Demand and Supply Measures for the Steel and Cement Transition

The case for international co-ordination

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Abstract

A massive scale-up of markets for transformative near-zero emissions steel and cement is needed to achieve internationally agreed net zero goals. Yet early movers on both the supply- and demand-side – that is, material producers and consumers – face substantial barriers related to high costs and risks, among other factors. This has led to relatively slow market growth for near-zero emissions materials, at a moment when reinvesting in long-lived high-emissions production could have repercussions for governments to achieve their stated climate goals. Policy makers have the opportunity to play a decisive role in unlocking markets for near-zero emissions materials. Governments are well-positioned to reduce risk during market formation, and targeted policy measures can provide the certainty that is currently lacking in markets. Furthermore, international collaboration will be vital to make the transition faster and less costly, given the international nature of markets for industrial products, the need for large and capital-intensive technology demonstrations for near-zero emission production, and the larger demand signals that can be created by pooling commitments across borders.

This report – produced at the request of the Climate Club yet generally applicable to policy discussions for industrial decarbonisation – offers considerations and options for governments to scale up markets for near-zero and low-emissions steel and cement, while concurrently reducing reliance on high-emissions materials. It makes the case for why both demand-side and supply-side measures are important to kick-start markets for near-zero emissions materials, summarising progress to date and highlighting gaps that rationalise government action. Key policy options are outlined, illustrating the variety of measures available to governments as they implement strategies tailored to their particular circumstances. The value of international co-ordination on such measures is discussed, and an initial illustrative proposal is elaborated for those governments that may wish to consider coming together around a collective pledge for scaling up the market share of near-zero emissions materials.

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Executive summary

The seeds for producing and using near-zero emissions materials have been planted, but acceleration is needed

The industry sector requires a massive scale-up of markets for transformative near-zero emissions materials to contribute to the achievement of internationally-agreed government objectives for net zero emissions. Such scale-up requires the production and use of these materials to grow from essentially zero today to capture nearly the entire market within the next few decades, shifting away from high-emissions conventional production and demand. The steel and cement sectors account for 14% of global energy and process-related emissions on a direct basis, making them central to the decarbonisation challenge.

First mover producers of near-zero emissions materials are beginning to position themselves to compete in such markets, including through the development of definitions, certification and labelling systems for near-zero emissions steel and cement – in some cases through collaboration with government – like the Low Emissions Steel Standard initiated in Germany, the voluntary CO_2 standard of the China Iron and Steel Association, and the Global Cement and Concrete Association's definitions proposal. Yet, while progress is underway, it has not yet advanced at the speed and scale needed: announced capacity for near-zero emissions iron-based steel production and cement production by 2030 amounts to only about 10 Mt and 35 Mt, respectively, equivalent to 10% of that required in the same year on a pathway to net zero emissions by mid-century.

On the demand-side, some material-consuming companies – like auto manufacturers and construction companies – are already committed to procure near-zero emissions products, indicating a willingness from some buyers to pay a price premium. The quantities are so far quite small – offtake agreements for near-zero emissions steel for which quantities are publicly disclosed account for only a little under 2 Mt per year of demand by 2030. Material purchasers have announced a willingness to purchase an additional 3 Mt through the First Movers Coalition Near-Zero Steel 2030 Demand Challenge and the RMI Sustainable Steel Buyers Platform, although this demand has not yet been met. Together, this nearly 5 Mt of demand is estimated to have a combined value of roughly USD 3.5 billion. Further demand that has not yet been fulfilled may already be much larger but is difficult to quantify outside of such initiatives. Nevertheless, offtake agreements so far lack regional diversity and remain too small to provide the certainty needed for a sufficient number of producers to take on the risk of early deployment.

Despite relatively modest beginnings, markets have the potential to grow substantially in the coming years. By way of example, the global market value of near-zero emissions steel alone would reach close to USD 300 billion (about 20% of today's total steel industry global market value) by 2035 if markets grow at a pace commensurate with government climate pledges. By 2035, this market value would reach close to USD 550 billion on a pathway compatible with reaching net zero emissions by mid-century. The market value for near-zero emissions cement could reach up to USD 100 billion by 2035, depending on the policy settings.

Policy action is vital to establish international markets for near-zero emissions material production and use

Early adoption of near-zero emissions materials and production technologies requires overcoming a number of barriers, most notably cost. Early offerings of near-zero emissions steel and cement carry a price premium resulting from an estimated 10% to 125% higher production cost compared to conventional production, depending on regional and technological factors. The international nature of industrial markets, which means that producers are trade-exposed, further accentuates the risks for the first private sector investors.

Against this backdrop, targeted demand and supply policy measures implemented by governments globally could help push markets for near-zero emissions steel and cement over important thresholds. For example, past experience suggests that at around 1% of market share, technologies typically have sufficient maturity to have a tangible effect on supply chains. This makes wider adoption afterwards more straightforward due to the experience from early projects and economies of scale in production that help lower cost. Reaching these thresholds can take up to several decades, especially for large and site-tailored technologies typical of industry. As industry players look for new ways to secure a competitive advantage in the currently challenging market context – and with mid-century only one investment cycle away for long-lived industrial plants – government support could make the difference in spurring growth for near-zero emissions materials.

Demand-side measures are critical to provide certainty given the higher costs and risk of early deployment

Government measures have a particularly important role to play in the near term for scaling up markets: well-designed targeted demand-side measures can create early lead markets for near-zero emissions materials, paving the way to more widespread market opportunities thereafter. Governments are well-positioned to help buffer the higher risk through targeted policies during market formation, until other dynamics may be able to take over in the longer term. Policies to support innovation and early deployment can help shrink the price premium through technological learning and economies of scale. Moreover, the price premium on final products like cars and houses is likely to be relatively small – up to 5%, but often less – given that steel and cement make up a relatively small portion of overall costs. Yet in the short-term, supply chain complexities can make it difficult to pass through additional costs to final consumers – policies may be able to help bring markets to the point where cost pass-through could be more feasible. Over the longer term, increasing stringency and global coverage of broader policy measures like carbon pricing would raise the cost of high-emissions materials and may help enable near-zero emissions materials to eventually reach price parity.

The approach taken to provide critical early demand-side support can be tailored to each governments' circumstances and preferences. Targeted measures could include policies aiming to cover the price premium, like contracts for difference and public procurement of near-zero and low-emissions materials. They could also include mandatory regulations that require a growing market share of near-zero emissions materials or establish compulsory emission intensity performance levels. These can be supplemented by measures that target end-products, like policies that set embodied carbon limits on buildings or vehicles, or product design codes that consider lifecycle emissions. Government involvement to ensure clear, consistent and verifiable labelling and certification can underpin these policies and facilitate demand by providing transparency and reducing complexity.

Supply-side measures can work hand-in-hand with demand-side policies to help drive a shift in capacity

Investment decisions made today directly impact the stock of facilities operating mid-century. For a trajectory compatible with internationally agreed government objectives, near-zero emissions production needs to be scaled up rapidly while high-emissions production is reduced in an orderly manner. Yet the window is narrowing to bring near-zero emissions technologies to market: 15% of the global steel production fleet around 2035 and 40% for cement around 2030 will face a reinvestment decision. These figures increase to 50% and nearly 100% for Climate Club members.

New investments will require careful consideration: at present, over 200 Mt of high-emissions conventional steelmaking capacity is either planned or set to come online in the next years, virtually all in emerging economies. Meanwhile, achieving net zero emissions by mid-century requires that production eventually transition away from high-emissions conventional production. This means that new capacity additions would be constructed to be near-zero emissions "capable", if not fully near-zero emissions, with clear plans and technical capabilities for conversion to near-zero emissions production prior to mid-century. In some jurisdictions, this may also entail the retrofit or replacement of high-emissions existing assets with near-zero emissions technologies during the upcoming investment cycle.

Governments can make use of a variety of targeted supply-side measures to design a strategy for their industry transition. Economy-wide measures such as carbon pricing can help backstop policy strategies and improve the cost-competitiveness of near-zero emissions materials, but are most effective when coupled with targeted measures. These include incentives such as grants, contracts for difference, tax credits, or other financing that can support technology demonstrations, commercial-scale early deployment, and operating costs for clean energy technologies. Policies targeted at supporting and co-ordinating scale-up of enabling infrastructure – including for low-emissions hydrogen and electricity production, transmission and distribution, and CO_2 transportation and storage – can facilitate more rapid roll-out of near-zero emission technologies. Meanwhile, regulatory measures like retrofit-ready or near-zero "capable" requirements, moratoriums on new builds of high-emissions capacity, or targets to reduce production and use of emissions-intensive materials can be ways to ensure assets are decarbonised sufficiently quickly, while also reducing excess capacity that contributes to depressed market prices that make it harder for industry players to invest in decarbonisation.

Collaboration across borders on demand and supply would bring multiple benefits

The international nature of markets for industrial products – along with the need for large and capital-intensive technology demonstrations for near-zero emission production – means that international collaboration is vital to make the industry transition faster and less costly; weak international co-operation could delay the transition to net zero by decades.

Investments in supply of near-zero emissions materials tend to be large and lumpy – that is, a new million-tonne steel or cement plant is a major investment that will supply many buyers over decades. International co-operation on demand commitments can send larger signals to markets, thereby helping to de-risk such investments. Aggregating demand from multiple public and private sector buyers, as well as across borders, can increase certainty and help secure a business case for producers. Such efforts are already underway; for example, ten governments are collaborating on public procurement of low-emissions materials under the Industrial Deep Decarbonisation Initiative (IDDI), of which five have committed to a Green Public Procurement Pledge. Together, they procure over 30 Mt of steel and 55 Mt of cement per year. Such efforts need to be widened to a larger number of governments, and ambition needs to be raised overall, to achieve critical mass.

On the supply side, international knowledge-sharing and collaboration can help speed-up technology development and cost reductions. International finance can also help accelerate deployment in multiple regional contexts, helping to achieve economies of scale on technologies across more regions and with increased pace.

Co-ordination is also needed to address challenges that are fundamentally global in their nature, such as excess global industrial capacity that has implications across international markets.

Co-ordinating policy ambition across governments can be a central part of co-operation efforts. Raising policy ambition and setting similar paces of decarbonisation across multiple countries can help mitigate carbon leakage as markets for near-zero emissions materials grow. It can also help share the policy burden, in that larger international markets for near-zero and low-emissions goods would reduce the extent to which individual governments may need to provide export subsidies for early producers. For market actors, this co-ordination can also provide the predictability and transparency needed to accelerate market growth.

Collaboration among governments on policy ambition can take different forms and levels. At a higher level, collective international pledges can spur dialogue on ambition and send powerful early signals to markets. At the more granular level, governments may choose to discuss possibilities for co-ordination and alignment of specific policy measures. These could include similar rates of subsidies under contracts for difference, comparable carbon prices, aligned emissions thresholds used in emissions intensity regulations, co-ordinated requirements within public procurement policies for near-zero and low-emissions materials, or similar timelines for reducing reliance on high-emissions production.

Climate Club members have an opportunity to become collective first movers and shape future markets

Across various areas of the energy system, co-ordinated pledges have emerged in recent years as a rallying point for increasing global ambition and policy efforts, while sending important global market signals. Governments around the world came together around global pledges at COP29 to scale up to 1 500 GW of energy storage and 25 million kilometres of electricity grids, at COP28 to triple renewables and double the pace of improvement on energy efficiency, and at COP26 to reduce methane emissions by at least 30%. Meanwhile, initiatives like the Beyond Oil and Gas Alliance and the Powering Past Coal Alliance target reductions in emission-intensive technologies and processes. In the case of the latter alliance, its members retired 35 GW of coal power capacity from 2018-23 and plan to retire well over 100 GW of further capacity by 2030.

A comparable, easily communicable global rallying point for the industry transition has not yet gained widespread traction. Pledges that have emerged recently among smaller coalitions of governments, such as the IDDI's Green Public Procurement Pledge and a collaborative call to action launched at COP29 by several governments on scaling international assistance for the industry transition, could provide seeds and learnings for a broader international collective pledge.

As a high-level co-operative initiative for increasing ambition on industrial decarbonisation, the Climate Club has the opportunity to provide a forum to discuss collaborative action and explore the possibility of a broader collective pledge for the industrial transition. Accounting for just over 25% of global production and demand for steel, and around 20% for cement, Climate Club members could act as collective first-mover and have a major impact on global markets. Meanwhile, parallel discussions in other workstreams of the Climate Club on international assistance and finance will be critical to help all members consider ambitious participation in such a pledge.

An international pledge on industrial decarbonisation could send an important market signal

In this report, at the request of the Climate Club, the IEA has developed an illustrative proposal for a collective pledge that could serve as a starting point for consideration and discussion by Climate Club members. It aims to address demand- and supply-side challenges faced by global near-zero emissions steel and cement markets, as well as the transition away from high-emissions conventional materials. These are areas where international collaboration is deemed particularly valuable; complementary measures by members to advance other industrial decarbonisation strategies such as material efficiency and circularity would be useful in parallel.

At the centre of the pledge proposal are simple-to-communicate, tangible, quantitative, and time-bound targets for the market shares of near-zero emissions steel and cement, in line with the ambition of the Net Zero Emissions by 2050 Scenario. These provide a starting point for discussion. The target for steel is higher than that for cement, as a considerable portion of the steel target could likely be met with fully scrap-based production. Supporting the proposal are four categories of actions that governments could consider committing to implement in order to realise the pledge, including through domestic policy implementation, as well as international co-operation, assistance and finance.

In considering such a pledge, Climate Club members could explore how to ensure commitment to the pledge can be formulated in a way that takes into account different countries' circumstances, and how international assistance can bolster possibilities for raised ambition. Additionally, to be effective, such a pledge would need to be followed through with implementation plans by signatories. This includes, in particular, the design and adoption of a robust portfolio of demand and supply-side measures tailored to the unique circumstances, budgetary considerations, competitive advantages, and policy objectives of each signatory.

