition, alongside increased recycling. Policies that contribute to directly introducing these technologies were seen as having the most transformative potential. In contrast, policies and technologies that only partially reduce emissions could inadvertently extend the life of the current high-emitting system of steel production. Participants also recognised the need to address risks that could undermine progress, including persistent global overcapacity, regional employment impacts, political backlash against climate policy, and technological lock-in through transitional investments that extend the life of high-emission assets.

There is scope for a more substantial discussion of international cooperation on the steel transition than is currently taking place among major steel-producing countries. Participants identified multiple opportunities for international cooperation to strengthen transformative drivers of the steel transition, while recognising that none are free of political difficulty. Interoperable standards emerged as an essential area for cooperation, with common definitions of low and near-zero emission steel foundational for many other policies. Green iron trade agreements could reduce costs and accelerate the global deployment of near-zero emission steelmaking technologies. Options for cooperation on carbon pricing and CBAMs, clean steel subsidies, regulatory policies to create demand, and clean steel tariff exemptions were all seen as worth exploring, despite each involving its own challenges. Cooperation on wider areas, such as renewable power and electrolyser deployment, could also support the transition.

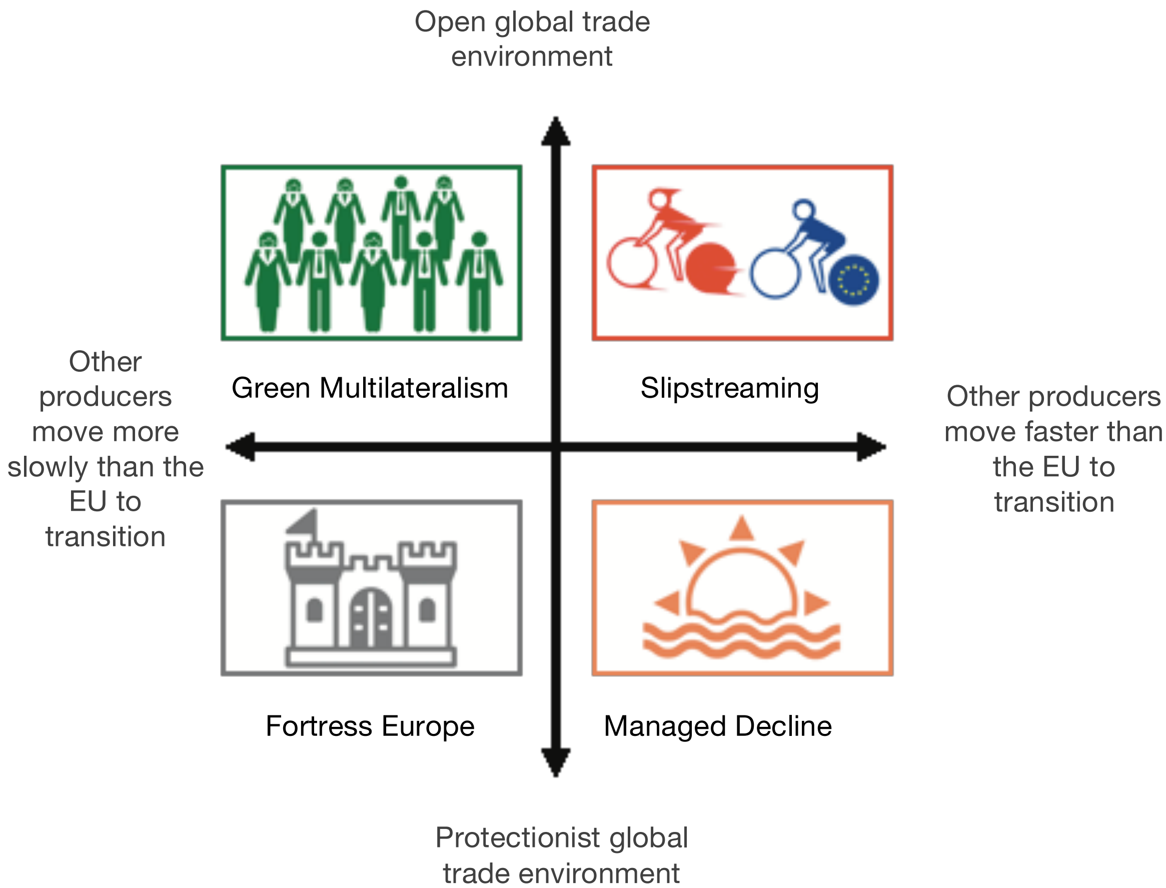
The core political challenge is aligning policy to direct competition towards the development of a near-zero emission steel industry. Steel is widely viewed as a strategic industry, and concerns around competitiveness, national security, and regional employment shape governments’ policymaking in the sector domestically and internationally. These concerns are unlikely to change in the near future. The central challenge for international cooperation is to identify pathways forward that are consistent with these national interests, aligning competition in global markets with the shared objective of developing a near-zero emission steel sector instead of with the preservation of an industry dependent on high-emitting technologies.

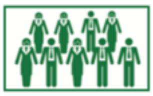
Appendix A: Narrative scenarios for the European Union

Scenarios for the global steel transition

s-curve economics

Appendix A: Narrative scenarios for the European Union





Green Multilateralism

Green Multilateralism describes a future where the global trade environment is open and where other producers move more slowly than the EU to transition to low carbon steel production.

Europe's steel industry has emerged as a market leader in low-carbon production. The EU has reached agreements with other major countries to ensure a level playing field for clean steel in international trade and its steel producers have become premium suppliers in a global market that increasingly values carbon credentials, traceability and regulatory certainty.

A convergence of interests

In the mid 2020s, the EU pushed ahead with steel decarbonisation in a bid to meet its climate targets and show the rest of the world what was possible. With the US dropping out of the clean energy technology race, the EU doubled down on its ambition to meet its climate goals and improve its industrial competitiveness, with the aim that it could compete with China in future.

Europe's leadership initially created risks to the competitiveness of its own industry. As free allowances were wound down within the EU Emissions Trading System, the industry shouldered an increasing cost from carbon prices. The Carbon Border Adjustment Mechanism proved to be a weak defence: some overseas producers circumvented it by 'resource shuffling' (selling recycled steel to Europe and high-emission steel elsewhere); others by moving up the value chain and selling products made from steel that were not caught by the mechanism. Meanwhile, without any rebate of carbon pricing for exports, European steel was uncompetitive in overseas markets.

Faced with this risk, the EU shifted the focus of its domestic policies from carbon pricing to clean steel subsidies and demand creation. Existing clean steel plants had already received large amounts of public investment and the EU did not want to see these become 'green stranded assets'. It also radically revised its international approach: instead of leading by example and hoping others would follow, it began engaging in active diplomacy with the aim of establishing a level playing field for clean steel in international trade and creating new green iron supply chains to improve the EU's competitiveness.

Negotiations were tough, but gradually a convergence of interests emerged. China believed it could eventually surpass the EU in clean steel technology, given the huge resources of its steel industry. So did Brazil, due to its abundant iron ore and low-cost renewable energy. India, Japan, and South Korea had interests in energy security that aligned with the transition and wanted to retain access to the European market. The USA, fearful of being left out, joined the negotiations in 2028.

Floods, heat waves, droughts and fires continued with unprecedented ferocity during the late 2020s. The Intergovernmental Panel on Climate Change's sixth assessment report issued a stark warning that the window of opportunity to secure a liveable and sustainable future for all was closing rapidly. Its seventh assessment report, published in 2029, presented evidence that the jump in global temperatures in the mid 2020s was not an anomaly and that permafrost thaw, sea-ice melt, and other feedbacks were now driving a faster rate of warming.

As most countries had either failed to align their Nationally Determined Contributions (NDCs) with the Paris agreement goals or failed to align their policies with their emissions targets, support grew for focusing climate change diplomacy on practical cooperation.

The key measure of success

In 2030, the EU, China, India, Brazil, Japan, Korea and the USA – seven jurisdictions accounting for 80% of global steel production – signed the Comprehensive Agreement on Steel Trade and the Transition. This set out common guidelines on clean steel subsidies, reciprocal tariff reductions for near-zero emission primary steel, common definitions and standards, and a system to ensure transparency in production processes and traceability of steel products.

The Agreement finally aligned the forces of competition and trade with the transition to clean steel. Investment in hydrogen DRI steel plants surged globally.

Staying ahead

The EU's massive investment in clean power generation and distribution in the late 20s and early 30s, enabled by strong and consistent political support and funded by public-private partnership, has tripled Europe's renewable power capacity, modernised its electricity grids and storage infrastructure. The EU super-grid ensures all member states have access to clean, low carbon energy.

The hydrogen backbone which now links low-cost iron production in Spain, Portugal, the North Sea, and Eastern Europe to demand centres in Germany, Benelux, Poland and elsewhere has dropped the cost of hydrogen and green DRI production, increased its availability and led to a restructured but more efficient and competitive steel value chain in Europe.

A global leader

Even despite restructuring, Europe's steel industry still requires more low-cost, green iron than it can produce domestically. EU Member States and Europe's steel producers have therefore built strong and trusted partnerships with countries that produce and export green iron cheaply - such as South Africa, Brazil and Australia - supporting these bilateral offtake agreements initially with government subsidies. They have increased the use of scrap steel in production, aided by strong policy measures that require product design to facilitate recycling and reuse of materials. Europe has also been able to remain open in its trade relationships due to its improved competitiveness globally and has avoided policies such as scrap export bans that would hinder the transition in other countries. As a result, interests in the transition have spread globally.

Blast furnaces have been gradually phased out without need for any strong regulation. Today, nearly 75% of EU crude steel is produced using hydrogen-based direct reduced iron and electric arc furnaces powered by renewable electricity.

The European industry is in a strong place. It has adapted to changing circumstances quickly and, by doing so, has moved ahead of the competition. It has invested in the technology required to make the transition and in the skills, processes and industry relationships to sustain it.

It is today a global leader in premium low-carbon steel, supplying materials to electric vehicle platforms in North America, to offshore wind farms in Southeast Asia, and to infrastructure development projects across Africa. Europe has improved its industrial standing, and used its leadership and diplomacy to put the global steel sector well on its way towards decarbonisation.