An illustrative pledge on industrial decarbonisation

The illustrative pledge example for discussion, and its supporting actions (which are detailed in the report, along with considerations for discussion) are as follows:

Climate Club members could pledge to work together and develop supporting policies to contribute to reaching a share of 35% near-zero emissions steel and 25% near-zero emissions cement globally by 2035.

To bolster the high-level pledge, members could pledge to take further concrete actions, for which it would be for Climate Club members to decide together if the pledge implies committing to work on all of these actions collectively, or rather whether members would choose which of these supporting actions to commit to individually. Key areas of concrete action could include the following:

- **Creating near-zero emissions material demand:** including through setting ambitious targets for public procurement of near-zero emissions materials, and aggregating signals internationally, e.g. through signing up to or increasing ambition within the IDDI Green Public Procurement pledge; and through developing policy mechanisms to support increased private sector purchases.
- **Scaling-up of near-zero emissions material production:** including through finance mechanisms to enable first-of-a-kind “lighthouse” projects; policies to facilitate broader early commercial deployment; and supporting development of enabling infrastructure. This may include international co-operation such as targeted international financing and technical support in emerging markets and developing economies (EMDEs); sharing RD&D costs and learnings among governments for a portfolio of technology demonstrations; and international partnerships along value chains.
- **Encouraging new capacity additions to be near-zero emissions capable:** including through policies requiring that all projects built after a particular date, inclusive of those based on conventional technologies, have clear plans and technical capabilities for transitioning production to near-zero emissions without requiring a major reinvestment (if they are not already near-zero emissions from the start); and through ending international public finance of high-emissions production not related to the implementation of transition plans aligned with achieving net zero emissions by 2050.
- **Reducing production and use of high-emissions materials:** including through financial incentives or regulatory policies that facilitate the replacement or retrofit of existing high-emissions conventional facilities towards near-zero emissions technologies at the end of planned investment cycles; through developing a clear and ambitious schedule to reduce high-emissions production; removal of subsidies for emissions-intensive production; engaging in international discussions on possible collaborative actions to reduce overcapacity; or, on the demand-side, setting a date after which purchases of high-emissions steel and cement are no longer permitted.

Introduction

Achieving net zero emissions by mid-century in cement and steel sectors

Key message: The steel and cement sectors account for a large share of global emissions, and meeting internationally agreed government objectives for net zero by mid-century requires their decarbonisation. This would entail a rapid scale-up of near-zero emissions technologies and their supply chains, including a transition away from high-emissions conventional material production and use, facilitated by government support.

Limiting global temperature rise to levels consistent with internationally agreed government objectives requires a massive transformation of the global energy system to one that is consistent with achieving net zero emissions by mid-century, and all sectors must contribute. Global energy system emissions have not yet plateaued, reaching nearly 38 billion tonnes of CO_2 in 2023. Of this, the industrial sector is the second highest-emitting sector, producing both energy and industrial process emissions that account for nearly one-quarter of global emissions on a direct basis, and 40% if indirect emissions are also included. Meeting national and international net zero commitments requires that industrial emissions decline rapidly.

The steel and cement sectors have an important role to play in clean energy and industry transitions, being the two most emissive industrial sub-sectors. Together, their production makes up just over half of global industrial emissions (14% of global energy-related emissions on a direct basis). In the IEA's Net Zero Emissions by 2050 Scenario (NZE Scenario), emissions in these sectors decrease by over 20% by 2030, nearly 50% by 2035, and more than 90% by 2050 compared to current levels.

However, in such a scenario, global steel and cement production volumes remain at similar levels in 2050 as today, sitting at just under 2 Gt per year of crude steel and roughly 4 Gt per year of cement. These levels are sustained primarily by growing demand from emerging markets and developing economies (EMDEs), despite an increasing focus on material efficiency and circularity. Furthermore, these materials serve as critical inputs for infrastructure and consumer goods and lack scalable alternatives. Significant efforts are therefore needed to transform current production processes to those compatible with net zero emissions. Governments around the world have identified the opportunity to expand their clean energy manufacturing capacity, unlocking socio-economic benefits from building secure and resilient global supply chains that leverage regional advantages and enable participation in global markets that will increasingly prioritise clean energy.

The steel and cement sectors are particularly difficult to decarbonise due to the nature of their emissions, which result from high-temperature heat requirements and the inherent industrial processes used in conventional production. These emissions are largely generated during iron and clinker production, which are the most emissions-intensive steps for steel and cement production, respectively. Material efficiency and circularity, energy efficiency improvements, and switching to lower emissions fuels within conventional production routes, while necessary strategies, are incremental and insufficient on their own to fully decarbonise these sectors. While these strategies help lower energy and emissions intensity, they are unable to eliminate industrial process emissions nor provide globally scalable solutions for fully decarbonising high-temperature heat. Moreover, given that demand for steel and cement is expected to be robust for many decades to come, global availability of steel scrap and conventional supplementary cementitious materials will not be sufficient to wholly substitute iron and clinker.

Ultimately, "near-zero emissions" production routes that use transformational clean hydrogen-based processes, carbon capture and storage (CCS), direct electrification, and alternative raw materials must progressively replace emissions-intensive iron and clinker production. Such technologies are characterised by emissions intensities that are compatible with an energy system at net zero emissions. According to the IEA's definitions, for steel, near-zero emissions production represents an emissions intensity of 50-400 kg CO_2-eq per tonne of crude steel, varying according to scrap share of metallic inputs; for cement, it represents 40-125 kg CO_2-eq per tonne of cement, varying according to the clinker-to-cement ratio.

As a complement to this, "low-emissions" production that does not meet these thresholds but still provides meaningful emissions reductions can serve as a key interim measure. In some cases, low-emissions production can serve as an important step to develop and invest in transformational technologies, and ideally would incorporate technical capabilities to be converted to near-zero emissions in the future.

If aligning with the ambition of the NZE Scenario, near-zero emissions steel and cement would reach approximately 35% and 25% of their respective total market shares in 2035, and over 90% in 2050, up from essentially zero market share today. For steel this includes contributions from both iron-based and scrap-based steel. The transformation in market share would be driven not only by a scale-up of near-zero emissions technologies and their supply chains at an unprecedented pace, but also by a co-ordinated shift away from conventional production and continued efforts to deploy transformational low-emissions technologies. Such a concerted global transition would necessitate buy-in from all stakeholders, and complementary action across sectors can reinforce progress to bring solutions to scale. However, it is governments that play the critical role in providing the necessary enabling conditions and steering the industry transition along a trajectory for net zero emissions by mid-century.

Rationale to consider international co-ordination on demand- and supply-side measures

Key message: Targeted government support can help to overcome the multiple and complex challenges involved in scaling up near-zero emissions materials and reducing use of high-emissions materials. International co-ordination would allow governments to collectively send a stronger signal of their ambition for the industry transition to global markets than any country can do alone, while setting the basis for policy action and making progress easier to achieve for all. If a coalition of governments, such as the Climate Club, took on this challenge, it could act as a collective first-mover and drive progress to tear down market barriers for all actors, bringing benefits in terms of both climate progress and new economic opportunities.

The industry transition requires a transformational shift across its value chains, centred around a massive investment in near-zero emissions technologies that have not yet reached commercial scale, concurrent with reduced reliance on high-emissions production. An orderly transition across global fleets of steel and cement plants will be challenging, not least because in most settings near-zero emissions production will cost more than high-emissions conventional production. Furthermore, critical innovation gaps need to be closed. In the NZE Scenario, 35% of total emission reductions come from technologies that, while known, are not yet commercially available on the market. For heavy industry, this share is 50%. To ensure these technologies are ready for widespread deployment from 2030 onwards, accelerated efforts are urgently needed to demonstrate them at scale, bolstered by deployment of transformational low-emissions technologies.

Being among the first to shift to near-zero emissions production comes with significant risk, which exacerbates already high costs, causing the private sector and governments alike to hesitate on investments. The challenge is further accentuated by the international nature of industrial markets that leaves producers trade-exposed. Meanwhile, current challenges related to global excess industrial capacity are depressing market prices, creating challenging financial conditions for industrial producers and making it even more difficult to invest in near-zero emissions technologies.

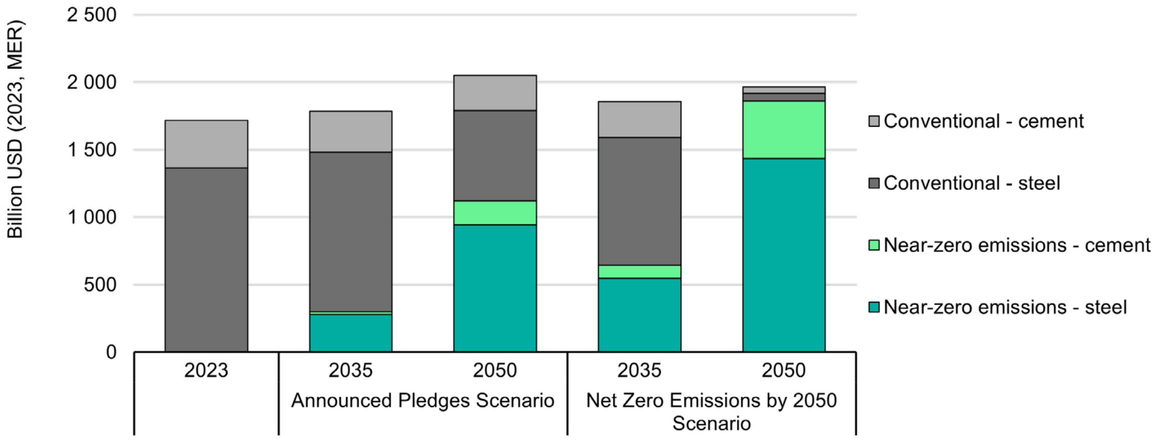
Despite this, some producers are taking steps to position themselves to compete in markets for near-zero and low-emissions materials. Early movers are starting to mobilise finance: the first facilities are set to come online beginning in 2025 and there are early signs of market formation with initial offtake agreements. Some industry associations are also developing definitions, certification and labelling systems for near-zero emissions steel and cement – in some cases through collaboration with government – like the Low Emissions Steel Standard initiated in Germany, the voluntary CO_2 standard of the China Iron and Steel Association, and the Global Cement and Concrete Association's definitions proposal. However, these first steps alone do not create a strong enough market signal to drive the level of investment needed to significantly grow the market share of near-zero emissions production.

Ultimately, policy supports are needed to de-risk investments in early deployment of near-zero emissions production at a commercial scale. While broader government policies, such as carbon pricing, are being implemented in some regions and can help send the right signal to markets for emissions reductions, current price levels are insufficient to make near-zero emissions production competitive with conventional production, nor is global coverage broad enough at this stage. Consequently, carbon prices alone do not provide the assurance necessary to create a robust business case for investment in higher-cost early deployments. Likewise, development of industry transition strategies can provide a high-level framework to guide policy development, and emerging common ground among proposals for standards and definitions can serve as a critical enabler of policy measures, but neither on their own are intended to directly incentivise near-zero emissions technologies.

To this end, targeted demand- and supply-side government policy measures are critical to provide first movers with the necessary market security and price certainty to drive market creation for near-zero emissions materials, while increasingly shifting away from high-emissions production. In fact, major industry players have begun calling on governments to implement such policies, for example through the open letter to government leaders co-ordinated by the Industrial Transition Accelerator and the call to action for governments and policymakers from the Global Cement and Concrete Association, both launched at COP29. According to the Business Breakthrough Barometer, 90% of leading businesses would invest more in clean technologies if stronger policies were in place.

Calls from industry to strengthen policies suggest that despite the challenges, industrial producers also see opportunities brought by the emerging clean energy economy. Near-zero emissions materials, in particular, can be a major economic opportunity. For near-zero emissions steel, the global market value would reach close to USD 300 billion (about 20% of today's total steel industry global market value) by 2035 if countries follow through with their climate pledges, with opportunities for advanced economies and EMDEs alike. The market would be even larger on a path to net zero by 2050, reaching close to USD 550 billion by 2035 and over USD 1 400 billion by 2050. For near-zero emissions cement, the global market could reach up to USD 100 billion by 2035 and up to approximately USD 400 billion by 2050, depending on the policy settings. Working together internationally would increase the likelihood of realising these opportunities and create possibilities of new competitive advantages for industrial players that may be facing challenges in the current market environment.

Global market size of near-zero emissions and conventional steel and cement by scenario, 2023-50



Notes: Assumed materials prices are derived using the evolution of levelised cost of production and demand in each scenario. Near-zero emissions steel includes both iron-based and scrap-based production.

Policy efforts will be stronger and more effective if multiple governments act together. Co-ordination and, where possible, alignment in policy ambition across jurisdictions can be an effective tool for reducing risks of international spillovers from mitigation policies such as carbon leakage and competitiveness concerns. This can help prevent situations in which a reduction in high-emissions production in one jurisdiction is neutralised by an equivalent addition of high-emissions production elsewhere. Meanwhile, co-operation can help create positive spillovers and help the transition advance more quickly. Analysis by the IEA found that weak international co-operation would delay the transition to net zero by decades. Heavy industry was identified as the sector most affected by low international co-operation, given its high exposure to international markets, as well as the need for large and capital-intensive technology demonstrations. In addition, low co-operation limits potential benefits from sharing of technology learnings to help reduce production costs and from strong market pull to accelerate decarbonisation. These factors can result in considerably slower demonstration and diffusion of technologies with limited co-operation. Consequently, in such a hypothetical case, heavy industry becomes the largest emitter by 2050, with 6 Gt of direct emissions remaining, equal to 40% of the global total emissions in that year. Shared global markets and the large innovation challenge make co-operation critical for industry.

A key component of co-operation for the industry transition is creation of larger international demand signals. When pooled together across borders, demand commitments can achieve a greater market scale to de-risk investments in supply. Investments in supply of near-zero emissions materials tend to be large and lumpy; that is, building a new million-tonne steel or cement plant is a large investment, that will likely supply many buyers over decade-long timespans. As such, aggregating demand from many buyers – including both public sector and private buyers – increases certainty and helps secure a business base for producers. Such efforts have started already, for example with governments collaborating on public procurement of near-zero and low-emissions materials under the IDDI. Still, progress needs to be widened to a larger number of countries and ambition needs to be raised overall in order to reach critical mass.

On the supply side, international knowledge-sharing on innovative technologies and collaboration on project development can help speed technology development and reduce costs. Historical experience on energy technologies – including solar, wind and electric vehicles – has shown international co-operation to be instrumental in reaching economies of scale on deployment more quickly, which has been key to cost reductions. International finance can facilitate accelerated deployment in multiple regional contexts, helping to achieve economies of scale on technologies across more regions and with increased speed. Policy co-ordination can also help share the policy burden, in that larger international markets for near-zero and low-emissions goods would reduce the extent to which individual governments may need to provide export subsidies for early producers. Meanwhile, co-ordination is needed to find solutions to challenges that are fundamentally global in their nature, such as how to address global excess high-emissions industrial capacity that has implications across international markets.

Valuable collaboration among governments on policy ambition can range from the high level to the detailed. At the high level, a collective international pledge can spur dialogue on raising ambition and already send powerful aggregated signals to markets. A collective pledge in this context refers to a joint statement made voluntarily by a group of governments at an international level, characterised by an ambitious shared goal – that is quantitative and time-bound where possible – and recommended supporting actions, ideally backed by plans for implementation through adequate policies and enabling conditions. At the more granular level, governments may choose to discuss possibilities for co-ordination and alignment of specific policy measures. These could include, among others, similar rates of subsidies under contracts for difference, comparable carbon prices, aligned emissions thresholds used in emissions intensity regulations, co-ordinated requirements within public procurement policies for near-zero and low-emissions materials, co-ordination of innovation funding to cover a balanced portfolio of projects, similar timelines for reducing reliance on and subsidies for high-emissions production, and co-ordinated trade policies for low-emission and/or high-emissions products.

The Climate Club – whose mission includes supporting effective implementation of the Paris Agreement and keeping 1.5 °C within reach – could consider taking the opportunity to lead in creating a strong collective market signal for the industry transition. Building on experiences made in other sectors, a first step could be to develop a collective pledge that aggregates the ambitions of members. This could be then actioned by implementation of demand- and supply-side policy measures, with the possibility to explore co-ordination among members. Collectively, the 46 Climate Club members (as of mid-March 2025) account for just over 25% of global production, and a slightly higher share for demand, in the steel sector; for the cement sector, they account for roughly 20% of production and demand. As such, they could play a crucial role as global first movers.

This report aims to provide evidence to help identify where government support could be useful for scaling up both demand and supply of near-zero emissions materials, to facilitate dialogue on international co-ordination around such measures, and to explore the possibility of a collective government pledge. Governments have numerous policy options at their disposal to help accelerate the industrial transition. Strong policy frameworks are likely to be those that diversify means of support by using a combination of different demand- and supply-side measures. As each government tailors their policy approach to their own country contexts, governments could together create larger, shared markets through co-operation and alignment of policy measures. Ideas and recommendations shared here are intended for consideration by Climate Club members as a starting point for discussions on collective ambition and co-ordinated action.

Demand-side measures

The rationale for demand-side measures

Diverse market barriers exist for buyers

Key message: Multiple barriers have emerged as buyers try to advance ambitions to procure near-zero and low-emissions materials and to meet supply chain emissions reductions targets. Cost is one of the largest barriers. The lack of cost-competitiveness of near-zero and low-emissions materials in most cases means that public sector aid is important for inducing demand and establishing markets.

Globally, momentum for the industry transition continues to build, with many governments and companies declaring targets for achieving net zero emissions at a national, subnational, or organisational level by mid-century. While direct and indirect electricity-related (Scope 1 and 2) emissions are receiving the most attention in global dialogue, there is a growing awareness among purchasers of the need to address their broader supply chain (Scope 3) emissions. This is particularly true for buyers of emissions-intensive materials like steel and cement.

In the public sector, efforts are progressing, with many governments undertaking measures to address emissions from government operations and procurement, including reducing embodied emissions from steel and cement used in publicly funded construction works. This includes international co-ordination and experience-sharing through initiatives such as the Net Zero Government Initiative, Greening Government Initiative, First Movers Coalition, and Industrial Deep Decarbonisation Initiative.

This momentum is also evidenced in the private sector through growing membership of platforms like the Science-Based Targets initiative (SBTi), through which companies can set targets for Scope 3 emissions reductions.[1] Of the over 10 000 companies using SBTi (as of March 2025), approximately 2 900 are from sectors that are primary buyers of steel and/or cement, 30% of whom have set

[1] SBTi works with companies to develop voluntary emissions reduction pathways and uses science-based evidence to verify the compatibility of a corporation's climate target with the goals of the Paris Agreement. It also encourages reporting and tracking of company-wide emissions.

targets for Scope 3 emissions reductions. Other initiatives such as the ResponsibleSteel Standard require that companies measure and report their Scope 3 emissions.

Despite the growing number of climate commitments, these governments and companies often face various unique barriers to adopting near-zero emissions materials. Such barriers often apply to low-emissions materials as well, albeit to a lesser extent. Therefore, while the following discussion references near-zero emissions materials, it is also relevant to low-emissions materials.

Organisations seeking to reduce their emissions and looking to buy near-zero emissions materials – or the resulting end-products – are often confronted with a higher price tag compared to conventional materials or products. This price uplift, known as the price premium (and sometimes called the “green premium”), can prove difficult for organisations to justify, even under a growing push to reduce emissions and emerging opportunities to establish early market presence. For instance, companies face continued pressure to minimise expenses and deliver larger profits, especially in publicly traded companies with obligations to shareholders, industries with narrow profit margins, and trade-exposed sectors subject to highly competitive global markets. This creates a competitive environment where buyers are incentivised to procure the lowest-cost materials. While not focused on profits, governments still face their own challenges. Competing budgetary priorities, fiscal spending constraints, accountability to the public, and obligations for the cost-efficient delivery of programmes and services all make public procurement of near-zero emissions materials difficult.

At the same time, there are practical limitations related to near-term availability of near-zero emissions materials and derived offerings of specialised products (for example, certain components of wind turbines), which can impede buyers who would otherwise be willing to adopt these materials. Lack of regulatory clarity around the industry transition can be a hindrance for buyers who are looking to limit their exposure to legislative risk, and in some cases can preclude the use of innovative materials, especially in construction and other industries where codes and standards are generally conservative. In addition, certain industries – often those that are highly regulated – tend to be risk-averse due to the potential for liability, which results in a slower rate of adoption for innovative materials for which performance may not be well-established. While more transparency related to environmental performance can support uptake, inconsistent data quality in emission-reporting schemes and a proliferation of labelling and certification schemes that can sometimes be difficult to understand can lead to further hesitancy from buyers. On an organisational level, there may be competing priorities that limit ability to procure near-zero emissions materials, especially in cases where there are limited financial resources.

Key barriers to purchase of near-zero emissions steel and cement

Consideration	Description of barrier
Purchase cost	Near-zero emissions materials typically carry a price premium compared to conventional materials, making their use less attractive to buyers who may not prioritise reducing supply chain emissions or who may need to respond to other stakeholder priorities. This is especially true for publicly traded companies that have a fiduciary responsibility to their shareholders, and governments which are accountable to the public. In industries with tight margins and/or trade-exposure, buyers may have limited ability to pay for higher-price materials or goods.
Availability of materials	Buyers may be willing to purchase near-zero emissions materials, even at price premiums compared to conventional materials, but are unable to do so due to insufficient availability on the market.
Regulatory environment	Buyers may be hesitant to commit to offtake agreements with suppliers due to regulatory uncertainty and exposure to risk from legislative changes around climate policy. This could be due to risk of repealing existing regulations due to shifts in domestic policy, lack of clear targets for near-zero emissions materials in regulations, or lack of sufficient regulations for the industry transition altogether.
Familiarity with materials	Buyers may be hesitant to adopt near-zero emissions materials due to lack of familiarity with their performance, supply chains and/or suppliers, especially for cement and concrete, due to the sector's diverse offerings of materials. This is despite, in many cases, equivalent performance of near-zero emissions and conventional materials. Some buyers may be unaware of these materials altogether.
Industry practices	Certain industries tend to follow conservative practices due to significant regulation, liability risk, capital intensity, and the high-stake nature of projects, which discourage the adoption of certain near-zero emissions materials, particularly those that have a different composition and/or higher cost. Common in public agencies, use of tendering practices where contracts are offered to the lowest bid can also make it difficult to procure higher-cost, near-zero emissions materials.
Existing design codes and standards	Existing design codes and standards may hinder or even preclude the use of near-zero emissions materials in certain applications, especially the use of cement in construction, in instances where the materials are of a different composition (and can potentially result in different performance) compared to more conventional compositions.
Standards and definitions for emissions intensity thresholds	Despite progress made by key initiatives, uncertainty and inconsistency around definitions of emissions intensity thresholds for what constitutes near-zero emissions materials may result in slower uptake from buyers who want a recognised level of environmental performance in exchange for paying a price premium. This includes uncertainty on the underlying emissions measurement and reporting methodologies, as well as a lack of a common or interoperable certification system.
Quality and credibility of data from suppliers	Due to difficulties in tracking and reporting emissions intensity data for materials, buyers may be unable to verify the accuracy or credibility of a material's performance. Further, they may face difficulty comparing materials using different standards or certifications, especially if there is a lack of transparency on the underlying data or poor data availability.
Organisational objectives	Some organisations might not yet include procurement of near-zero emissions materials in their operational strategy or may prioritise other goals instead. In some cases, organisations may want to procure these materials but are limited by internal policies or budgetary restrictions.

While all the aforementioned barriers contribute to reluctance from buyers, the price premium is often the biggest perceived impediment. Data from the 2024 Buyer Questionnaire (see box below) revealed that nearly 85% of respondents felt that higher cost was a key barrier to adoption of lower-emissions materials. In addition, a related 2024 survey of the construction sector by the Royal Institution of Chartered Surveyors (RICS) observed a similar emphasis on high costs. The result of this reluctance is a weakened demand signal to suppliers, who consequently are slow to invest in production facilities without the assurance of a guaranteed market. Targeting buyer uncertainty and finding ways to bridge the price premium, is therefore critical to inducing demand and kick-starting lead markets.

2024 Buyer Questionnaire

In July 2024, Ramboll and Climate Group conducted an online survey of global steel and concrete users, referenced in this report as the "2024 Buyer Questionnaire".

Survey questions were developed in collaboration with the IEA with the aim to better understand the market demand and outlook for near-zero and low-emissions steel and concrete. These included questions related to willingness to pay a price premium, as well as barriers and enabling factors to procuring lower-emissions steel and concrete.

In total, the survey received 259 responses across 42 countries and 21 sectors, with an over-representation of Europe-based organisations and more specifically, United Kingdom-based organisations. Of these responses, 18 self-reported as public authorities. The survey was voluntary and shared through Ramboll, Climate Group, and IEA networks, limiting the number of organisations that may have been aware of the survey and completed it.

Consequently, findings from this survey are referenced as indicative insights throughout this work but are not intended to be taken as a representative data set of global lower-emissions steel and concrete buyers.

Ramboll and Climate Group provide further findings through their joint study published on the topic.

Higher prices, in particular, restrict purchases

Key message: The elevated price of near-zero emissions materials is a result of higher capital investment, lending risk and production costs. The IEA estimates that costs of near-zero emissions production are higher than conventional production by 10% to 75% for steel, and 30% to 125% for cement, depending on the region and technology choice, driving the price premium encountered by early movers. While there is a willingness from some steel and cement buyers to pay a higher price to support decarbonisation, this is only up to a certain extent and not among all buyers.

The price premium, or price uplift, for materials produced using near-zero emissions technologies is partially a result of their early stage of development: there has not yet been sufficient time to establish robust supply chains and real-world operational experience necessary to optimise project development and technical performance. This high cost to producers – a product of the capital investment, contingency to account for high project and lending risk, and operating expenses – necessitates a market price well above that of conventional materials in order for producers to recuperate their investment. Policies like carbon pricing can help bridge the gap, as discussed further below, but are unlikely to be sufficient on their own at current carbon price levels, particularly for early deployments. Furthermore, while near-zero emission technology costs are likely to fall over time thanks to technology learning and economies of scale, higher costs relative to conventional technologies are likely to persist in many cases, even in the long-term for both capital expenses (e.g. use of CCS requires additional equipment, the purchase and resulting cost of which is simply avoided for production not using that equipment) and operating expenses (e.g. use of CCS necessitates additional energy consumption), and thus would require sufficiently strong policies to bridge the gap. Low-emissions materials carry a more moderate price premium and can facilitate market entry, but are ultimately interim measures.

The IEA estimates that in the absence of policy support (e.g. carbon pricing, subsidies), the production cost of near-zero emissions crude steel will typically carry a 10% to 75% premium compared to today's conventional crude steel production cost, varying with technology type and regional factors like energy and labour costs. On average across global regions and key technology options, this translates to a premium of approximately USD 225 per tonne of crude steel in 2030 – 40% higher than current conventional crude steel. Seller mark-up is not considered, meaning final price uplifts could be higher.