Fortress Europe

Fortress Europe describes a future where the global trade environment is protectionist and other producers move more slowly than the EU to transition to low carbon steel production.

Europe has not abandoned decarbonisation — but it *has* narrowed its focus. Faced with rising geopolitical volatility and uneven global willingness to address climate change, EU policymakers have chosen to defend the integrity of their domestic green transition rather than gamble on global alignment. Steel production has transitioned to low carbon processes protected by high tariffs, but output has fallen and is focussed on the domestic market.

The great unravelling

The world began its journey towards full-blown protectionism in the mid 2020s with the introduction of increased tariffs between the United States, China and other nations.

What started out – in some observers' eyes at least – as political posturing quickly escalated into an all-out trade war as the US sought to protect its manufacturing base by increasing tariffs for (it seemed at the time) everything, everywhere, all at once. China responded with export restrictions on critical minerals required for the manufacture of cars, semiconductors and weapons. The World Trade Organisation (WTO), hindered by America's continued belief that it acted against US interests, was powerless to intervene.

Multilateralism eroded as trading partners aligned with one or other side. High tariffs and technology export controls were used to restrict access to the clean technologies that could support the transition if they were not produced or manufactured locally. Rare earths were, at best, costly and at worst, not for sale.

The post-Cold War vision of an integrated, cooperative global economy unravelled and was replaced by an adversarial, politically constrained global system in which trust, transparency and open access had melted away.

Cooperation on climate change fared no better. Action remained almost entirely unilateral. While a populist US administration opposed the transition on ideological grounds, large emerging economies saw steel decarbonisation as too costly and risky due to weak global demand for clean steel products and did little more than impose nominal carbon prices that were token gestures towards the transition.

For European policy makers – still with high ambition around climate change – the implications were clear: Europe could not rely on global markets to be conducive to decarbonisation and would have to do the hard work on its own. Trade defences and tariffs would be necessary to prevent the EU's steel industry from being undercut whilst it transitioned. If Europe was to both reach net zero and retain strategic control over the materials and technologies underpinning the transition, it would have to internalise the risk, invest in technology development and drive change forwards as fast as it could.

How far that change might go was uncertain. To say the least.

No time to lose

There was no time to lose and Brussels moved swiftly with a raft of pragmatic internally-focussed policies - the European Green Industrial Compact - to catalyse decarbonisation. Chief among these were carbon contracts for difference (CCfDs), financial instruments designed to limit risk in long-term investments in clean hydrogen and low-carbon steel production. These policies effectively guaranteed a minimum carbon price to industrial producers adopting green technologies, unlocking a wave of investment in hydrogen-based steel production.

The Carbon Border Adjustment Mechanism (CBAM), originally an emissions-based tariff, was extended beyond goods to cover a wider range of industrial inputs, deepened to include embedded emissions across value chains, and bolstered by additional tariffs and safeguards. The primary ambition - to protect European producers as they decarbonised – proved largely successful, but only at the cost of significantly constraining trade between Europe and the rest of the world.

These protective measures were not, however, applied indiscriminately. Europe used them strategically and succeeded in negotiating special terms for critical supply lines such as iron ore from Australia, Brazil and Canada.

EU member states — often slow to act in concert — pulled together in the face of an external hostile environment to coordinate subsidies, regulatory frameworks and just transition programmes across the bloc. Investment rose.

Less production, lower output, lower carbon... but for what?

The EU produces less steel in 2035 than it did a decade ago — but over half is produced by low carbon processes. Production is centred in the Nordic countries and Iberia and supported by manufacturing in Central and Eastern Europe. Legacy blast furnaces have been phased out or converted, and electric arc furnaces — powered by renewables or fed with clean hydrogen iron — dominate the production landscape. Scrap recycling has been restructured around new internal collection and processing networks.

Exports are limited, of course. The rest of the world has no desire for expensive low-carbon European steel, and in any case, other countries have reacted to the EU's CBAM and tariffs with import controls of their own. Instead, European steel flows into domestic infrastructure, automotive and defence procurement pipelines, supported by national industrial policies that emphasise local content, security of supply and emissions compliance.

A difficult hand

Geopolitics has dealt the EU a difficult hand – and in some ways it has played it well. Its industrial strategy aims to restore sovereign production capacity, reduce dependence on volatile international markets, and ensure that green materials are available to strategic sectors without the need to rely on imports from countries with weaker climate standards.

It is working so far, at least for the European industry. But there are dark clouds on the horizon. Not everyone celebrates the EU's continued pursuit of net zero in isolation from other, worse, emitters. Since global emissions remain high, the EU's strategic objective of limiting climate change risks has not been achieved, and critics like to ask what the point of the EU's unilateral decarbonisation has been.

Global steel emissions continue to rise. Continuing global tensions continue to affect global resource security. Relations with other steel making countries and with energy suppliers are worsening. The lack of export opportunities (in steel and elsewhere in the economy) continue to constrain trade and returns on investment.

The strategy appears politically secure for now. The big question, though, is which way those dark clouds are moving. And how fast.

Managed Decline

Managed Decline describes a future where the global trade environment is protectionist and where other producers move faster than the EU to transition to low carbon steel production.

Other regions have taken advantage of abundant low-cost renewable power to stake out leadership positions in clean steel and have put up their own trade barriers to prevent imports of high-emission steel. Europe has struggled to follow due to inefficiency, limited investment and uneven standards, which have ensured the sector's strategic vulnerability. Europe still has a steel industry, but largely due to political intervention rather than industrial transformation.

Challenging times

The early 2020s were a challenging time for Europe.

Russia's war on Ukraine created instability and deep uncertainty about how to secure peace on Europe's borders. The Israel-Gaza conflict led to rising tensions in the Middle East and disruption of global oil markets. Hostile cyberattacks exploited vulnerabilities in critical infrastructure. Global migration rose dramatically, driven by climate change, regional conflicts and economic failure in Africa and the Middle East. In 2025, the Doomsday clock moved forward to 89 seconds before midnight – the closest (at that time) it had ever been.

Faced with such uncertainty – and a fractured NATO alliance - Europe's governments had little choice but to increase spending on defence and security. To this day, defence continues to attract more funding and more talent than other sectors.

The early 2020s were challenging at home, too. Green policies became politically contentious as populations became concerned that the economic advantages were flowing to other countries. Rising unemployment caused by AI and automation sparked anger and protest from a labour force that claimed employers were more concerned with profit than with social responsibility. Structural problems - such as the growing pension and health burden caused by the ageing population and the growing skills shortages in key economic sectors - were serious concerns that regional governments struggled to address.

Europe could perhaps have overcome these challenges if member states had agreed a coordinated response - but faced with political fragmentation and populist pressures at home they chose to revert to national-level social and industrial policies.

Competitive manoeuvring

They weren't alone. As governments across the world focussed on putting their own houses in order, international relationships began to weaken. Rather than working through challenges together, the larger, more powerful global actors began to act as disruptors, changing quotas and tariffs - without negotiation – to enhance their own competitiveness and preferring to maintain the *status quo* of a contested and unregulated trade system rather than seek its resolution. It was an effective strategy that played well with domestic audiences.

Steel was an early casualty of Europe's fragmentation. Other major producers, notably those in China and the Middle East, took advantage of abundant low-cost renewable power and the EU's relinquishing of leadership to establish highly competitive clean steel production. They used subsidies to avoid any risks to competitiveness, enabling their industries to produce clean steel for export as well as for domestic consumption.

Meanwhile, the EU's efforts to invest in the clean power, hydrogen infrastructure, cross-border electricity grid upgrades and clean steel innovations it needed became snarled up in political disagreements between members states, regulatory disputes, drawn-out permitting processes and competitive lawsuits about what qualified for state aid.

The Commission's efforts to pull everything together were valiant but ultimately doomed. No matter what it did, one party always wanted – or objected to someone else's - exemptions and carve-outs. Moving forwards became practically unworkable. As a result, the EU's energy prices remained far higher than other countries, and open competition became a major risk.

Political leaders, eager to protect jobs, demanded state aid rules be relaxed and began to pour subsidies into their own industries - not to support decarbonisation, but to prevent mass closures. The strategy worked for the larger states. Smaller states were not so lucky.

The EU now finds itself with an ageing steel industry: partially decarbonised, heavily subsidised, and largely uncompetitive on global markets. Export volumes have collapsed. Domestic demand is met, but at inflated costs which means that strategic sectors such as automotive, defence and some manufacturing are losing competitiveness.

Delaying the inevitable

The impact on emissions has been stark. Delays in project permitting, hydrogen supply bottlenecks, and political resistance to plant closures have left the EU way off its decarbonisation trajectory.

Where once the EU feared 'carbon leakage' - an adverse effect on its industrial competitiveness arising from being a first-mover in the transition – it now finds itself dealing with late-mover risk. The relocation of investment is increasingly redistributing global steel production. Chinese producers have become even more dominant. Other multinational steel companies have shifted their investment towards the Middle East, India, and Southeast Asia. Several producers have shifted capital expenditure to the United States, enticed by generous subsidies maintained by Congress, anxious about jobs in their own states despite the gutting of other elements of the Inflation Reduction Act.

The steel industry remains important to the bloc's security and, for the time being, is protected by Europe's leaders. This is good in the short term, but it is an open secret that protection is only delaying the inevitable. The industry is now using outdated technology. Governments cannot subsidise production forever and the only strategic choice is whether to hold out for as long as possible or cut and run. Governments have chosen the former – for now - but the decision is under constant review.

In light of this, it is hardly surprising that the sector (despite being classed as a strategic industry) also sees innovation and skills development as a cost to be avoided. The number of jobs remains high, certainly, but the level of skill is declining and the efficiency and performance of the sector is, like its own future, in managed decline.

Slipstreaming

Slipstreaming describes a future where the global trade environment is open and other producers move faster than the EU to transition to low-carbon steel production.

The global steel industry is in the midst of structural transformation, driven by rapid innovation and cost declines in clean steel technologies. Europe has fallen behind, held back by strategic hesitation, disjointed national policies and slow execution. The sector has made the bold strategic decision to enter a licensing partnership with China to access the technological systems and services that Europe needs to decarbonise.

A wave of alignment

International trade relationships got a little rocky for a while during the mid 2020s – but what started out as sabre-rattling between major trade blocs soon settled down as world leaders took fright at the risks of inflation and financial instability.

China and the US – seeking to move on from a tariff war that neither really wanted or needed – agreed to stabilise tariffs at relatively low levels. Responding to the unpredictability of US policy, the EU, Mercosur, China, and the countries of the Trans-Pacific Partnership moved to secure deeper trade relationships with each other.

Meanwhile, rapid innovation transformed the landscape of industrial decarbonisation. Ongoing development of solar photovoltaics saw their costs continue to fall by 80% in a decade. Combined with breakthroughs in electrolyser chemistry, this led to green hydrogen DRI steelmaking becoming close to cost-competitive against blast furnaces and gas-DRI in the countries with the best solar resources, such as the Middle East, Brazil, and Australia, as well as China. Molten oxide electrolysis emerged as an even lower-cost steel production technology in the late 2020s, prompting a new wave of industrial restructuring, relocation and retirement of old assets.

Too much talk

At the policy level, the EU seemed ready to take advantage of the new regime. The European Green Deal had laid the groundwork, and early pilot projects in Sweden, Germany and Spain showed technical promise. But as global demand for low-carbon steel rose, Europe paused, caught up by bureaucracy - permitting delays and planning disputes slowed infrastructure rollout for hydrogen pipelines and renewable energy integration - and political disagreements about the right strategic approach - priorities for early action, timelines, technical standards, subsidies.

Investors, uncertain about long-term policy clarity, reallocated capital. “There was too much talk and too little action,” the head of one European infrastructure fund famously said at the time. “We needed deals and cheap power. So we moved on.”

Forging ahead

It wasn’t only the investors who moved on. So did some steel producers who, frustrated by the bloc’s failure to capture opportunity, shifted their focus to overseas markets. The few companies in Sweden, the Netherlands, and Germany that had developed early expertise in hydrogen-based DRI, electric arc furnace retrofits and digital traceability began to relocate production to the US and elsewhere. For them, the future looks good.

It's becoming less certain for those left behind. For some domestic manufacturers — particularly in the auto and appliance sectors — cheap, clean steel from abroad has boosted competitiveness and the decline of the EU’s steel sector is no great loss to them. Those with strong ties to legacy steelmakers are, however, more exposed as the sector continues to lose market share, investment appeal and political leverage. Europe’s lack of competitiveness in manufacturing clean technologies doesn’t help.

European governments increasingly see maintaining large-scale steel production in their countries as impossible and unnecessary, and most have chosen to embrace low-cost imports of low-emission materials and goods as an opportunity to increase productivity across the economy whilst meeting their climate goals.

The steel companies that remain believe they can operate in the new market conditions – those early decarbonisation pilots delivered proven results; Europe still has a (partial) hydrogen infrastructure in place; and, critically, it still has a highly skilled workforce – but they also know that they have to move quickly if they want to survive. They know, too, that Europe remains increasingly reliant on others' technology, having failed to invest in innovation itself.

And so, Europe's steel sector has made a bold decision to enter a licensing partnership with China to access the technological systems and services that it needs to produce competitive, high-quality zero-emission steel. It's a high risk strategy and it's not clear how it might play out. But it offers the potential reward of allowing European steelmaking to continue to supply small but high-value niche markets. The Chinese industry has the technical expertise that Europe needs and, in return, can be given increased access to the European market.

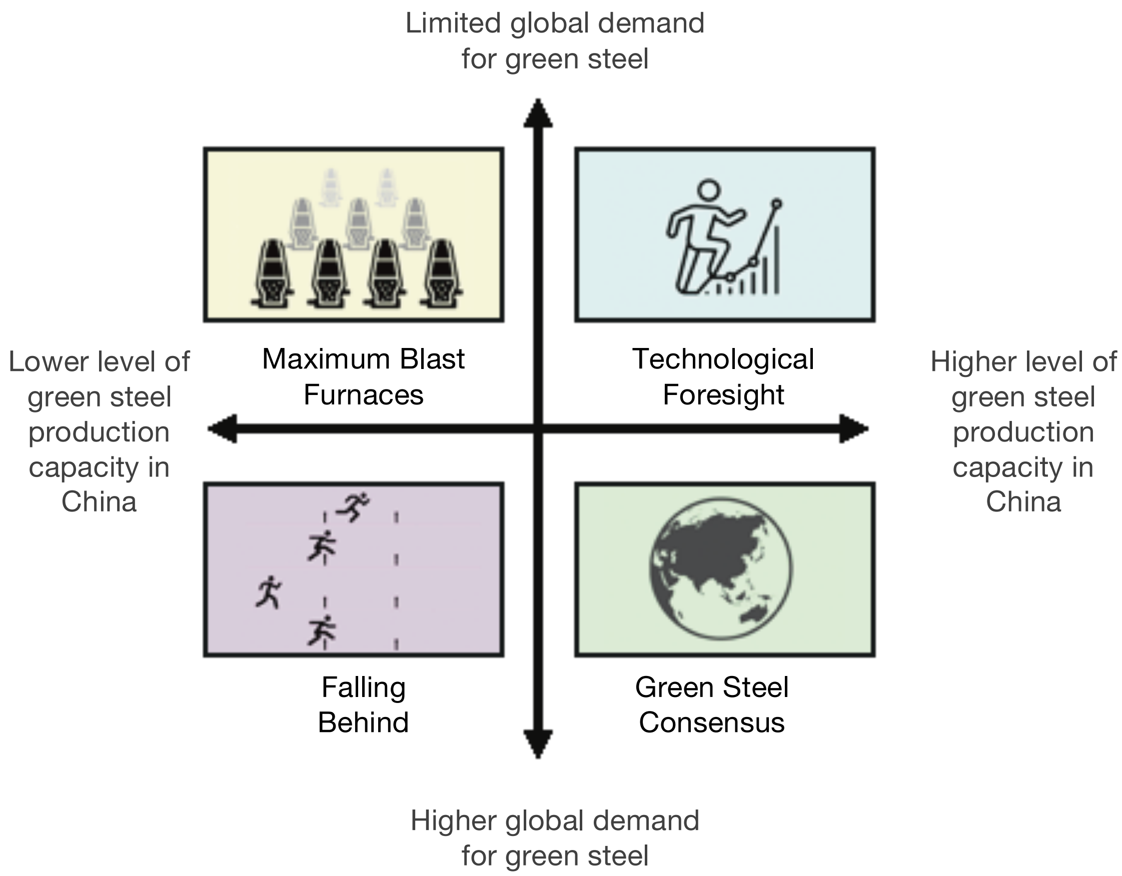
It might just work – but European governments need to put their disagreements aside and work alongside the industry to ensure that any deals remain fair.

Appendix B: Narrative scenarios for China

Scenarios for the global steel transition

s-curve economics

Appendix B: Narrative scenarios for China



Technological Foresight

Technological Foresight describes a future where global demand for low carbon steel is limited and green steel production in China is high.

The global effort to decarbonise energy-intensive industries has gained little momentum over the last decade. Political instability and economic uncertainty mean that many governments and industries are risk averse. Investment has fallen and planning is reactive.

There are exceptions. Some countries – including China - remain focussed on developing leadership in clean technologies. The pace of change is slower than was anticipated in the 2020s but they continue to press ahead.

The view from 2035

As China enters the Year of the Pig, the leaders of its steel companies are optimistic, but their optimism is tinged with frustration. As they mark the end of the New Year holiday, they feel that China has secured its future as the undisputed global leader in steel production. That it has done so is a testament to the wisdom and foresight of those leaders who decided a decade ago that China's future was best served not by waiting for global markets to demand green steel, but by acting in anticipation.

Their frustration is due to the fact that global demand for green steel remains low for now. That is not a threat to China's producers: they are able to serve the domestic market and prepared to wait until the current turbulence in foreign markets has settled down. But they have not yet been able to reap the rewards that they feel they are due, from years of patient development of new technologies, bold investments in new plants, and difficult structural change.

A challenging decade

The last ten years have not been easy for the global economy. The disruptive forces that were clearly visible at the start of 2025 – extreme weather events, energy shocks, debt overhang and rising job losses due to the adoption of AI – accelerated through the mid 2020s and left many countries struggling to respond. It quickly became clear that these were global challenges beyond the control of any individual nation state acting alone.

Instead of agreeing a way forward together, the advanced economies turned inwards to relieve domestic pressures. Some believed this to be a sub-optimal approach but were unable to secure the political leverage they needed to make difficult long term changes. Others believed that putting their own needs first was the only way to secure future prosperity.

Whatever the causes, the effects were the same: investor confidence hit an all-time low, growth stalled and national economic planning and policy making became increasingly short termist. Protectionism spread, with increasing disregard for international trade rules.

The developed economies were in firefighting mode and no-one, it seemed, had the vision or appetite to invest in the long term. Industrial transformation and green infrastructure development simply fell off the public agenda.

Preparing for the future

China was not immune to the economic headwinds, and suffered from slow growth as domestic demand faltered and its exports faced increasing barriers. While managing the short-term pressures, the government continued to invest strategically (if carefully) in new technologies, seeing this as the best way to secure long-term growth.

Green steel was high on China's agenda. Its ambition was to build on its industrial capabilities and market dominance and establish itself in pole position for the shift to green steel. It took a measured approach, building capacity steadily; both to ensure it remained on track to achieve its Dual Carbon Goal and to minimise the social cost of switching some capacity away from Blast Furnace-Basic Oxygen Furnace (BF-BOF) production.

The first stage of investment focussed on three key building blocks: developing large-scale hydrogen production capacity in strategically located industrial zones, expanding the national fleet of Electric Arc Furnaces (EAFs) supported by improved scrap collection, and establishing the first wave of hydrogen direct reduced iron steel plants in key steel-producing provinces.

Learning from past successes in solar photovoltaics and electric vehicles, these efforts were underpinned by state-directed investment, preferential financing for near-zero emission primary steel technologies and coordinated infrastructure development to ensure alignment between clean energy supply, industrial demand and logistics. Long-term subsidy contracts, awarded through a reverse auction process, enabled the hydrogen DRI plants to compete on a level playing field with BF-BOF and scrap-EAF plants. The cost of these contracts was funded by a small charge on all steel consumption, so that the policy was revenue-neutral from the government's perspective.