Although steel producers have yet to share price premiums for crude steel specifically, public announcements for steel end-products are indicative of general alignment with IEA estimates. In 2023, Stegra (formerly H_2 Green Steel) stated that their steel will have a premium of 25%, while SSAB estimates they will charge a premium of EUR 300 (USD 315) per tonne of its SSAB Zero steel, which encompasses the costs of carbon pricing, production and value-added by the product. For crude steel, similar analyses from Mission Possible Partnership, World Economic Forum, and IEAGHG report comparable figures to IEA estimates.

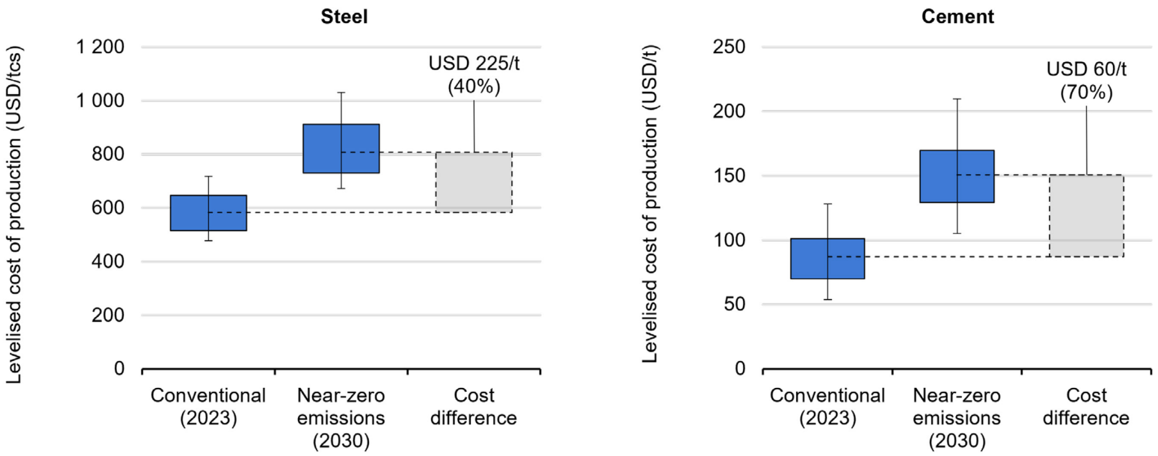
Similarly, the IEA estimates that the production cost of near-zero emissions cement will typically carry a premium of 30% to 125% compared to current conventional cement production cost, depending on regional and technological factors. Globally, this would add an average premium of USD 60 per tonne of cement – 75% higher than current conventional cement (without consideration of seller mark-up). For concrete, the premium is expected to be smaller since cement accounts for only a portion of concrete production costs; however, it is still significant, with Mission Possible Partnership estimating a 15% to 40% premium for low-emissions concrete.

Producers have yet to announce price premiums for their near-zero emissions cement or concrete, although available company estimates of achievable production costs could be indicative. For example, an analysis from Leilac estimated a cost increase of EUR 54 (USD 57) per tonne of CO_2 avoided for their innovative CCS technology applied to cement, or roughly USD 30-45 per tonne of cement (which would imply a roughly 35-50% premium). Analyses from Mission Possible Partnership, World Economic Forum, and RMI report similar premiums.

Despite this price premium, some buyers are still indicating a willingness to purchase near-zero emissions materials. Data from the 2024 Buyer Questionnaire reveals deeper insight here. For deep decarbonisation of steel and concrete to levels compatible with near-zero emissions, just over half of buyers overall indicated they would be willing to pay up to 25% more compared to conventional materials. This willingness differs regionally, with roughly twice the share of buyers in Europe being willing to pay up to a 25% premium for near-zero emissions steel compared to non-European buyers. For near-zero emissions concrete there is a similar trend, although the disparity is not as large. For both steel and concrete, across all regions, there were fewer willing buyers for these materials as premiums increase, with only one-fifth of buyers willing to pay up to 50% more and less than one-tenth willing to pay 75% more. Another survey by McKinsey arrived at similar conclusions, while also noting sectoral trends like the willingness from the automotive sector to pay a higher price premium. Consistently higher premiums in Europe were also reported, underscoring the effect of regional factors.

These early-mover buyers are key to seeding demand that can help build momentum in markets for near-zero emissions materials, especially in sectors and regions where willingness is higher. However, these buyers lack the scale to send a sufficient demand signal and alone are unable to take on the full risk needed to form robust lead markets. Moreover, certain buyers may have the budgetary tolerance to only partially cover the price premium, meaning the remainder must be covered through other means.

Indicative levelised cost of production for conventional in 2023 and near-zero emissions steel and cement in 2030 in the Net Zero Emissions by 2050 Scenario



Notes: tcs = tonne of crude steel. Levelised cost of production (LCOP) for 2023 conventional production and 2030 near-zero emission production. Estimates are based on regional averages and cover various technologies. Costs do not include any policy supports, e.g. carbon pricing or subsidies. The box represents the range of expected typical LCOP values, while the whiskers include the average LCOP in higher- or lower-cost regions. The cost difference represents the cost differential between the average global LCOP for near-zero emissions production in 2030 and conventional production in 2023.

Market formation requires bridging larger near-term gaps

Key message: In the near term, targeted demand-side measures need to be introduced to overcome initial barriers and kick-start formation of lead markets for near-zero emissions steel and cement. Governments could play a crucial role here. Once strong demand and strong supply chain linkages are established, it may be possible for steel and cement buyers to pass through higher costs to customers with minimal impact on end price, helping to share risk across the supply chain. Eventually, in the NZE Scenario, the price gap between near-zero emissions and conventional materials is closed as the market matures and policies scale up to bridge the remaining gap in the long-term.

Carbon pricing can be an effective tool for reducing the price premium, putting a price on pollution and making more emissions-intensive production less cost-competitive. This is especially true as carbon prices rise over time, and as learning effects simultaneously lower the cost of transformational technologies, which can even be further reinforced and accelerated by mechanisms such as revenue recycling targeting technology innovation. In the NZE Scenario, carbon prices (and/or other policies with implicit carbon prices) are assumed to increasingly help close the price gap between near-zero and emissions-intensive production, largely by increasing the cost of conventional, higher emitting production. Regional variability in carbon pricing means that the price premium is addressed to differing degrees in different regions in the medium-term. With carbon pricing assumed to continue increasing in all regions, and to expand in regional coverage over time in the NZE Scenario, it can provide an increasingly level playing field for near-zero emissions and low-emissions materials to start emerging as the preferred business case.

In the interim, one approach to help address the price premium is for buyers of steel and cement to pass through the additional cost of materials to customers of end-products like cars and houses. This is possible particularly because the knock-on effect of the price premium for steel and cement on consumer end-prices is generally small, given that materials account for a relatively small share of total costs for end-products. Furthermore, a survey of consumers conducted by Boston Consulting Group revealed that there is a willingness to pay a price premium on end-products, to an extent. In 2030 in the NZE Scenario, the cost of typical clean energy technologies such as electric cars, heat pumps, wind turbines, and solar photovoltaics increases just 0.2-5.5%, due to fully switching to use of near-zero emissions steel and cement. Similarly, residential housing sees an increase of only 0.7-2.6%. Other analyses have found similar results for buildings, cars, ships and white goods.[2] True cost pass-through may be slightly higher as successive companies in a supply chain raise prices to maintain cost markups, but this effect is unlikely to be substantial.

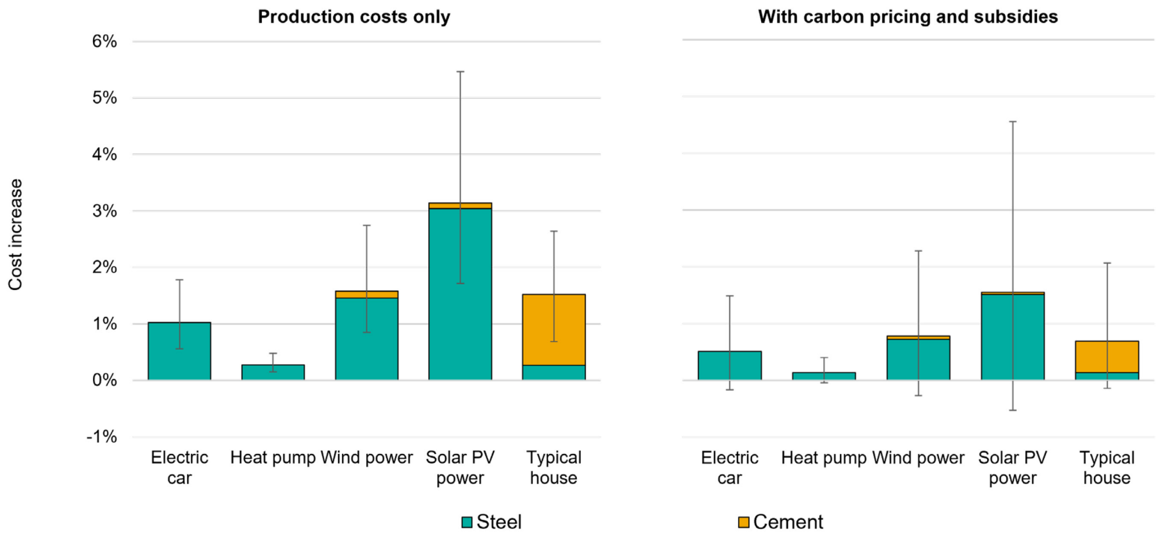
Cost pass-through may be easiest to do in sectors with many companies offering differentiated products, such as the automotive and home appliance manufacturing sectors. These markets tend to have companies with strong consumer brand loyalty and that offer products with competitive advantages beyond cost alone, allowing them to retain their market share in cases of modest

[2] European Federation for Transport and Environment (2024), Cleaning up steel in cars: why and how?; Transition Asia (2024), Green Steel Economics; IEAGHG (2024), Clean steel and environmental and technoeconomic outlook of a disruptive technology; Mission Possible Partnership (2023), Making Net-Zero Concrete and Cement Possible; Mission Possible Partnership (2022), Making Net-Zero Steel Possible; World Economic Forum (2024), Net-Zero Industry Tracker 2024.

price increases. They may even gain market share from sustainability-minded purchasers who may allocate a portion of their discretionary income to these products.

Meanwhile, cost pass-through can also be possible for other sectors where the product involves large labour costs and high overall investments, as is the case with construction. For these reasons, the added premium from the material costs of near-zero emissions steel and cement can, in many cases, fall well within the typical tolerance for cost variability. In addition, one survey suggests that buildings with sustainability features are already attracting higher valuations and rent premiums compared to less sustainable buildings, allowing companies to offset any higher material costs.

Cost increase of selected clean energy products from passed-through production cost as a result of switching from conventional to near-zero emissions materials, and the effect of carbon pricing and subsidies on cost pass-through in the Net Zero Emissions by 2050 Scenario, 2030



Notes: Capital costs in 2030 for clean technologies follow the reductions of the Net Zero Emissions by 2050 Scenario, and are based on 2021 capital costs of typical products, which are USD 36 000 for an electric car, USD 11 000 for a heat pump, USD 2 860 per kilowatt (kW) of offshore wind power, USD 880 per kW of solar PV power, and USD 300 000 for the construction of a single-family home. The assumed material intensities are global averages and constant over time. Capital cost increases are derived from the difference in production cost between near-zero emissions and conventional steel and cement, following the methodology provided in the figure presented in the previous section. The bar represents the global average cost increase, while the lines account for the average cost increase in higher- or lower-cost regions. For each clean technology, the left panel represents the cost increase without inclusion of any policy support (e.g. carbon pricing or subsidies) and the right panel represents the cost increase with inclusion of policy support. Carbon price is based on the global average in the Net Zero Emissions by 2050 Scenario.

Other supply chain considerations could help reduce the price premium in these end-products, making the cost pass-through more palatable to customers. Especially in the near term, limited availability of near-zero emissions materials will likely lead to only partial substitution of conventional steel and cement, resulting in lower cost pass-through, at least initially. Furthermore, sharing the price premium across the supply chain could reduce the premium faced by consumers, but would require companies to forego a portion of revenue. Mechanisms such as better supply chain co-ordination and/or agreements may be needed to make sharing the cost pass-through feasible, given that there would still be a price uplift at the various points of intermediate product sale along the supply chain, but this should not be an insurmountable problem.

Regions with strong carbon pricing and innovation support could see even lower price premiums. In 2030 in the NZE Scenario, when accounting for the effect of carbon pricing, the cost pass-through for the applications previously noted is on average halved globally and even drops to zero in certain regions where carbon pricing is high. Finally, end-users of products derived from steel and cement can employ best-available design and material efficiency measures to lower overall costs, potentially increasing their capacity to absorb this cost pass-through.

At present, however, steel and cement buyers, in many cases, face difficulties in bearing the costs and risks that underlie the price premiums on near-zero emissions materials. This is due, among other reasons, to uncertainties during the market formation stage around how the premium is shared across complex supply chains and how end-customers would respond to higher prices. This is in addition to other demand-side barriers that hamper market formation, as noted earlier. To get markets moving, government-led measures can target these barriers to alleviate some of the risk and cost burden faced by early movers, and help start making stronger collaborations across supply chains, until such time that other policies and market dynamics take over and steel and cement markets reach a new equilibrium.

Progress to date and lessons learned

First-mover offtakes show promise but are not yet sufficient

Key message: Private sector offtake agreements from first movers are emerging and serve as key models for prospective buyers of near-zero emission materials. However, they are not able to offer demand at the scale needed for the industry transition. These agreements reveal regional gaps, with Europe accounting for most of the global demand, and show that demand for near-zero and low-emissions cement lags steel. Despite this relatively slow and uneven growth, there are indications that additional and more regionally diverse underlying demand exists for both steel and cement, for which policy could help overcome barriers that are currently preventing it from being realised.