There was considerable optimism in Beijing about the path ahead.

The rocky road

China had fully expected that global demand for green steel would be weak for some time, but it was nevertheless surprised how flat the market remained through the late 20s and into the 30s.

This was partly due to continuing risk aversion in the developed economies. While many countries operated carbon pricing mechanisms, they did so at relatively low levels that were sufficient to drive a shift towards more recycling but not sufficient to enable the deployment of any clean primary steel production.

The bigger challenge was the sustained global overcapacity that caused other countries to raise trade barriers to protect their domestic industries - resulting in a reduction of Chinese exports of conventional steel. Struggling to find international buyers, China could only sell into the slowing domestic market. The industry contracted, causing closures and job losses that were particularly difficult for industrial communities in the regions.

It was a challenging time politically but Beijing maintained its investment in green steel production, convinced of its long term strategic importance.

Vindication?

The last few years have provided what optimists see as a vindication of Beijing's approach. Strong urban growth and infrastructure development in India, Southeast Asia and across the Global South has grown to mop up significant overcapacity. China is selectively introducing green steel into the mix of its exports, especially in Europe and parts of East Asia where standards are at last tightening up.

The transition still has a long way to go. China has built a modest stock of green primary steel production capacity that accounts for just over a tenth of its total production, while scrap recycling has risen to 20% and BF-BOF production remains high at close to 70%. Globally, the pace of change remains uncertain.

China's competitors, many of whom have spent the past decade wrestling with short term challenges, have lost sight of how well it plays the long game. When they raise their heads again – as they surely will – and resume their internal discussions on how to transition to near-zero emission carbon steel production, they will find that China has built its platform already. And that it is ready to launch.

Green Steel Consensus

Green Steel Consensus describes a future where demand for low carbon steel is high and green steel production in China is high.

The global transition to low carbon steel has moved ahead at pace. Governments in first-mover countries have implemented mandatory green public procurement policies and green steel subsidies. This, together with growing green iron production in countries with abundant renewable energy has prompted other countries to follow to protect their long-term competitiveness.

China has secured competitive advantage in the global green steel market by investing strongly in clean power and in green hydrogen production.

The view from 2035

Global steel production today stands at just over 1.9 billion tonnes, a figure that has remained relatively stable over the past decade. But beneath the surface, the industry has begun a structural transformation. The stock of high-emission steel is shrinking, with targeted subsidies, public procurement, clean steel tariff exemptions, and investor expectations accelerating the shift toward certified green steel. Over 40% of global steel output is now low-carbon, recycled steel. A further 10% is near-zero emission primary steel.

Green steel is no longer a niche product. It is the new benchmark of industrial competitiveness.

China was not the first country to deploy near-zero emission primary steel, but was one of several places where initial technological breakthroughs were made, with others coming from a mixture of start-ups and established industry leaders across Europe, Japan and the United States. And China did what it has done so many times before: mobilised industrial transformation at an unprecedented scale and a pace that was simply unstoppable.

The result? China is now the world's largest producer of green steel.

At a crossroads

The global steel sector stood at a crossroads ten years ago. Overcapacity was chronic, emissions were high and low-carbon production mainly remained stuck in the pilot stage.

It was not a good situation, either for the industry or for those governments who professed themselves determined to drive the transition to net-zero. It was clear by the mid 2020s that the technologies existed and that it was a lack of policy alignment and incentives holding industry back from taking them up.

It was also clear that governments needed to drive the change. They did so, not because of climate idealism, but because the transition offered some producers the promise of increased industrial competitiveness, and when they acted, others felt that standing still was increasingly risky. The switch from seeing decarbonisation as a cost to seeing it as an investment in long term strategic advantage was key.

Early movers

The accelerated expansion of carbon contracts for difference in Europe, enabling competitive near-zero emission primary steel production, was an early win. When this policy support was opened to steel plants using imported green iron from Brazil, costs fell, showing the advantage of producing green iron in locations with the best renewable energy and iron ore resources. China followed suit, with the government supporting state-owned steel companies to import green iron from Australia. Public procurement policies — especially in Europe, Brazil and some US States - were updated to mandate low-carbon materials in infrastructure, housing, transport and defence. Global demand for green steel began to rise, led by sectors such as electric vehicles, offshore wind and commercial construction.

These early developments caused some turbulence in the market and there were moments when it felt as if the transition might falter. Governments of countries that had moved early, such as Sweden, Germany and South Korea, were concerned that the strong policy support given to steel companies to scale up the first wave of hydrogen DRI pilots to commercial production would be difficult to replicate for the whole sector, unless conditions in the global market changed. This would depend disproportionately on the actions of the world's largest steel producer countries, China, India, Japan and the USA.

Building momentum

By 2029, the economic logic of green steel had become harder to ignore. With Europe and China having shown that a subsidy-led approach to deploying near-zero emission primary steel was viable, and with green iron production in Australia and Brazil threatening to reshape the sector's global supply chains, industry and government perceptions shifted. Whereas before, first-mover risk had dominated their concerns, now the risks of being a late mover in the transition appeared more significant. Following the lead of Europe and China, first Japan, then India, and then the USA began directly subsidising steel decarbonisation projects. Green hydrogen production scaled up across Europe, India and the Gulf.

With confidence in clean steel technologies increasing, carbon tariffs hardening, and lifecycle emissions standards in end-use sectors tightening, high-emission steel found itself locked out of premium markets. In response, trade diplomacy turned its focus towards the transition.

New bilateral agreements — such as green iron offtake deals between Australia and China, and clean steel access pacts between Europe, the US and India — established preferential terms for certified near-zero emission steel. These agreements began to knit together what would later become an informal green steel trade zone. Negotiations between Europe and China centred on reducing excess capacity in China in return for Chinese near-zero emission steel having tariff-free access to the European market.

The demand side also matured. Global automakers pledged that all new electric vehicles would use 100% green steel by 2040, recognising that this would add less than one percent to the cost of a car, and that it was likely soon to become a regulatory requirement in any case. Today, in 2035, over 90% already do. Green building codes took root in the global megacities. Solar and wind developers required green steel for project finance eligibility.

National governments

Circular design principles and scrap-sorting technologies advanced significantly, improving the availability of high-quality steel scrap. The shift enabled more efficient dismantling, easier separation of steel components and reduced contamination in scrap flows. At the same time, innovations in automated sorting — such as sensor-based material recognition, AI-assisted classification, and robotic disassembly —dramatically improved the quality and consistency of recycled steel inputs.

Deploying at scale

Once the conditions aligned — cost parity between electrolytic hydrogen and natural gas, a critical mass of demand for clean steel globally, and adequate renewable electricity infrastructure — China redoubled its commitment to the transition. Blast furnace steel production had no growth prospects, and its harmful effect on local air quality had long been a problem. Drawing on the learning from its first wave of hydrogen DRI projects, as well as those of other early movers, China was able to deploy the new technologies on an unrivalled scale.

What had been an assortment of pilot projects – scattered across the country in the late 2020s – were built up, replicated, connected to the national electricity network, and transformed into a growing fleet of large-scale hydrogen DRI plants in the early 2030s. This was supported by integrated policies across ministries and state-owned enterprises, ensuring alignment on land, power, finance and logistics. EAF capacity was rapidly scaled up in parallel, supported by improvements in scrap collection, circular design and digital traceability. The government in Beijing deployed capital, coordination and political will.

Green steel – including both primary and secondary – now accounts for a third of Chinese production. It has built its bilateral partnerships to co-develop green iron and steel production hubs with Australia and South Africa. Its exports are certified, traceable, and compliant with global standards - which means China once again has access to high-value markets that were previously closed to it due to high-emissions.

Radical. Different.

Today, the global steel market looks radically different. Countries accounting for over two thirds of global production now operate under harmonised low-carbon steel standards. While high-emission steel still accounts for the majority of global production, it is no longer viable in high-margin markets. Investment is now easier to access for companies planning to build new near-zero emission steel plants, and far harder to secure for any new blast furnaces.

The global transition is not over. Competition remains fierce, particularly in emerging markets. Trade disputes remain, particularly around the fairness of countries' clean steel subsidies, echoing the disputes over electric vehicles in the mid-2020s. But the direction of travel is clear: green steel is not only the future — it is the present.

Falling Behind

Falling Behind describes a future where demand for low carbon steel is high and green steel production in China is low.

Demand for green steel has been slow to take off but is accelerating as western nations push hard to decarbonise, and other countries take advantage of rapid technological progress.

China has strong capabilities in clean steel technology but has been caught out by the pace of the transition. The scale of change it must now make domestically to regain its global position is significant, allowing other, more nimble producers to capture significant market share.

The view from 2035

The global steel industry has undergone a dramatic transformation in the last decade, shaped by strong policies, market forces, and surprisingly fast technological progress, sparking a decade-long race to capture the green iron and steel value chain.

The sector, once defined by overcapacity, carbon intensity and relentless price competition, has become a proving ground for the decarbonisation of heavy industry. Policy instruments including green public procurement and subsidies for near-zero emission technologies have restructured global trade flows, redirected investment and reshaped corporate strategy. Breakthroughs in electrolyser technology, and in its application to molten oxide electrolysis, have made clean steel production viable in a wide range of countries. In many economies, green steel is no longer a policy aspiration but an industrial strategy. Market access, financing terms, and competitive positioning are now inextricably linked to emissions credentials. Meanwhile, countries are using trade defences vigorously to protect jobs in the high emitting steel plants which still account for the majority of global production.

China, the undisputed heavyweight of global steel a decade ago, has been caught out by the pace of change. While others acted quickly, China continued its initial policy mix of low-level carbon pricing and clean steel demonstration projects a little too long, holding back from stronger policies out of concern to protect jobs and government budgets. As a result, it was too slow to invest in new primary clean steel plants, and too slow to make those plants operational on a large scale. It wasn't by much – but it was enough to fall behind.

Reset

China's initial stance was completely understandable a decade ago. The high level of global overcapacity and the fragmented approach to climate policy across major economies made the prevailing view - that steel would remain one of the hardest sectors to decarbonise – hard to challenge.

Yet within a few years, that's exactly what a disruptive group of producers began to do, building momentum for the transition on the back of rising concern about climate change and a strategic rethink of industrial policy.

The EU, UK, Canada and Japan moved first, introducing and expanding carbon border adjustment mechanisms (CBAMs) that taxed high-emission imports and shielded those domestic producers who had invested early in clean steel technologies. Public procurement policies simultaneously moved to require certified green steel for public infrastructure, transport systems and defence contracts, creating guaranteed demand for compliant producers. Competitive advantage began to shift toward low-carbon production.

As clean industrial capacity scaled up, trade incentives (and barriers) were layered in. Green trade blocs emerged, not through international treaties but through gradual policy alignment. Compliant producers were welcomed; emissions-heavy exporters found themselves shut out or priced out. This was motivated as much by the desire to protect national industries (including conventional steel producers) from global overcapacity as it was by the need to protect clean steel producers from being undercut by high emitters in other countries.

What had seemed at first like a gradual market evolution reached a tipping point in the late 2020s as technological change accelerated. The effect was a dramatic reshaping of the producer landscape.

The world turned upside down

Europe — often written off in the 2020s for its bureaucratic inertia — took a lead in the emerging production landscape. Stringent carbon pricing, generous support for hydrogen-based production and an aggressive CBAM turned its industry into a high-cost, high-value export engine. German and Scandinavian mills, long dependent on coal, became pioneers of hydrogen DRI routes powered by clean hydrogen and renewable electricity.

India, once seen as a potential loser in the green steel race due to its fast-growing domestic demand, reliance on coal-based production, and low-quality iron ore, recognised the danger of being locked out of the newly emerging green trade blocs. It moved decisively to align industry practice with the direction of growth in global demand, expanding its national hydrogen strategy - coupled with state-backed incentives for solar-powered hydrogen DRI, and investment in the development of new technologies for low-cost beneficiation.

Both India and Brazil mandated the use of green ammonia in fertiliser production, motivated by food security interests. Europe followed. This caught investors' imagination and money flooded into the electrolyser industry, with the result that by 2029, electrolytic hydrogen could be produced at cost-parity with fossil fuel based 'grey' hydrogen.

Japan and South Korea focussed on achieving competitive advantage in high-quality speciality steels, and in developing disruptive new clean steel technologies. Their strengths in innovation have paid off and they now hold a premium market niche, as well as remaining competitive in the high-volume market.

The US's Inflation Reduction Act (IRA), passed in 2022, provided powerful incentives for decarbonisation for a short time – but after these were cancelled in 2025, the domestic steel sector was slower to pivot than its counterparts in Europe or Asia. The US government nevertheless used carbon-based tariffs to protect its domestic production which was already dominated by EAF capacity. At the same time, molten ore electrolysis (MOE) technology developed by a US company outperformed early expectations, and attracted large-scale private investment. The US exported the MOE technology to be used in steel production in other countries. Its small, modular nature allowed it to be deployed at first in smaller capacities, making it easier to secure finance and grid connections. By the early 2030s, MOE was being used to produce steel in Southeast Asia, Africa, the Middle East, and Central and South America.

Caught out

China - focussed through the mid 2020s on preserving jobs, minimising disruption and maintaining provincial economic stability - was caught out by the speed and direction of global change.

Policy directed at marginal gains - efficiency upgrades, emissions monitoring and modestly increasing scrap utilisation – proved enough to meet the policy target of peaking the sector's emissions before 2030, since domestic demand for steel had plateaued by the late 2020s, and trade protectionism in the global market left no room for export-led growth. The emissions trading system contributed to the push towards recycling, but created only weak incentives. The capability for hydrogen DRI production was there, but without strong deployment policies, it remained far too long at the demonstration stage. Structural inertia and fragmented governance meant that producers lost sight of the wider picture. Producers simply underestimated how quickly green trade standards would limit access to key export markets. And nobody had expected the rapid breakthrough of MOE.

When Beijing finally pivoted toward strong deployment policies for near-zero emission primary steel production in the early 2030s, the rest of the world was already racing ahead. Now, in 2035, the consequences are clear. China's share of global steel production has fallen below 40%. Its high-emission producers are blocked from many markets by carbon border adjustments, tariffs and quotas. It needs more time to build near-zero emission plants that qualify to supply the new green steel trade blocs, which means market share is certain to fall further before it recovers. And as small-scale MOE steel production spreads, a growing number of countries have developed interest in building and protecting their own domestic steel industries.

New order

The global map of steel production looks markedly different than it did a decade ago. More steel is produced in the ‘sunbelt’ countries where renewable energy is abundant and cheap. Less is produced in the ‘rustbelt’ of older centres of production in Europe, North America, and North Asia, but through a mixture of specialisation and protectionism, these industries continue. Green steel is no longer a niche product; it is becoming the standard in most advanced economies. Production is more distributed, thanks in large part to the rise of MOE. No single country dominates as China once did. No single country may ever do so again.

Maximum Blast Furnaces

Maximum Blast Furnaces describes a future where demand for low carbon steel is limited and green steel production in China is low.

Economic uncertainty hampers growth and limits collaboration on technologies and trade frameworks that support the decarbonisation of energy intensive industries. Policies relating to steel production focus primarily on keeping energy costs low.

China, like most major producers, avoids the economic risks of producing higher-cost green steel. Its strategy is to maximise profits from blast furnace production and exports, while building readiness through small scale clean steel pilot projects, to hedge against the long-term risk of the transition.

The view from 2035

It takes a lot of time and effort to turn an industry around when the market conditions are favourable and when demand and supply are moving into alignment. Transition is a different ball game entirely when conditions are unfavourable or when demand and supply are mismatched.

That is the situation the global steel industry has found itself in for the last decade. The industry is effectively trapped in a holding pattern characterised by clean primary steel pilot projects that never quite develop into commercial-scale production, incremental efficiency gains and gradually increasing use of scrap steel, cautious hedging and sustained traditional production in blast furnaces. The overall ambition to achieve the transition to clean steel is broadly shared (or to be more accurate, perhaps, widely stated) but no government or company seems willing to move first.

The story of the last ten years, then, is not one of denial but of drift. Steel remains one of the world's most carbon-intensive industries. Confidence in near-zero emission primary steel production technologies has increased but their adoption has been partial, small-scale, and limited to a few regions. The global steel industry is optimised for cost and efficiency, just not for the climate.

Caution: bumpy road ahead

Following the inflationary shocks of the early 2020s, the global economy entered a cautious recovery in 2026. Steel demand began to pick up, driven by sustained infrastructure development in the ASEAN nations, India, Africa and Latin America. But while economic activity returned, transformative investment in green steel did not.

Policy mechanisms like the EU's emissions trading system turned out to have less leverage than expected, incentivising increasing use of scrap steel but not the deployment of clean primary steel technologies. The EU extended the steel sector's free allowances under the scheme, recognising that the carbon border adjustment mechanism (CBAM) provided an incomplete defence against high emitting foreign competition. Several of the emerging economies adopted emissions trading systems but kept carbon prices low by avoiding any tight caps on emissions. Most international trade agreements remained focussed on generating growth by any means; most production focussed on keeping costs as low as possible. Maintaining legacy infrastructure, streamlining operations and improving efficiency without substantive investment were the order of the day.

With hindsight, some Chinese analysts say that China's reaction to market conditions – deemed prudent at the time - was too cautious. With the market for green steel remining sluggish at best, Beijing's policymakers prioritised energy security and economic stability over systemic decarbonisation. Early progress on pilot hydrogen DRI plants, expansion of EAF capacity, and anti-pollution measures in industrial regions all slowed. Meanwhile, new blast furnaces were approved for construction as the industry pursued growth opportunities in the emerging markets. It was hardly a surprise when, despite official optimism, China failed to reach its steel emissions peak by 2030.

The global reaction was subdued but significant. Investors took the missed target as confirmation that the business case for green steel remained unproven beyond its use as a niche product in prestige demonstration projects. Opponents of the transition in other countries used it to strengthen their arguments for continued inaction.

Course correction

China's failure to achieve peak steel emissions led to debate in Beijing about what should be done next. Some argued that a course correction was needed to minimise negative narratives about China's commitment to its long term carbon goals.

Other officials and analysts highlighted the global conditions that caused the delay, pointed out that China's steel industry had remained strong and profitable over the past decade and argued that there was no point investing in higher-cost clean primary steel technologies unless it was clear that other major markets were committed to that path.

The debate was won by those who argued for a strengthening of the hedging strategy to prepare more seriously for a transition that appeared likely to take place sooner or later. They pointed to steel producers in the UAE and Saudi Arabia in particular who were also trying to build green steel capacity, despite having strong interests in continuing to export fossil fuels.

With a modest renewal of policy support, the industry picked up where it had left off a few years earlier, renewing its investment in green steel industrial clusters with access to renewables, hydrogen and export infrastructure. Established hydrogen DRI pilot facilities received new investment with a mandate to develop a scalable model for large-scale deployment, enabled by central government finance, low-cost capital and preferential electricity pricing. Output would be utilised in public procurement and in partnerships with automotive, shipping and infrastructure companies.

An uncertain future

The approach strengthens China's preparedness for a future low-carbon steel sector through disciplined, strategic experimentation. But it falls short of a commitment to taking a leading role in making that transition happen.

While other major producers also prevaricate and hedge their bets, the question of exactly when that transition will begin remains uncertain.

The green steel pilot programme has certainly piqued the interest of investors and other producers but they remain cautious. The world has not rejected green steel but China's renewed efforts have not done enough to move the world on.

That is why, pilot projects and future aspirations notwithstanding, China's steel industry today remains firmly anchored in BF-BOF production. Green steel remains confined to niche applications and regulated export markets, while conventional output flows at scale to price-sensitive economies across Asia and Africa.

While overcapacity remains and carbon pricing remains limited in scope, the *status quo* seems likely to hold for now. For many in the steel sector, that is just fine.