Some individual first-mover buyers in the private sector have shown willingness to purchase early offers of near-zero emissions materials on the market. The private-sector offtake agreements now emerging can help serve as templates of purchasing strategies for near-zero and low-emissions materials.

For near-zero emissions steel, there are now over 70 private sector commitments from 47 companies, of which 49 are publicly announced offtake agreements. However, over 80% of these agreements have been made with just three producers: Stegra, SSAB, and Salzgitter. Furthermore, just one-third of the offtake agreements disclose information on quantities or values of steel, which together account for approximately 1.5 Mt per year of steel offtake by 2030.[3] This falls well short of the approximately 110 Mt of near-zero emissions iron-based steel in 2030 in the NZE Scenario.

Demand to date has also shown uneven growth globally: roughly half of the announced offtake agreements come from the automotive sector or suppliers within its supply chain. Furthermore, nearly all offtakes are from buyers located in Europe. This is corroborated by the observed higher willingness of European steel buyers to pay a price premium in the 2024 Buyer Questionnaire and perhaps to an extent the regional availability of near-zero emissions steel (discussed later in the report).

Progress in the cement sector has been slower compared to steel. Just two commitments for cement that is likely to qualify as near-zero emissions have been publicly announced to date, with no stated quantities, coming from one supplier with relatively small production volume: Sublime Systems. Factors likely contributing to this include a comparatively smaller number of projects that would meet near-zero emissions thresholds and are sufficiently advanced, as well as supply chain complexities (e.g. cement is less traded globally). In some cases, lack of full confidence on the quality and comparability of emissions data may hinder connections between potentially interested supply and demand actors. Unlike steel, some near-zero emissions cements could have differences in chemical composition, which may raise uncertainties around performance, particularly for first adopters, which may also be driving slower adoption.

Progress has been stronger for low-emissions materials when compared to near-zero emissions. Low-emissions materials are important in the industry transition as they enable partial emission reductions and, in some cases, are a step along a path to develop transformational technologies, facilities and value chains that could later transition to near-zero emissions. There are a growing number of offtake agreements for low-emissions steel and cement, which features a larger

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[3] Some offtake agreements are made for a given value of steel rather than a quantity; for these, an estimate was made on the value per tonne of near-zero emissions steel to convert to a quantity.

share of buyers from outside Europe compared to those for near-zero emissions materials. While some of these include already existing lower-emissions technologies, others support development of transformational technologies. One notable example of the latter comes from Heidelberg Materials, who has launched their evoZero marked cement that employs CCS. This product will initially be produced in the Brevik project (Norway), where CCS reduces about half of the cement's emissions, meaning it would therefore be considered low-emissions. The brand will likely later be expanded to other CCS-enabled facilities, and at that stage may also include fully near-zero emissions cement.

There is evidence that underlying demand already exists, even in regions and sectors that are under-represented by announced offtake agreements. Responses to the 2024 Buyer Questionnaire reveal that Asian buyers generally have the same level of ambition as European buyers for procuring steel and concrete that have lower embodied emissions than conventional materials. Moreover, similar rates of buyers in Europe and Asia – roughly one in every seven – target deep emission reductions when procuring lower-emission steel and concrete. These trends may exist in other regions as well, particularly North America, but there was insufficient data to draw meaningful conclusions. This underlying demand may not yet be realised due to the various barriers discussed previously, which targeted government efforts could help overcome.

Alternative chain of custody models – in which the physical product is partially or fully disconnected from its emissions-related attributes – are emerging as a potential route to facilitate increased demand and connections to supply for near-zero and low-emissions materials. One such model is book-and-claim, which would enable the emissions attributes of near-zero or low-emissions materials produced in one part of the world to be sold to an interested buyer in another part of the world. This model may be particularly useful for cement, since it is less frequently traded, and could open new opportunities for international support of projects in EMDEs. Another model is the use of emissions reduction certificates, also sometimes referred to as a mass balance approach, which aggregate partial emission reductions and then label a subset of their production as lower emission.

Such alternative chain of custody approaches can be useful in certain instances to spur markets for low-emissions materials and even support the development of transformational technologies. However, they should be used judiciously, include robust third-party verification systems, and be communicated transparently, particularly in terms of whether the resulting product comes from conventional or transformational production methods. Otherwise, there may be a risk of diverting attention and investment away from transformational technologies that can achieve near-zero emissions, as well as the double-claiming of emissions reductions. Governments may want to consider such approaches carefully and set guardrails on their use. Ultimately, near-zero emissions materials – and not only low-emissions materials – are critical for attaining an industry sector consistent with net zero emissions by mid-century.

Private sector demand aggregation initiatives continue to expand

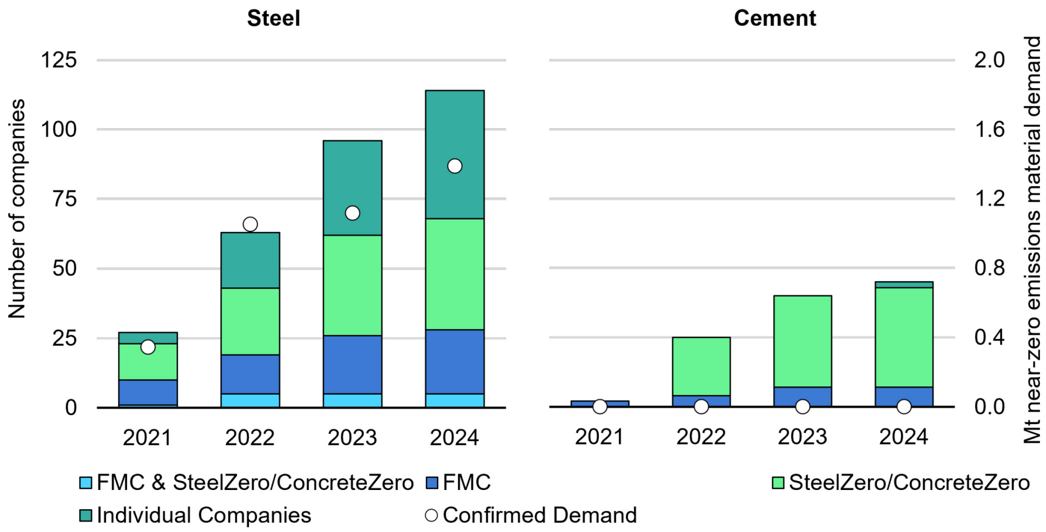
Key message: Private sector demand aggregation initiatives have helped to reveal underlying demand for near-zero and low-emissions materials, while simultaneously sending larger market signals to suppliers to support market formation. Membership for these voluntary commitments has seen strong growth since inception, but they have resulted in a lower number of offtake agreements than expected and still have some regional and sectoral gaps in membership.

Revealing underlying demand can play an important role in accelerating market growth, and efforts have already commenced through private sector-led initiatives. In the First Movers Coalition (FMC), members can make commitments to procurement targets that align with near-zero emissions steel and low-emissions cement or concrete. Through the SteelZero and ConcreteZero initiatives, members can commit to procurement targets that align with low-emissions materials in the near term and near-zero emissions materials in the long-term. Importantly, these demand aggregation coalitions help to amplify the market signal sent to suppliers.

Membership in these initiatives has grown substantially since their launches in the early 2020s. A total of 68 companies have taken up steel commitments through these initiatives: 28 through FMC and 45 through SteelZero (with 5 companies taking up both). Meanwhile, commitments for cement and concrete now reach 43 companies in total: 7 with FMC and 36 through ConcreteZero.

In addition to these coalitions, supporting activities to help spur private sector demand scale-up are also underway. Schemes such as the FMC's First Suppliers Hub and RMI's Sustainable Steel Buyers Platform (SSBP) provide platforms to connect suppliers with buyers and bring attention to supply of near-zero emissions materials and value chain projects, facilitating partnerships for market growth. This includes potentially bringing together multiple buyers to support an offer by one steel producer, which could be a helpful aggregation, given that one buyer alone may be unlikely to cover all demand of a steel production facility. For example, as part of a recently launched request for proposals, SSBP members are seeking bids to meet their demand of 1 Mt of near-zero emissions steel starting in 2028. Another initiative, the FMC Near-Zero Steel 2030 Demand Challenge, aims to surface demand for near-zero emissions steel by collecting expressions of interest for its purchases. By January 2024, the challenge reported submissions representing an aggregated volume of 2.3 Mt. The expressed demand from these two initiatives, as well as the already committed 1.5 Mt of demand from offtake agreements mentioned above, amounts to as much as nearly 5 Mt of quantifiable demand, which is estimated to have a combined value of roughly USD 3.5 billion. Another option that has been proposed to facilitate demand scale-up are "Green Market Makers" – intermediary actors that help overcome early market failures to facilitate supplier-buyer connections. Industry sector applications of this option could potentially draw learnings from models in other sectors such as the H2Global mechanism for hydrogen.

Number of companies committed to purchase near-zero or low-emissions steel, cement or concrete, and announced demand for near-zero emissions materials by 2030



Notes: FMC = First Movers Coalition. Based on announced figures as of March 2025. For the steel commitment, FMC members commit to purchase near-zero emission steel by 2030. For the cement and concrete commitment, FMC members commit to purchase low-emissions cement or concrete by 2030. SteelZero members commit to purchase lower-emissions steel by 2030 and net zero steel by 2050. ConcreteZero members commit to purchase lower-emissions concrete by 2025 and 2030, and net zero concrete by 2050. Individual company commitments include publicly announced commitments of the purchase of near-zero emissions steel by 2030, including letters of intent, memoranda of understanding, and offtake agreements. Companies are only counted once, regardless of membership in multiple initiatives or number of purchase commitments. Confirmed demand includes announced quantities of near-zero emissions steel and cement. Some offtake agreements are made for a given value of steel or cement rather than a quantity; for these, an estimate was made on the value per tonne of near-zero emissions steel and cement to convert to a quantity.

Identifying and matching potential supply and demand is an important step, but it does not constitute a committed offtake agreement, for which progress remains sluggish. Only 9 of the 95 companies who have joined either FMC, SteelZero or ConcreteZero have signed public offtake agreements for near-zero emissions materials. Together, they account for just 20% of publicly announced offtake agreements for near-zero emissions materials, constituting less than half the total volume of publicly committed demand. The rest of these offtakes come from companies not committed to these initiatives (discussed in the previous section). Despite this, more notable progress through these initiatives may emerge later this decade, as members advance towards the 2030 targets for these commitments.

These initiatives also require support to enhance their regional and sectoral representation: nearly 80% of companies come from Europe and over half represent the construction and engineering sector. As these initiatives continue to grow and reach a broader audience, member diversity should expand. Still, it is unclear if they alone will be able to fully encourage global participation at the pace and scale needed for the industry transition.

Governments are starting to develop various demand-creation measures

Key message: Governments are well-positioned to help buffer the risks associated with earlier stages of market formation. Targeted public demand-side measures are ultimately needed to stimulate global demand and support lead market creation by offering large market signals for near-zero emissions materials. Although many measures are still at early stages of implementation, there are clear examples to build upon.

To ramp up substantial demand for near-zero emissions materials globally, targeted public support measures are ultimately needed to fill in gaps that the private sector alone cannot address. First suppliers are looking for buyer certainty through long-term offtake agreements, but elevated and volatile costs amplify buyer risk during market formation. Governments are well-positioned and, at least in some cases, already ready to take on this risk: in the 2024 Buyer Questionnaire, public authorities, mainly European, exhibited a higher willingness to pay a price premium, with well over three-quarters willing to pay up to 25% more compared to conventional materials (in comparison to about half among private sector respondents). Demand-side policy measures are already being introduced around the world and selected examples are explored below in the context of lead market creation.

Targeted measures for stimulating demand for near-zero emissions materials are necessary to increase market share, especially in the near term when conventional materials are still the dominant market offering. Public procurement can serve as a considerable market signal by leveraging the substantial purchasing power of governments and by providing the private sector with a proof-of-concept for procuring near-zero and low-emissions materials. According to the

Clean Energy Ministerial Industrial Deep Decarbonisation Initiative (IDDI), the public sector accounts for 25% of steel and 40% of concrete demand globally, although demand varies significantly by country. To date, public procurement policies have been a major focus of government demand-creation efforts.

While some existing public procurement policies already target materials with better-than-average emissions intensity, most only provide suggested thresholds or lack targets for steel, cement, and/or concrete altogether. Momentum is growing for inclusion of mandatory emissions intensity thresholds in public procurement, but there is still a lack of targeted support for near-zero emissions materials. Instead, policies legislated to date are largely aiming for overall reductions in embodied emissions or thresholds for "lower" emission materials. This tends to drive the use of scrap and clinker substitutes rather than transformational near-zero emissions steel and cement, respectively. Clear plans to increase threshold stringency and integrate specific measures for procuring near-zero emissions materials would help provide a stronger demand signal to markets for deeper emissions reductions. Beyond mandatory thresholds, near-zero emissions materials could be also targeted using other public procurement mechanisms such as discounted tender prices for projects that use these materials.

Significant work is being done by the IDDI here. This international coalition, currently with ten member countries, works to stimulate demand for near-zero and low-emissions materials while helping governments navigate key considerations around implementing public procurement policies that target these materials. For example, procurement rules are often complex and procedural, making it challenging to introduce sustainability elements into existing frameworks. Updates to these rules require careful co-ordination of internal procedures across agencies and policies, while maintaining alignment with international treaty requirements. International experience sharing in the IDDI is helping address these challenges. Further details and discussion on the progress made in the IDDI is provided later in this report.