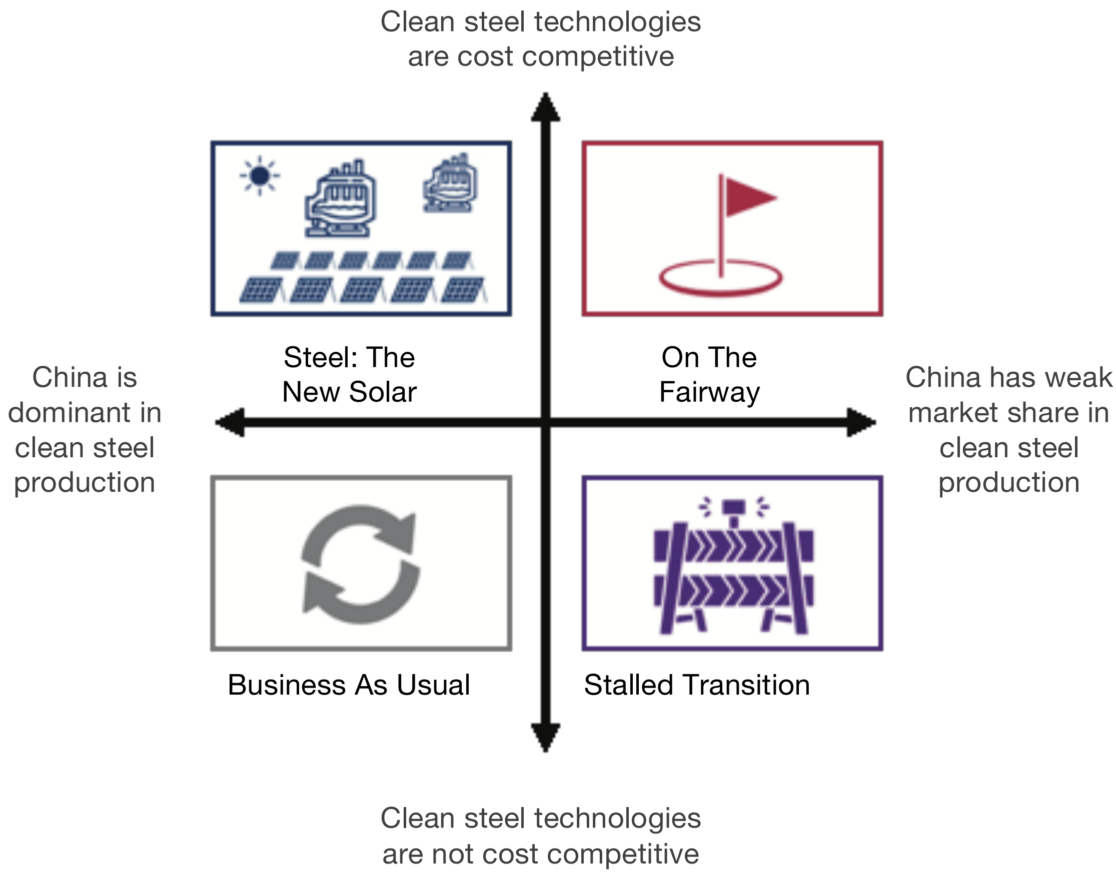
For policymakers focused on limiting the risks of climate change, the outlook is more troubling. Progress in developing zero emission solutions is slow across the set of energy intensive industry, agriculture and land use sectors that together make up nearly half of global emissions. The world has already started experiencing individual years with global average temperatures more than 2°C above the pre-industrial baseline. As national net zero targets look increasingly optimistic, and carbon cycle feedbacks in the Earth system prove stronger than expected, analysts now predict a temperature increase of 3-4°C before the end of the century – a level that has traditionally been described as 'catastrophic'.

Appendix C: Narrative scenarios for the United States

Scenarios for the global steel transition

s-curve economics

Appendix C: Narrative scenarios for the United States



On The Fairway

On The Fairway describes a future where clean steel technologies are cost competitive and China has weak market share in clean steel production. America's desire to be at the forefront of innovation has driven long term investment in low carbon technologies. Washington has forged a coalition with other producers to align standards for low and near-zero emission steel and to impose tariffs on high-emission imports.

China has not invested in clean steel technologies or standards and is locked out of the trade flows shaping the high-value global economy. The US steel industry enjoys first-mover advantage and has no intention of letting its advantage slip.

Teeing up

Back in 2025, the idea that the United States could dominate the clean steel market sounded like wishful thinking. Certainly, the US had vast scrap-EAF production, but hydrogen DRI was expensive and MOE was unproven. Moreover, the BF-BOF workhorses that had run the industry for a century were still reliable and still consistently producing steel at $550–$600 a tonne – while it was around 65% more expensive to use near-zero emission routes. Most analysts were firmly of the view that the *status quo* would remain for some time to come.

Most analysts, however, underestimated America's desire to be at the forefront of innovation.

Motivated by strategic competition with China, the US doubled down on long-term research and development. Although conventional renewable energy technologies faced political headwinds under changing administrations, cross-party support for innovation in strategic clean technologies held firm. Private investment flowed into developing the technologies underpinning MOE, as well as advanced nuclear and geothermal power. Development funding for blue hydrogen technologies came in close behind. Investors enjoyed early returns.

The US Department of Energy (DOE) and Department of Commerce (DOC) mobilised for scale up, launching multi-billion dollar funding rounds for pilot and first-of-a-kind plants in hydrogen DRI and MOE alongside grants for advanced scrap sorting and processing. These were paired with tax credits and loan guarantees to de-risk private investment.

There remains some debate today about which actors – industry, investors or administration – were the main catalyst of the US transition. There is, however, no debate at all about its impact: America bet on its innovation prowess and, in doing so, rewrote its own industrial story.

Driving forward

The US understood from the start that pouring capital into R&D would not be enough to beat the competition. Seeking to both isolate China for what it saw as unfair market practices and to maximise the rewards from its growing competitive advantage in clean steel, Washington used trade policy to reshape market conditions. Working with the EU, Japan, South Korea and Canada, Washington forged a coalition that aligned carbon accounting rules, agreed new standards for low and near-zero emission steel and imposed tariffs on high-emission imports.

The coalition created a protected premium market for clean steel across advanced economies. China objected strongly but was diplomatically isolated. With its own move to clean steel production held back by complicated domestic politics, China saw an opportunity to double down on conventional steel production and exports. Beijing kept its BF-BOF fleet running and strengthened its exports to meet demand.

Excluding Chinese producers from high-value markets gave the coalition's mills the breathing space they needed to scale up clean technologies without being undercut. Confidence fed investment, investment drove competitiveness, and a virtuous cycle of growth in market share and jobs followed.

Going for the green

2031 was a big year for technological change in the US steel industry. A decade of concentrated development finally delivered a step-change with MOE being proven to work at scale and to be replicable. Furthermore, innovation in nuclear and geothermal electricity combined with advances in electrolyser manufacturing and energy storage meant that the cost of low-emission hydrogen in the US fell below $1.50/kg.

These advances pushed both hydrogen DRI and MOE into cost parity with BF-BOF for high-grade steel production. At the same time, the National Scrap Quality Strategy (launched in 2029 in response to industry demand) started to deliver. Automated dismantling systems, digital scrap passports, and improved alloy sorting created a reliable flow of high-purity feedstock. The economics shifted almost overnight: US producers could run EAFs on a flexible diet of upgraded scrap and clean DRI, balancing cost, quality and emissions performance.

Venture capital flowed into clean steel start-ups; incumbents raced to acquire them and retrofit plants. By 2031, the first wave of commercial-scale MOE and hydrogen DRI facilities were operational in Ohio, Pennsylvania and Texas. Blast furnaces were shuttered in favour of these routes, fed by both DRI and high-quality scrap.

Course management

Having achieved cost competitiveness, US producers turned outward, using a mix of trade protections, brand reputation and standards diplomacy to win contracts across the markets of countries in the US-led coalition, from automotive steel for German carmakers to plate for Japanese shipyards.

Washington also positioned itself as a technology exporter. Licences for American MOE designs and hydrogen integration systems were sold to producers in Brazil, Morocco, and Australia; countries with abundant iron ore and renewable energy potential but lacking in proprietary technologies. This created new diplomatic leverage, as access to American clean steel technology became a key bargaining chip in trade negotiations.

By the mid-2030s, the concept of paying a premium for clean steel had largely disappeared in advanced markets. In the early stages, data centres, prestige carmakers, and infrastructure projects were somewhat willing to pay extra to meet ESG commitments. But once cost parity was achieved, “clean” became the default — a hygiene factor rather than a luxury attribute.

In consumer-facing industries such as automotive and appliances, the benefits of lighter, stronger steel (enabled by new processes) added value in their own right — improved EV range, lower fuel use, better safety performance — further embedding clean steel in supply chains.

China falls below par

China remains the world’s largest steel producer, but has become a marginal player in clean steel, misaligned with the technologies, standards and trade flows shaping the high-value global economy.

Trade barriers and intellectual property protections have limited its ability to acquire and scale new technology quickly and, although China’s EAF capacity is large, it suffers from a relatively high average emissions intensity in the sector which the standards adopted by the US-led coalition have been designed to punish. Domestic efforts to upgrade scrap recycling trail far behind OECD peers and the industry has successfully lobbied against domestic policies that would have forced a move away from its coal-hungry blast furnaces. It has been supported by provincial governments worried about potential job losses.

This has led to major competition for new markets in now booming regions for steel demand such as Africa and Asia. While the US and OECD allies seek to export clean steel and its component technologies, China has triggered a price war by seeking to offload its higher emission BF-BOF steel at rock bottom prices.

Playing partners

Europe has been a key partner for the US in reshaping the global steel market. Building on the Green Deal Industrial Plan, Brussels backed hydrogen valleys, supported hydrogen DRI plants in Sweden, Germany and Spain and established EU-wide scrap recycling programmes. The CBAM and trade defences protected European producers, while domestic subsidies smoothed the transition until new technologies reached cost-competitiveness, ensuring guaranteed markets for low-carbon steel. Europe's automakers and infrastructure projects became anchor customers, embedding clean steel in global supply chains.

While the US led in breakthrough technologies such as MOE, Europe's strength lay in regulation, demand creation, and circularity. Together, the transatlantic economies set the rules that locked China out.

On the leaderboard

Today, the US steel industry enjoys first-mover advantage, control over its scrap supply chain and a robust export portfolio.

It's a powerful position – but there is no room for complacency. Canada, Australia, and Brazil are scaling up their own clean steel capacity, leveraging vast iron ore reserves and cheap renewable energy. If they achieve lower cost at scale, they could eat into US export markets. And while China lags, its ability to mobilise capital and industrial capacity means it could still catch up fast — as the solar panel industry learned the hard way. The US industry is alert to these threats. It has no intention of letting its advantage slip.

Steel: The New Solar

Steel: The New Solar describes a future where clean steel technologies are cost competitive and China is dominant in clean steel production. Despite being well-positioned to compete in the global race to transition to clean steel, America fails to respond when China's leadership classifies clean steel technology as a strategic national priority. US steelmakers still do well domestically but are under pressure from overseas suppliers. For US policymakers, the choice now is whether to accept this weaker position or to launch a second push.

Opportunity lost

The United States appeared well-positioned to compete effectively in the global transition to clean steel back in 2025. EAF production already dominated the US steel sector. American universities and entrepreneurs had pioneered MOE. The US remained committed to investing in politically acceptable clean energy technologies. Market forces continued to drive investment in clean technology start-ups.

But then America hesitated - and China pulled ahead.

China continues to dominate conventional steel production but is also now the undisputed leader in clean steel production. Its clean steel is now cheaper than traditional BF-BOF steel, eliminating the green premium that once slowed take up. In many markets, it is the only clean primary steel available at scale.

China has secured this position through its own actions, of course, but America's hesitation — a combination of policy drift, fragmented investment and an overreliance on market forces to solve what was always going to be a state-backed, scale-driven race – certainly cleared the path to the front of the race.

A pivotal moment

The late 2020s were a decisive window for that race. China's leadership moved quickly to classify clean steel technology as a strategic national priority on a par with semiconductors, batteries, and electric vehicles. The designation unlocked state financing on a scale Western steel-producing countries could not match.

China's state-owned enterprises began simultaneous deployment of hydrogen DRI plants and large-scale upgrades of electric arc furnaces running on high-quality scrap and clean power.

There were, of course, some concerns that closing blast furnaces could lead to job losses in the future, but these did not have to be faced immediately. The priority - investment in the new technologies needed to drive clean steel production forward – took precedence.

In 2026, China's National Development and Reform Commission mandated that all new public construction use a minimum threshold of near-zero emission steel, creating guaranteed domestic demand. By 2027, long-term renewable power purchase agreements with integrated energy storage gave steelmakers electricity that was reliable, near-zero emission, and lower cost than grid electricity in most other large economies.

Crucially, China cut the two cost drivers of hydrogen steelmaking by developing cheaper electrolysers and achieving ultra-low power costs from massive wind and solar deployment backed by long-duration energy storage. The combination delivered a structural advantage that competitors simply could not replicate.

The US response was piecemeal: fragmented policies to scale up hydrogen hubs and Carbon Capture and Storage (CCS), modest R&D grants, a political focus on tariffs over investment and a reluctance to invest aggressively in new clean power sources. Washington assumed that clean steel was only of interest to governments attempting to address climate change, ignoring the lesson that China's state-driven innovation in clean technologies could transform the economics of the sector as it had for the power and automotive sectors.

Taking the lead

By 2030, China's first generation of industrial hydrogen DRI plants had reached commercial scale. Paired with low-cost green hydrogen and upgraded scrap-EAFs, they delivered near-zero emission steel that undercut BF-BOF on cost in most markets.

China seized control of the value chain. It became the world's largest electrolyser manufacturer, secured iron ore through strategic acquisitions and partnerships, and invested heavily in downstream sectors from shipbuilding to automotive — ensuring Chinese clean steel fed Chinese-controlled industries.

On the diplomatic front, China worked hard to secure agreements with a growing number of countries that cemented new low-emission definitions and standards to enable trade in near-zero emission steel.

Chinese clean steel was increasingly attractive to emerging economies given its high quality and lower cost. Ministries in Southeast Asia, Africa and Latin America signed multi-year contracts that locked in Beijing's market share and integrated supply chains around its grades and specifications. Those countries seeking to build the competitiveness of their own steel industry entered arrangements to import Chinese clean steel technologies. As the cost-competitiveness of those technologies increased, so did countries' willingness to agree standards preventing trade in high-emission steel.

For the US, the strategic competition implications were stark. While those sectors important to national security sourced steel exclusively from domestic producers regardless of cost and emissions, others – such as construction, manufacturing and infrastructure - valued the lowest cost outputs they could source, and increasingly valued lower emissions materials for exports.

Although the US's steel had been highly competitive in the past, its position had weakened dramatically due to technological change and the spread of new standards. Efforts to build a "steel alliance" with Europe, Japan, and Australia, centred around arguments that China's approach was market distorting, met with partial success in high-value segments but had little impact on the mass market.

Still, US steel producers began to follow the leaders in the transition to new technologies, spurred on by the new quality and emissions standards set by the Chinese industry. They adopted Chinese electrolysers, deployed large-scale hydrogen DRI complexes in energy-rich states and blended domestic R&D with imported engineering know-how. Several MOE projects finally reached commercial scale, with US firms leaning on their strengths in process integration, certification, and quality assurance. American mills regained competitiveness in high-trust segments — aerospace, defence, and premium automotive — where domestic supply and quality commanded a premium.

It was a meaningful recovery, but not enough to offset China's overwhelming advantage in cost and scale.

Europe's shrinking foothold

Europe maintained influence over sustainability standards through its leverage as a large consumer and its capacity for designing regulatory frameworks, but its share of global production shrank steadily. High energy costs and fragmented national industrial policies meant European mills could not scale up near-zero emission production at the pace or cost of their Chinese counterparts.

A coalition of northern European producers attempted to maintain a premium green steel brand combining near-zero emission with high standards on labour rights and environmental pollution, targeted at automotive and high-value manufacturing supply chains. This secured niche demand in Germany, Scandinavia and Japan. Yet in construction, shipbuilding, and most mass-market applications, Chinese clean steel was the default choice.

Europe's predicament was paradoxical: it set many of the rules, but lacked the industrial weight to fulfil them globally.

Where to go from here?

China's dominance has become self-reinforcing. Clean steel has become the default commodity and Beijing's technical norms and certification schemes set global standards.

The clean steel race underscores a lesson America has learned before but forgotten - in sectors where technological change faces high initial barriers, waiting for the market to deliver can be a losing strategy. Semiconductors, aerospace, and defence all became global strengths through early, sustained and strategic public investment, before markets took over. The transition to clean steel technologies required the same approach, but Washington treated it as a secondary priority until the race was already lost.

Today, US steelmakers still matter domestically, but are under continued pressure from cheaper Chinese imports, much like in other parts of the clean energy economy. In the global market, the rules, the prices and the supply chains are set elsewhere.

For US policymakers, the choice now is whether to accept this weaker position or to launch a second push — one that recognises that in clean industrial technologies, the competition is not just about invention, but about building fast enough and big enough to set the terms for everyone else.

Business As Usual

Business As Usual describes a future where clean steel technologies are not cost competitive and where China is dominant in clean steel production. US steel producers focus on their strengths in EAF production and BF-BOF. China sees clean steel as a low risk gamble and, mobilising a small number of state-owned mills to develop commercial-scale technologies, comes to dominate the market.

Efforts to build the US clean steel sector fail to gain traction as producers argue that being a “fast follower” makes more sense than risking first-mover disadvantage. As other producers move into clean steel, there are growing concerns that the US industry will fail to keep pace.

Wait and see

In the mid 2020s, American steel producers faced a choice: invest heavily, early and at scale in still-expensive clean primary steel technologies — knowing they are not yet cost-competitive — or keep running and extending the existing BF-BOF and scrap-EAF fleets until the economics improve.

The lack of strong policy signals (carbon pricing, public procurement mandates or subsidies) meant there were simply no incentives to decarbonise. Yes, US steel remained cleaner than that of most countries in that more of it was produced via recycling in EAFs; but the electricity grid remained carbon intensive and plenty of coal was still used in BF-BOFs. And so, rather than bet on expensive, immature technologies, US steel producers overwhelmingly chose the conventional path – to retain their strengths in EAF production for secondary steel and invest to extend the life of BF-BOF plants.

That strategic bet meant the US risked having no cost-competitive clean steel capacity to bring to market by the early 2030s. Neither investors or producers could tell how the bet would play out. All they could do was wait and see.

High hopes…dashed

Europe’s early ambitions to lead the transition meant its industry made early investments in hydrogen DRI and ultra-low-emission EAF when the US chose not to; but high renewable electricity prices, grid congestion and much higher hydrogen costs than they had envisaged meant they, too, faltered.

While some European producers shifted towards a greater share of EAF production due to inevitable market forces, others stuck with conventional BF-BOF production. There was some investment in efficiency upgrades to reduce the cost of compliance with the EU emissions trading system, but no commitment to large-scale replacement. The EU maintained the CBAM but – in a market where most European producers were focussed on defending domestic share and had successfully lobbied for the continuation of free allowances – the effective ETS carbon price remained low. CBAM's impact was muted.

A throw of the dice

Like others, China saw clean steel as a gamble. Unlike others, however, it had a capacity and scale that meant its gamble was relatively low risk. With state-owned giants able to cross-subsidise clean steel pilots, Beijing could afford to experiment in ways Western firms could not.

So, while Beijing continued to run high-emission BF-BOFs for the bulk of its output – keeping global prices low and defending its dominance in commodity steel – a small number of state-owned mills developed and perfected commercial-scale technologies. Their aim was to export near-zero emission primary steel selectively to Europe and Japan, supplying those niche markets where voluntary private businesses or policy demanded it.

This approach had two immediate impacts. First, China secured what little demand there was for near-zero emission steel; second, it ensured that no rival could build equivalent scale.

Emerging markets, lacking carbon border measures or procurement mandates, continued to produce and buy conventional steel.

Grounded

The US Government and industry's failure to invest in nascent primary clean technology for steel and its lack of ambition on providing cheap clean power had stark consequences.

Start-ups focused on clean steel technologies struggled to raise capital. Many folded or were acquired by Chinese investors, transferring intellectual property overseas. A few projects clung to life, resulting in a single demonstration plant here and there, but without the volumes needed to drive down costs they remained expensive curiosities. Venture capital exited the sector entirely.