A variety of policy levers – which include but are not limited to those related to public procurement – could be used to support demand creation. Some examples of existing policies are listed below, including those that target either or both of near-zero and low-emissions materials, and each type of policy measure is further detailed in the next section, along with their advantages and disadvantages:

- **Public procurement policies with defined emissions intensity thresholds** for near-zero and low-emissions materials, either mandatory or voluntary, include Thailand's Green Public Procurement and Green Label Scheme and Türkiye's Communiqué on the Promotion of the Use of Green Cement with Low Carbon Emission in Public Procurement Contracts. Similarly, Australia's Environmentally Sustainable Procurement Policy and Reporting Framework requires disclosure of emissions for embodied carbon in public procurement.

- **Contracts for difference** schemes can be designed to directly address the price premium. For example, Germany's Carbon Contracts for Difference (CCfD) programme subsidises production facilities to enable the materials they produce to be sold at market value (see more details on this policy in the box below).
- **Regulatory measures** are also gaining prominence, such as Denmark's National Strategy for Sustainable Construction, Finland's Building Act, France's RE2020 environmental regulation, and the European Union's Ecodesign for Sustainable Product Regulation and revised Energy Performance of Buildings Directive. These policies either set, or look into establishing, emissions intensity thresholds on materials or end-products. Such policies are typically designed with a clear schedule for increasing threshold stringency to incentivise continued emissions reductions without excluding use of low-emissions materials in the near term.
- **Labelling and certification schemes** for steel, cement and concrete, while often industry-led, have also been supported by governments in some instances. The Low Emission Steel Standard (LESS) labelling and certification system for steel was developed in partnership between the German government and industry through a broad consultation process. Other national schemes include China Iron and Steel Association's Low-Carbon Emission Steel Evaluation Method and India's Taxonomy of Green Steel.
- **Incentives to promote private procurement** are an emerging policy type, with Japan recently announcing a new subsidy for clean energy vehicles built with low-emission steel.
- **Pre-commercial public procurement programmes** that **target innovative materials** can help to provide a proof-of-concept. One key example is the European Union's Horizon Europe funding for innovation procurement. Materials produced from pre-commercial technologies can also be supported through mechanisms that allow advanced market commitments, such as the United States' proposed IMPACT 2.0 Act introduced as a bill in 2024.
- **Material circularity measures**, despite providing much weaker support for near-zero emissions materials, can promote market demand for materials with better-than-average emissions intensities. Examples include India's Steel Scrap Recycling Policy that promotes use of scrap steel, and the United Arab Emirates' Ministerial Decree No. 21 of 2019, which promotes the use of recycled materials from construction and demolition waste.

Alongside targeted policies to kick-start demand, economy-wide measures can provide a complementary broader market signal for emissions reductions and help shift the competitive landscape towards cost-effective near-zero emissions materials in the longer term. In addition, they offer a solid foundation for countries to build industrial decarbonisation strategies. **Carbon pricing**, for example, had been implemented across 93 national and subnational jurisdictions as of February 2025. In some cases, carbon pricing schemes can provide more targeted support for industry, with schemes such as the New Zealand Emissions Trading Scheme (ETS), Korea's ETS, or the EU ETS targeting large emitting industrial facilities.

More recently, the People's Republic of China (hereafter "China") has announced plans to expand sectoral coverage of its national ETS to cement and steel. With proper scope and stringency, carbon pricing can shrink the cost gap to conventional materials and make near-zero emissions materials the default business case in mature markets.

Carbon pricing can be supplemented with measures that aim to minimise spillover effects and carbon leakage that could slow the industry transition. The most prominent example of this to date is the European Union's Carbon Border Adjustment Mechanism. Discussions on this type of policy have also arisen in other regions such as Australia, Canada, and the United Kingdom. At present, the impacts and effectiveness of these policies on global markets and trade are not yet fully understood, meaning international co-operation is important during implementation of such policies to help maintain and foster trade relationships in support of the industry transition. This is especially necessary with EMDEs that may not have the means to decarbonise as rapidly, nor well-developed technical capacity for emissions reporting. Other knowledge gaps that can be more effectively understood and addressed through a co-operative approach include equivalency of non-ETS policies in third countries and at which point in the supply chain application can best balance the trade-offs between effectiveness and data reporting burden. In parallel, increased discussions on international technical assistance and finance – including those taking place in the Climate Club – may raise ambition on decarbonisation globally, helping lower risks of carbon leakage. Researchers have also outlined other policy options that could help encourage a level playing field, such as climate contributions.

Policy options to accelerate progress

Key message: Governments have a variety of policy options that could be developed and adapted to specific domestic circumstances to accelerate demand growth for near-zero emissions materials, including direct financial support, minimum content regulations, policies that set embodied carbon limits, revised design standards, and labelling and certification. In all cases, carbon pricing can complement and bolster these policies, helping to stimulate additional demand.

Demand-side policies aim to help secure a buyer or otherwise facilitate a market for near-zero emissions materials, or products made from those materials, despite higher prices. Although many industrial products are globally traded, domestic market dynamics and other circumstances can vary across regions. As such, any government aiming to strengthen demand for near-zero emissions materials could design a suite of demand-side measures that is appropriate for their domestic industry and government's preferred approach. As discussed, policies that specifically target demand creation are particularly important during the early stages of market formation, and are complementary to broader policies like carbon pricing, which on its own is likely insufficient to overcome barriers for first movers.

Due to the current risks, costs and uncertainties associated with procuring near-zero emissions materials, buyers are looking for policy certainty to ensure they can maintain competitiveness in a transitioning market. Policies deemed most helpful for accelerating procurement of lower-emissions steel and concrete were identified in the 2024 Buyer Questionnaire. Among those recognised as most helpful were embodied carbon limits or minimum standards (45% of respondents); green building codes (30%); and green public procurement (30%). Levers related to reporting transparency were also recognised, with modest support for making environmental product declarations mandatory (25% of respondents).

Key policy options highlighted here draw from the IEA's Policy Toolbox for Industrial Decarbonisation. Other recent analyses on demand-side measures offer additional perspectives on the topic, including the Industrial Transition Accelerator's Green Demand Policy Playbook and Agora Industry's report on demand-side policy options for creating markets.

Key demand-side policy options for near-zero emissions steel and cement

Policy option	Description
Public procurement policies for near-zero and low-emissions materials	May require a certain emissions intensity for materials purchased through public procurement, or otherwise incorporate CO_2 considerations into procurement. Can provide a substantial market for near-zero emissions materials by using the purchasing power of public bodies, despite potential higher prices. Benefits: size of public procurement can provide considerable demand certainty; could provide proof-of-concept to help spur private procurement. Limitations: procurement frameworks are procedural and difficult to update; budgetary limitations may constrain the possibility to set ambitious CO_2 requirements; as governments typically procure construction materials through one-time project contracts, it may not provide the same level of long-term certainty as longer-term offtake agreements.
Contracts for difference (CfDs)	Contractual agreements that provide a guarantee to cover the cost differential of carbon abatement and/or related energy inputs, relative to some baseline for a fixed period, typically between 10 to 20 years. Acts as a hedge through which the government absorbs price uncertainty resulting from near-zero emissions production. In addition to their utility as a supply-side measure, CfDs can be designed to function as a demand-side measure by covering the price premium that would otherwise be paid for by buyers in the absence of the policy.

Policy option	Description
Contracts for difference (CfDs) (continued)	Benefits: guarantees cost-competitiveness of near-zero emissions materials; provides longer-term price certainty to support . Limitations: can be relatively expensive for governments, who cover the entirety of the price premium; requires a clear metric to index the strike price.
Near-zero emissions materials minimum content regulations	Regulates a minimum and growing amount of near-zero emissions materials that must be met in a market by establishing purchasing requirements on the buyer side. Benefits: compliance requirements provide a clear, investible demand signal for near-zero emissions materials; can be designed to align with a trajectory consistent with a government's climate goals. Limitations: could lead to higher prices for customers; can create some market distortion if demand and supply are not well-matched.
Embodied carbon limits for final products and carbon product requirements	Imposes an upper limit on the emissions intensity of either the materials going into an end-product (embodied carbon limits for final products, for example on buildings or vehicles) or a material itself (carbon product requirements on steel or cement). Typically, the stringency of these limits is increased gradually to drive continued emissions reductions. Benefits: gives transparent requirements on emissions intensity performance level of products, helping create a pull and strengthening the business case for investment in increasingly lower-emission production; could be adopted across jurisdictions to align the pace of decarbonisation or tailored by an individual country to their own circumstances. Limitations: may not create a sufficiently strong pull for demand of near-zero emissions materials in the near term; in the case of steel, could increase demand for scrap to unsustainable levels; may drive up prices in the market, particularly in the case of carbon product requirements that set an absolute limit on emissions intensity and do not offer any flexibility mechanism; to be implemented effectively, requires high-quality data with clear measurement and reporting of emissions across the supply chain.
Revised design regulations and standards	Modifies existing design regulations (for example, building codes) to help remove barriers to the use of innovative near-zero emissions materials while ensuring they meet requirements for durability, quality and performance. These regulations are related to the composition and performance of materials (especially cement) and are distinct from other regulations that impose emissions intensity requirements. Benefits: could help unlock latent demand that may have been held back by regulatory barriers; could promote material efficiency measures that lead to additional emissions reductions. Limitations: industry conservativeness can lead to slow adoption of changes in standards; removes barriers to certain innovative materials but does not necessarily lead to increased adoption.
Labelling and certification schemes	Helps provide transparency on the emissions intensity of a material or product, allowing buyers to more easily make purchasing decisions. Can be integrated with chain of custody models to provide supply chain tracking. Can be voluntary or compulsory. Benefits: increased transparency around emissions intensity performance; can leverage existing certifications schemes.

Policy option	Description
Labelling and certification schemes (continued)	Limitations: does not establish a requirement to buy near-zero emissions materials; requires high-quality data with clear measurement and reporting of emissions across the supply chain to be implemented effectively.
Incentives to promote private procurement	Encourages buyers (e.g. car manufacturers, construction companies) to purchase and use lower emissions materials. Benefits: helps overcome the price premium for near-zero and low-emissions materials; would likely be more well received by purchasing companies than mandatory regulations. Limitations: could be relatively expensive for governments, depending on the amount and coverage of the incentive and especially if targeting near-zero emissions materials specifically; does not guarantee that buyers will choose to purchase near-zero or low-emissions materials.
Pre-commercial procurement programmes	Can leverage public infrastructure to pilot innovative technologies and materials that are at the edge of commercialisation but still carry too much risk to attract private investment, helping to demonstrate feasibility, develop supply chains, and de-risk market adoption. Can be provided in the form of direct funding or advanced market commitments. Benefits: can provide targeted demand for near-zero emissions materials; may help avoid constraints related to conventional procurement rules and budget allocation; can increase product familiarity and buyer awareness; generates data and knowledge on the use of innovative materials, especially new cement mixes, in real-world conditions. Limitations: likely provides a smaller demand signal than other demand-side measures; may not directly result in wider market adoption.
Carbon pricing schemes	Market-based mechanism (emissions trading system) or levy (carbon tax) that makes emissions-intensive production more costly (and thus near-zero emissions production more competitive) by incorporating the externality cost that CO_2 emissions generate. While carbon pricing is not considered a “targeted” demand-creation policy, it is included here since it can still play an important role in market creation, and in particular in market maintenance in the longer term as technologies mature and carbon prices rise. Its most direct effects are typically on the supply side, but carbon pricing can also help facilitate increased purchases of near-zero and low-emission materials by increasing their competitiveness and sending broad market signals that give clarity and certainty on the pace of the industry transition. Measures to help guarantee a market for lower-emissions materials (and avoid displacement by imported, higher emissions materials) can complement carbon pricing. An example includes placing a carbon tariff on imports from jurisdictions with lower policy stringency. Benefits: economically efficient and technology-neutral way of reducing emissions and helping make lower-emissions materials more competitive on markets; price and/or free allocations can be progressively tightened over time to send a clear market signal to buyers; can use revenue recycling to support investments in the industry transition or return revenue to citizens to offset any inflationary impact on prices; carbon border adjustments help guarantee a domestic market for lower-emissions materials.

Policy option	Description
Carbon pricing schemes (continued)	Limitations: on its own, and particularly in the near term when carbon prices are still relatively modest, unlikely to create sufficient demand for near-zero emissions materials due to their higher costs; may not incentivise the industry transition at the desired pace if not sufficiently stringent; may not provide targeted support for industry; can be politically challenging to adopt in certain regions; may create inflationary pressures that could increase prices for customers; for complementary measures like border carbon adjustments, trade implications and impacts on demand are unclear and implementation can be complex.

Critical to the implementation of many demand-side policies are definitions or standards for near-zero emissions and low-emissions materials. These can serve as emissions intensity thresholds for eligibility in policies like public procurement schemes for near-zero and low-emissions materials, or for labelling and certification schemes; they can also serve as a maximum permissible emissions intensity level in policies that set embodied carbon limits. Furthermore, definitions and standards are not only needed for government policies – they are also demanded by many private sector stakeholders who want greater reliability and clarity around performance of goods on the market. In addition, they can facilitate beneficial trade impacts by providing a consistent language to discuss the industry transition. Therefore, establishing globally interoperable definitions and standards is a key step in spurring lead markets and creating demand. Governments can take a lead role in signalling definitions to be used in markets and leading transparent stakeholder consultations to facilitate greater interoperability and strengthen industry buy-in. Ongoing efforts in this area are summarised in the IEA's recent report on emerging understandings around definitions.

These definitions and standards, as well as many demand-side policies, require high-quality data to account and measure the emissions intensity of steel, cement and other industrial products. In this regard, governments could play a key role by promoting greater use of primary data, as well as establishing publicly available databases of emissions factors for inputs and intermediate products to improve quality and comparability in cases when primary data is not available.

Supply-side measures

The rationale for supply-side measures

Market uncertainty hinders investment in early deployment of near-zero emissions production

Key message: Near-zero emissions materials production is not yet proven at a commercial scale in most cases, posing significant risks for investors due to high and unpredictable costs compared to conventional production. As suppliers contemplate future investments, clarity on the market direction is critical to avoid delayed investment in near-zero emissions materials, or reinvestment in high-emitting conventional facilities.

Technologies for near-zero emissions steel and cement production are known and have been shown to be technically feasible, thanks, in part, to RD&D funding that has accelerated innovation processes and demonstrated proof-of-concept at pre-commercial scales. However, bringing technologies that are on the edge of commercialisation to market poses a significant hurdle for companies. Overcoming this requires targeted solutions to unlock finance and execute first-of-a-kind projects.

Commercialisation of near-zero emissions production faces several key barriers. Paramount among these is the high production cost. The use of energy intensive and nascent technologies such as those that incorporate low-emissions hydrogen, CCS, direct electrification, and alternative raw materials can be expensive to operate. This is compounded by high capital costs resulting from a lack of project development experience from contractors and the use of highly specialised equipment. Together, these factors contribute to the price premium, dissuading buyers from purchasing near-zero and low-emissions materials. These prices will come down as supply chains are established and project developers gain experience, but early deployments are critical to facilitate this learning process.

Technology deployment at scale is also the point in development where funding often tends to be most scarce. Government funding is typically limited for projects at this stage and scale due to the high price tag and significant risk to public funds. Similarly, venture capital investors target earlier-stage companies where equity can be exchanged for relatively modest amounts of financing. Angel investors tend to invest at an even earlier stage. At the same time, institutional investors (e.g. banks, private equity firms, pension funds, multilateral development banks) often see these early projects as too risky, electing instead to defer funding until there is more clarity on the market trajectory. Some investors may be willing to make contributions, but they tend to be few and far between. At the international level, multilateral climate finance mechanisms like the Climate Investment Funds can be a route to provide targeted support for early deployment in EMDEs, but they currently lack the scale needed for the global industry transition.

This funding gap is a key factor in what is sometimes referred to as the "valley of death", the point where innovative technologies struggle to penetrate the market. However, support at this stage can be the most critical. Without it, there is higher possibility of competition for investment from lower-risk but emission-intensive conventional technologies, leading to locked-in carbon emissions and a delayed industry transition.

High capital and production cost affects the bottom-line for commercial facilities but is not the only risk for early producers. Lack of long-term certainty around operating margins, paired with a weak demand signal for near-zero emissions materials, is likely to dissuade potential investors. There can also be practical limitations, with lack of enabling infrastructure (which often lies beyond a company's direct purview) precluding deployment. Price uncertainty is another key concern, driven by volatility in low-emissions energy sources and augmented by an unclear or unstable regulatory environment. Investors need certainty on fiscal projections to achieve final investment decisions, making long-term regulatory clarity critical for mitigating their risk. This lack of long-term clarity goes beyond regulations alone: lack of consensus on clear definitions and standards for emissions intensity thresholds creates uncertainty on the bankability of a price premium.

Another consideration is that many suppliers already have steel and cement production assets in operation and there is a financial loss – in the form of lower than anticipated return on investment – associated with early retirement. While suppliers may want to switch to near-zero emissions production, the cost of early retirement of existing assets might be too high to enable a switch in the near term. Moreover, operational disruptions associated with switching to near-zero emissions production can create hesitation around investments, with companies having to go through inevitable "growing pains" that can create short-term financial instability. Consequently, early adopters need sufficient working capital to cover potential unexpected costs and must weigh the strength of the company's existing financial position before pursuing such endeavours. Internal barriers may also exist, potentially due to risk-averse internal policies or lack of buy-in from senior or board leadership.

Key barriers to growing the market share of near-zero emissions steel and cement production

Consideration	Description of barrier
Production capital and operating cost	Near-zero emissions production carries higher and more uncertain capital and operating costs compared to conventional production due to the use of nascent technologies that have not yet been proven at scale, exacerbated by uncertain access to and reliability of novel feedstocks and energy sources. This can often present too much risk for investors, especially in regions where there is no matching public support.
Demand signal	Uncertainty around the market forecast and lack of clear and sufficient demand for near-zero emissions materials creates risk for producers who may otherwise be ready to invest in innovative production.
Enabling infrastructure	Project developers may not have access to enabling infrastructure, or new enabling infrastructure may face long development timelines that delay deployment of near-zero emissions production in certain regions.
Regulatory environment	Producers may be hesitant to commit to final investment decisions due to a lack of long-term regulatory certainty that is necessary to reduce price risk and build a robust business case for near-zero emissions production. Long permitting and regulatory approval processes can also pose a challenge, especially under a rapidly shifting competitive landscape.
Standards and definitions for emissions performance	Clear, verifiable and widely accepted definitions backed by standards and certifications for near-zero and low-emissions materials can ensure bankability and justification for a price premium. The absence of or uncertainty around these assurances can slow deployment, as can lack of interoperability between systems for players operating on international markets.
Collecting and tracking data	Gathering and tracking data for emissions intensity along a supply chain can prove challenging, especially in cases where regulatory regimes have different reporting requirements that create confusion. Developing these processes can take time, slowing the rate at which near-zero emissions materials reach the market.
Workforce and skills	Due to the limited use of near-zero emissions technologies to date, the workforce may lack the training and skills needed to deploy and operate these technologies at a large scale and in a sufficient number of plants.
Existing assets	Producers may own existing conventional assets that have not reached the end of their operational lifetime and are still generating a return on investment. In these cases, early retirement (to replace with new near-zero emission capacity) or putting these facilities offline for long periods (to retrofit with near-zero emission technologies) may prove very costly.
Organisational objectives	Investing in near-zero emissions production may not yet be a major part of the operational strategy of certain organisations, possibly due to investments in incremental decarbonisation or other non-climate related objectives.

In all cases, market certainty is critical to overcome these barriers to adoption and tip the market balance towards near-zero emissions technologies. Left to markets alone, this shift in production is unlikely to occur at the pace needed for the industry transition. A coherent strategy and support from governments is thus important to co-ordinate and guide all stakeholders involved in this multi-faceted challenge.

Near-term investments can kick-start near-zero emissions production towards wider diffusion

Key message: Meeting production levels consistent with net zero emissions by mid-century requires a massive scale-up of near-zero emissions technologies, and markets are currently not developing at the pace needed for such a trajectory. With cases of historical commercialisation and mass market deployment for innovative technologies taking decades, achieving net zero emissions by mid-century necessitates that companies begin investing in commercial near-zero emissions production today to accelerate timelines for widespread diffusion on a global scale.

Near-zero emissions technologies are scaled up at a rapid pace in the NZE Scenario. Many of the key technologies required for the industry transition are close to reaching the point of commercialisation, but a concerted efforted is needed to push them over important thresholds. Past experience suggests that at around 1% of market share, technologies typically have sufficient maturity to have a tangible effect on supply chains. In turn, this makes wider adoption afterwards more straightforward as a result of the experience from early projects and economies of scale in production that help lower cost. Historical cases indicate that early market adoption of innovative technologies can vary from as little as several years to as much as multiple decades, depending on market demands and wider pull factors. For example, in the case of solar photovoltaics, it took 25 years to achieve a 1% share of the national electricity supply market after first being introduced in 1983 (in Spain and Germany). Large and site-tailored technologies – like those typical of the industry sector – can tend to take even longer to reach this threshold than small and modular technologies like solar photovoltaics. Naturally, reaching larger market shares takes even longer.

Once introduced, history has shown that accelerated market adoption is possible if a competitive advantage can be secured, typically through a combination of product affordability, availability and/or attractiveness. Successive deployments can begin to trigger reinforcing feedback loops like technology learning by doing, economies of scale, and knowledge-sharing, helping to drive rapid cost reductions that in turn accelerate market adoption. Acceleration into mass market adoption typically occurs after reaching about 5 to 10% market penetration for a technology. For example, once solar photovoltaics reached this threshold, market share proliferated, and capacity is now expected to more than triple by 2030. The steel sector saw a similar trend in the 1960s when basic oxygen furnaces were deployed at an annual growth rate of 35%.

However, with only 25 years until 2050, markets for near-zero emissions steel and cement cannot be afforded prolonged timelines to reach critical thresholds if the aim is to reach internationally agreed government objectives for net zero emissions by mid-century. Rather, their commercialisation needs to progress quickly to move from market introduction today to a market share of more than 90% by mid-century. This means gaining a foothold in the market in just a few years from now. Fortunately, history has demonstrated that accelerated market adoption is possible, including in the industry sector: for example, for direct reduced iron technology, achieving a 1% market share was comparatively faster than for solar photovoltaics, taking less than 10 years (in the United States).

A concerted near-term effort will be essential to get on track and establish near-zero emissions production as a cost-competitive venture. This means de-risking early commercial deployments of near-zero emissions production and ensuring these facilities start operating as soon as possible. Several near-zero emissions material production facilities are scheduled to come online in the next few years. With limited production currently in operation, these first-of-a-kind commercial facilities will be critical for building investor and operator confidence. Ideally, new facilities would be deployed across different regions and technology types to maximise market exposure to innovative technologies and test under different operating conditions.

Not all early deployments will necessarily be near-zero emissions from the start – in certain contexts, companies may elect to deploy technologies that are "near-zero emissions capable." These deployments, though falling short of near-zero emissions initially, can still contribute to significant near-term emissions reductions and would have the technical capabilities to be converted to near-zero emissions at a later date without substantial additional capital investments in core process equipment. Examples include hydrogen-ready direct reduced iron production facilities running on natural gas, or cement production facilities designed with clear technical specifications, space considerations and plans for future integration with CCS. This approach would still serve as a market signal of the intention to deploy near-zero emissions production, helping to spark development in these upstream industries. In all cases, a clear technical plan and timeline to transition is imperative to ensure the market share of near-zero emissions production continues to rise. Likewise, this strategy can only be effective if near-zero emissions production is concurrently de-risked and proven as commercially viable.

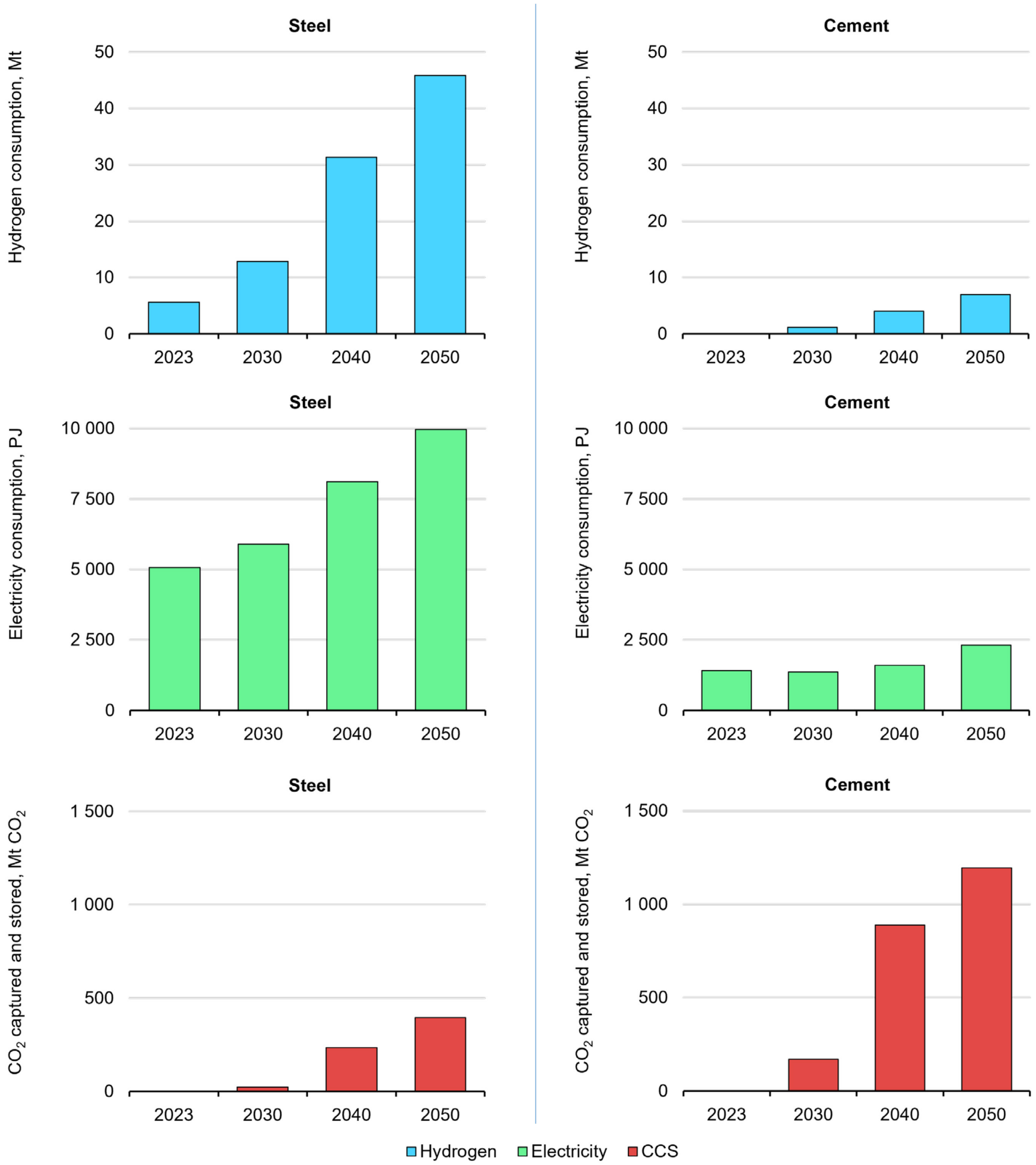
Enabling infrastructure is needed for rapid scale-up

Key message: To support rapid scale-up of near-zero emissions technologies, there will be a need for proportional investment in and scale-up of enabling infrastructure that these near-zero emissions technologies depend on, including production, transportation, and/or storage infrastructure for low-emissions hydrogen, low-emissions electricity, and captured CO_2. Currently, some of this enabling infrastructure is nascent and faces similar barriers to near-zero emissions technologies, and so support is needed to ensure consistent scale-up of both.