By the early 2030s, the US steel innovation ecosystem was hollowed out. Entrepreneurs moved to other industries, specialised equipment suppliers closed or pivoted away and university research programmes in metallurgy and process engineering found it hard to recruit.

Steel demand in the US grew, but only slowly, driven mainly by maintenance of existing infrastructure. The US steel fleet remained a mixture of EAFs and BF-BOFs; with no carbon pricing, no mandatory low-carbon procurement, no willingness to pay a green premium, and no potential beyond its small, policy-driven overseas niche, green steel simply failed to take off. Steel production remained cleaner than that of most other countries but the continuing failure to decarbonise the grid - together with taxes and other barriers to clean power deployment - meant producers were unable to target the small overseas niche markets that did exist for near-zero emission steel.

Think tank reports continued to make the case for decarbonisation, but without strong policy in the form of subsidies or binding mandates, producers still saw little incentive to move. In boardrooms, executives argued that being a “fast follower” made more sense than risking first-mover disadvantage in a high-cost, low-demand segment.

China reaches out

Since the global market for clean steel remained small, trade patterns remained largely unchanged into the 2030s. China continued to dominate conventional steel exports, keeping prices low enough to deter new entrants and to cause difficulties for US, European, and other East Asian producers. Its modest clean steel exports flowed into the few market segments that require near-zero emission materials, including a few small European countries and luxury cars in Japan.

Chinese state-owned enterprises moved into clean steel production quietly and efficiently, but with no desire to push growth further than the market would bear. Domestic demand remained overwhelmingly conventional, preserving low production costs and protecting the profitability of large integrated mills.

Strategic investment in steel mills in emerging markets – either through acquisition or through foreign direct investment – meant that Chinese steel became embedded in local infrastructure, automotive, and manufacturing supply chains.

It was an effective approach and one that means China remains firmly in control today.

National security matters

The erosion of the US steel industry’s competitiveness and capacity for innovation has revived concerns about strategic vulnerability. If clean steel technologies can come down in cost through a combination of cheap renewables, long-duration storage, and low-cost electrolysers, the US looks at risk of falling even further behind. There are fears that the collapse in the US’s steel innovation ecosystem could spread more generally.

Yet, even these fears have not spurred a surge of investment and, without cost-competitive technologies, the private sector remains reluctant to commit. Public investment on the scale required to bridge the gap is simply unrealistic.

Looking ahead

There are no obvious signs that the US’s business-as-usual trajectory will shift. Clean steel remains marginal and, without a cost breakthrough, few producers are willing to gamble on scale. China continues to dominate by keeping its commodity steel from BF-BOFs cheap, by flooding emerging markets and by undercutting any competitor tempted to build primary clean steel capacity. Its selective deployment of near-zero emission steel marketed to Europe and Japan secures the premium niche too, ensuring no rival achieves scale.

Europe has little leverage. The CBAM protects domestic producers while they make incremental emissions reductions but fails to generate global influence. European mills defend local markets, but their share of global trade is declining. Washington has no desire to see the sector decarbonise globally, but the complacency of the past decade is gradually being replaced with concern over its industry’s reduced capacity for innovation. China sets the terms — on price, on scale, and even on who gets access to clean steel.

For as long as steel remains marginal, as innovation continues to stall and as the bulk of global production continues to run on carbon-intensive BF-BOFs, patterns of global production and trade will not look much different from the past. But if clean steel technologies should finally break through into cost-competitiveness, a radical restructuring – one which the US industry is, unfortunately, far from prepared for – could still happen quickly.

Stalled Transition

Stalled Transition describes a future where clean steel technologies are not cost competitive and China has weak market share in clean steel production. The cost gap between clean steel technology and BF-BOF is wide and the transition is effectively stuck. Europe strikes out on its own, pairing subsidies for clean primary steel with a rising carbon price and a fully implemented CBAM. As Europe becomes stronger in clean steel and China doubles down on conventional steel, the US risks losing out in both markets.

However, it remains unclear whether the real race has begun and whether the US can strengthen its position before it does. For now, the technological future of the sector remains uncertain.

The next big thing…

Back in 2024, clean steel was supposed to be the next great industrial race — a test of whether the US could pair climate ambition with manufacturing competitiveness. Hydrogen DRI, MOE and EAF production were all hailed as processes that could make coking coal obsolete.

Ten years later, those technologies are still expensive science projects. The cost gap with BF-BOF remains stubbornly wide and the sector's transition is stuck in neutral. Near-zero emission steel production accounts for only a few percent of global output. The US slice is small.

…fizzles out

The commonly held view ten years ago was that China, the world's largest steel producer, would move into clean steel to maintain export dominance.

It didn't. Instead, Beijing calculated that, with political challenges at home, no significant global demand and abundant infrastructure needs in Africa and ASEAN, it was better off sticking with high-carbon BF-BOF production. By doubling down on volume and price, China flooded emerging markets with cheap steel, locking in buyers and keeping global prices too low for clean alternatives to compete.

This created something of a policy dilemma for Washington. China's move meant that US steelmakers would only be able to compete in export markets with government subsidies - but granting them would undermine Washington's argument that China was supporting its industry unfairly, and climate change remained a polarising topic amongst voters.

As policymakers and the industry grappled with how to maintain their position in a global market dominated by cheap, high-emission steel, the transition to clean steel simply fell off their priority list. Political representatives could not see any public appetite for it. Some steel executives stopped talking about "green steel" completely. Others used the phrase to refer to whatever recycling they already did.

Once it became clear that clean steel wouldn't be a market disrupter anytime soon, US producers dug in. They extended the life of their BF-BOF assets and confined very low-emission production to small volumes for prestige buyers — the Teslas and Apples of the world — who needed the ESG branding.

Technology providers wanted to push ahead, but without large orders, finance fizzled out. Some innovative firms continued to plug away at breakthrough technologies, but without supporting policies to make plants commercially viable, target dates for deployment were repeatedly pushed back.

Europe's Different Play

Europe faced the same cost challenges but chose a different path. Brussels doubled down on the Green Deal Industrial Plan, pairing subsidies for clean primary steel with a rising carbon price and a fully implemented CBAM. That shielded EU producers from underpriced imports and - even though the economics were tight - gave investors the confidence to fund large-scale hydrogen DRI projects in Sweden, Germany and Spain.

By aligning climate policy with trade defence, Europe kept its clean steel build-out moving slowly. Today, the EU's share of the global clean steel market sits at around 20 per cent, but that apparently small share includes most of the high-value, certified near-zero emission steel sold in the global market. EU producers dominate those specialised segments such as aerospace alloys and automotive steels where competitive advantage comes from quality and certification, not only from price.

Europe has, moreover, become a rule-maker. The EU's Clean Materials Club (EUCMC) – set up in the last part of the 2020s to provide a unified framework for measuring and certifying carbon intensity in steel, cement and other heavy industries – has expanded in the last 5 years. Japan and Canada joined early on and were quickly followed by Brazil.

Those who hesitate

Washington chose not to join the Clean Materials Club when it had the chance in 2030, partly because most producers remained unconvinced there were real opportunities and partly because those few producers who *were* trying to build scale didn't want to concede (as they saw it) rule-making power to Europe.

It was the wrong call. EUCMC certification became the gold standard and in 2033 participating countries became suppliers to the multinational automakers and aerospace companies that chose to be first-movers in buying clean steel.

The US was locked out. What few orders it had came under pressure from certified EUCMC members.

Who cares?

If American consumers noticed that the US was slow on steel decarbonisation, they showed little concern. Certified near-zero emission steel carried a premium that most buyers were unwilling to pay. What mattered to them was cost, reliability and availability — and conventional EAF and BF-BOF steel delivered on all three.

That, of course, turned out to be an advantage for the US producers who had delayed investment in clean technologies. Instead of being penalised for inaction, they benefited from lower capital costs and steady domestic demand. Companies extended the lifespan of existing BF-BOF assets, avoided expensive retrofits and continued to supply competitively priced steel to local markets.

Investors, too, saw little downside. While European firms wrestled with compliance costs and tight margins, US producers delivered stable returns. By the mid-2030s, the industry had settled into a paradoxical position: profitable and resilient at home, but increasingly left out in global trade as China continued to dominate the market for conventional steel and others supplied the niche markets for clean steel.

Beyond the transatlantic divide

Other steelmakers charted varied paths which, taken together, failed to create a critical mass in favour of steel's low-carbon transition in global markets.

India ramped up BF-BOF output to serve its vast infrastructure boom, while experimenting with small-scale hydrogen pilots supported by state subsidies.

Japan and South Korea aligned with the EU's certification standards and approach to carbon pricing, seeking to protect their advanced automotive and electronics supply chains, but did little to support the deployment of clean steel technologies at scale.

Brazil and Australia initially hoped to leverage their iron ore and abundant renewable power resources to position themselves as exporters of green iron, but found little demand for this globally as those jurisdictions that did support primary clean steel also supported their own domestic producers.

The Middle East, meanwhile, pursued green hydrogen megaprojects, but oriented these towards producing fertilisers and shipping fuels, as the markets for clean steel had yet to fully materialise.

The big question

The divide between Washington, Brussels and Beijing has hardened. China holds sway in high-volume commodity markets, but its weak clean steel share leaves it excluded from the premium segments that are beginning to shape advanced supply chains.

Europe has turned weak economics into institutional power: its carbon pricing, CBAM and the Clean Materials Club anchor a protected demand space that others — Japan, Canada, Brazil — have joined. Producers dominate the certified near-zero emission niches that are forming within sectors such as aerospace alloys and automotive steels, where quality and traceability as well as cost are decisive.

The US is stranded between these poles. Domestic producers remain profitable supplying conventional BF-BOF steel at home, but America is irrelevant in both global commodity and premium clean steel trade.

The sector is moving forwards, but cautiously, and one big question hangs in the air at the moment: is any country going to move decisively enough to reshape the global market?

Perhaps the EU and its partners can expand the niche markets they are developing for clean steel into larger sections of the global market. Perhaps US companies, having had more time for the development of breakthrough technologies, will re-enter the race once the firing gun finally goes off. Or China could reorient its enormous industrial capability towards clean steel.

For now, the technological future of the sector is still uncertain.

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