Underpinning the massive scale-up of near-zero emissions production is the proportional scale-up of key enabling clean energy infrastructure: low-emissions hydrogen production, low-emissions electricity, and CO_2 transportation and storage. Low-emissions hydrogen is largely required for use in direct reduced iron (DRI) production, with additional supply potentially needed as fuel to provide high-temperature heat in other aspects of steel and cement production. Low-emissions electricity supply serves to power electric arc furnaces (EAFs) and enable clean hydrogen, both for use in DRI steel production or as fuel, while also supporting the conversion of fossil fuel-powered equipment to electricity-powered in both steel and cement production. CO_2 capture, supported by CO_2 transportation and storage networks, is expected to play a large role for decarbonising cement production but can also play a role in decarbonising remaining blast furnaces and natural gas-fired DRI facilities. Beyond these highlighted examples, bioenergy and biogenic waste also have important uses as energy in cement kilns or as a substitute for coal in blast furnaces, necessitating build-out of supply chain infrastructure. Together, these serve as critical enablers for the industry transition.

The current scale of infrastructure is insufficient to support the industry transition. While low-emissions electricity is relatively mature in many regions, electricity consumption in steel and cement production nearly doubles by 2050 in the NZE Scenario. Moreover, in those two sectors, consumption of low-emissions hydrogen grows almost ten-fold and CCS capacity demand expands to 1.5 Gt CO_2 per year by 2050 from essentially zero today in the same scenario. Consequently, this will require large additional scale-up of grids that become increasingly complex to manage due to increasing penetration of variable renewable energy resources, as well as a massive expansion of infrastructure for low-emissions hydrogen production and transportation, and CO_2 transportation and storage. Infrastructure for bioenergy and biogenic waste processing and transportation will also be needed, albeit to a lesser extent. This poses a risk for meeting near-zero emissions steel and cement production targets, as such infrastructure often requires long timeframes for project permitting, development and construction. Moreover, this scale-up coincides with the clean energy infrastructure needs of other sectors, as well as other general infrastructure, leading to potential competing priorities or construction bottlenecks. On the other hand, this could open up the possibility to seek efficiencies through use of shared infrastructure.

Global demand for enabling infrastructure for the steel and cement sectors in the Net Zero Emissions by 2050 Scenario, 2023-2050



Notes: CCS = carbon capture and storage. Hydrogen consumption includes merchant hydrogen demand for use either as a fuel or as a reduction agent for producing direct reduced iron. Electricity consumption includes use in the production processes and use in on-site electrolytic hydrogen production. Captured CO_2 is assumed to be permanently stored.

Early and co-ordinated planning is therefore essential to ensure lack of infrastructure does not delay or preclude investments in near-zero emissions production and its supply chains. The industries behind this enabling infrastructure face similar challenges to near-zero emissions steel and cement – high costs, investor uncertainty, and lack of buyer demand, to name but a few – meaning complementary efforts can help them overcome barriers to early market formation. Additionally, given that efficient access to infrastructure is an important factor in shaping industrial plant siting, planning in a co-ordinated manner can facilitate progress. For instance, development of industrial clusters would facilitate infrastructure cost-sharing between a greater number of supply chain actors. Alternatively, a smaller group of stakeholders could co-ordinate on a full, stand-alone near-zero emissions steel or cement value chain to minimise transportation infrastructure needs. In all cases, broad stakeholder engagement is a key aspect of this process, helping to secure project support at a local, and in many cases regional, level.

Reductions or retrofits of emissions-intensive production must be planned to mitigate risks

Key message: Reliance on high-emissions conventional production needs to be progressively reduced on a pathway to net zero by mid-century. Winding-down new investment in high-emissions production would help lower the risks of stranded assets, carbon lock-in and excess capacity, while leaving companies with more available capital for rapid scale-up of near-zero emissions technologies and value chains. This means that high-emitting existing assets are retrofitted or replaced with near-zero emissions technologies during the next investment cycle, and new capacity additions shift to being either near-zero emissions or otherwise “capable” of transitioning over time to near-zero emissions. .

To meet internationally agreed government objectives for net zero emissions, high-emissions conventional steel and cement assets (particularly, iron and clinker production) need to either be retrofitted to incorporate near-zero emission technologies, or be steadily but sensibly retired, in the years leading up to 2050. At present, nearly all iron and clinker production uses high-emissions conventional assets. However, by 2050 in the NZE Scenario, use of such assets without incorporation of near-zero emissions technologies is reduced to only a marginal market share.

Scaling up new near-zero emissions production and its enabling infrastructure without concurrent attention to existing high-emissions capacity would limit possibilities to achieve absolute emission reductions, as well as exacerbate current challenges related to excess capacity. At present, particularly for steel, there is considerably more capacity available globally than is needed to meet demand. This depresses prices and creates challenging market conditions for the steel industry overall, making it even more difficult to invest in decarbonisation. This is all against a backdrop of growing affordability concerns from consumers and a recognised need to establish secure, resilient global supply chains for the energy transition. All told, this poses a complex yet critical challenge for countries to navigate; continued global dialogue is important to help tackle challenges and find solutions (e.g. collaboration to reduce subsidies for high-emissions production).

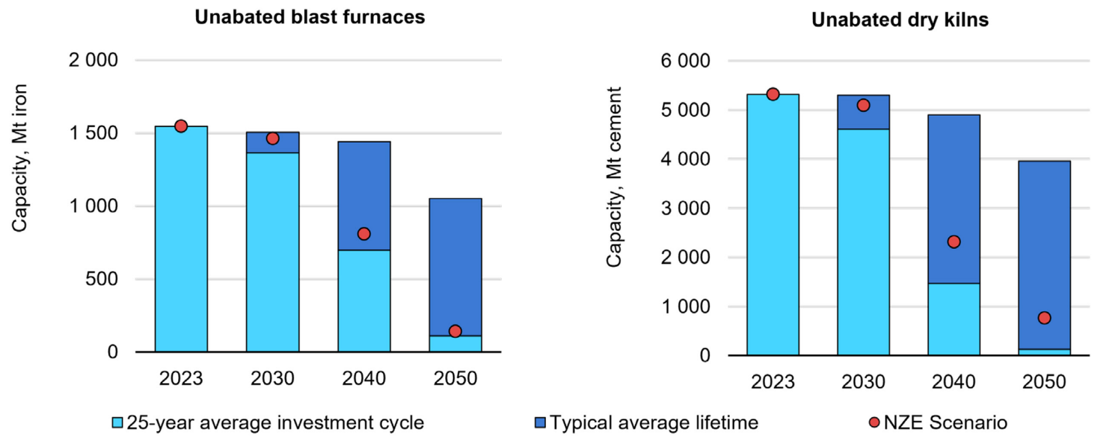
Reducing high-emissions production is not as simple as shuttering existing assets. Industrial facilities tend to have long lifetimes, typically operating for roughly 30 to 40 years. Furthermore, these assets may have cost several billion US dollars to construct, meaning extended lifetimes are required to amortise these facilities and allow project developers to maximise their return on investment. Early retirement could carry a significant financial penalty through lost revenue. On top of this, lower operating costs for conventional production relative to near-zero emissions alternatives in the absence of supporting policy makes it challenging for producers to rationalise early closure to switch to near-zero emissions production.

Despite their longer lifetimes, steel and cement assets typically have an approximately 20-25 year refurbishment cycle at which point facilities undergo a major reinvestment (e.g. blast furnace re-lining, replacement of core equipment). Blast furnaces undergoing second or third re-linings may have even more frequent refurbishment cycles. Without refurbishment, then, existing conventional production capacity would decline by natural attrition through the process of retiring existing assets as they reach their next investment cycle. Doing so would open space for the existing high-emissions global fleet to be replaced with one that is compatible with net zero emissions by mid-century.

Conversely, re-investment in existing high-emissions conventional assets without upgrades that make them near-zero emissions “capable”, or replacement of these assets with new high-emissions conventional assets, could “lock-in” high-emissions production for another investment cycle. This could have the knock-on effect of driving available capital away from near-zero emissions production, hampering its scale-up. Consequently, CO_2 emissions would significantly exceed those that would align with net zero emissions by mid-century. This is not to say that there cannot be a role for existing assets; for example, blast furnaces in the steel sector and dry kilns in the cement sector could be retrofitted with CCS to become near-zero emissions. For instance, CCS-based near-zero emissions technology accounts for about 35% of steel production in the NZE Scenario in 2050, a portion of which could come from blast furnace retrofits. Nevertheless, before this would be possible, accelerated and intensified innovation efforts would be needed to prove the viability of CCS-equipped blast furnaces – ideally within the next few years if blast furnaces are to continue to be viewed as a viable option in a net zero future.

For companies that re-invest in high-emissions conventional capacity without upgrades that make it near-zero emissions "capable", or invest in new high-emissions conventional capacity, there is an equivalent risk of "stranded assets". If the industry transition proceeds faster than they expect, high-emissions capacity that cannot transition to near-zero emissions would eventually become stranded as markets might then favour near-zero emissions materials and demand for high-emissions materials drops off. As a result, companies (and potentially governments if subsidies were given) could be left with substantial liabilities due to facilities that can no longer recuperate their investment.

Global capacity of existing unabated blast furnace steel and unabated dry kiln cement production facilities under different lifetime assumptions, and total unabated capacity in the Net Zero Emissions by 2050 Scenario, 2023-2050



Notes: NZE Scenario = Net Zero Emissions by 2050 Scenario. "Typical average lifetime" series represents projections of capacity from existing steel blast furnaces and cement dry kilns under an average lifetime of 40 years. "25-year average investment cycle" series represents capacity of these existing assets under an average lifetime of 25 years. These lifetimes are based on average historical operational lifetimes of assets from cement and steel industries. NZE Scenario represents the total unabated installed capacity of steel blast furnaces and cement dry kilns in the Net Zero Emissions by 2050 Scenario.

The risk of stranded assets is most acute in EMDEs which are currently experiencing a major expansion of new capacity for steel and cement production. For steel, all planned high-emissions conventional capacity, amounting to over 200 Mt, is located in these markets, with over half in India. Similarly, for cement, nearly three-quarters of the conventional production growth up to 2030 comes from EMDEs in the IEA's scenarios, led by growth in India, Southeast Asia, and the Middle East. This new capacity will likely continue to operate into the 2040s and could face growing market barriers as governments work towards their internationally agreed objectives for decarbonisation, especially as policies like the European Union's Carbon Border Adjustment Mechanism put financial pressure on high-emissions products.

There is a particularly pronounced risk in regions undergoing significant industrialisation and economic development. In Africa, for example, steel and cement production are anticipated to grow at annual rates well above the global average in the NZE Scenario. While industrialisation has historically been seen as a driver of economic development, these countries could instead face premature declines in productivity and employment if demand for high-emissions conventional materials weakens. Countries could benefit from strategic planning for the sustainable development of their domestic industry. For example, recognising this need, Malaysia implemented a two-year moratorium on new steel production in 2023, aiming to address overcapacity risk and better align the industry's trajectory with its 2030 Industrial Master Plan.

While it may not be possible to fully avoid early retirements and stranded assets, minimising these risks is important. Setting a time limit on investments in high-emissions conventional capacity could be an option to define clear guardrails for the industry transition and pave the way for growth of near-zero emissions production. An interim measure could be to require investments in conventional capacity to be near-zero emissions "capable", which is defined in this report as projects that will achieve substantial emissions reductions from the start – but fall short of near-zero emissions initially – with plans to continue reducing emissions over time such that they could later achieve near-zero emission production without substantial additional capital investments in core process equipment.

Building near-zero emissions "capable" production may be a useful strategy in certain instances in the near term. For example, near-term regional gaps in enabling infrastructure, limited availability of clean energy or certain raw materials, lack of technology readiness, or prohibitive costs could preclude immediate use of near-zero emissions production but need not delay all potential emissions reductions. For companies, near-zero emissions "capable" production can also provide a way to spread out the transition over a larger number of years, improving cash flow, while simultaneously reducing the risk of stranded assets and giving supporting policies time to scale up. This transitional capacity can be built, provided it is built with clear plans and technology specifications (e.g. guarantee of sufficient space, plans for access to enabling infrastructure) to cost-effectively shift to near-zero emissions in advance of 2050.

However, caution should be taken to avoid over-reliance on near-zero emissions capable production, which could lead to a higher overall cost of the industry transition by slowing the scale-up of actual near-zero emissions production. In some cases, there may also be added costs to convert facilities rather than build near-zero emissions facilities from the start (e.g. costs from temporarily stopping production). Therefore, near-zero emissions capable facilities should be designed such that the eventual switch to full near-zero emissions operation is quick, cheap and non-disruptive. Governments planning to rely on this strategy might consider employing stringent retrofit-ready requirements to permitting new-build facilities that are not near-zero emissions from the start, such as requiring a Front-End Engineering Design (FEED) study that demonstrates plans for future conversion to fully near-zero emissions.

Another possibility to bridge any capacity gaps until near-zero emissions plants can be built could be to pursue limited lifetime extensions of existing facilities reaching the end of their planned life. This would be limited to instances where it is possible without major re-investment and where safety and quality requirements can be assured. Such a strategy could help avoid investment in new high-emissions conventional facilities that, if delayed for only a few more years, could be rather built with near-zero emissions technology.

Ageing industrial fleets heighten the near-term need to accelerate innovation and redirect investment

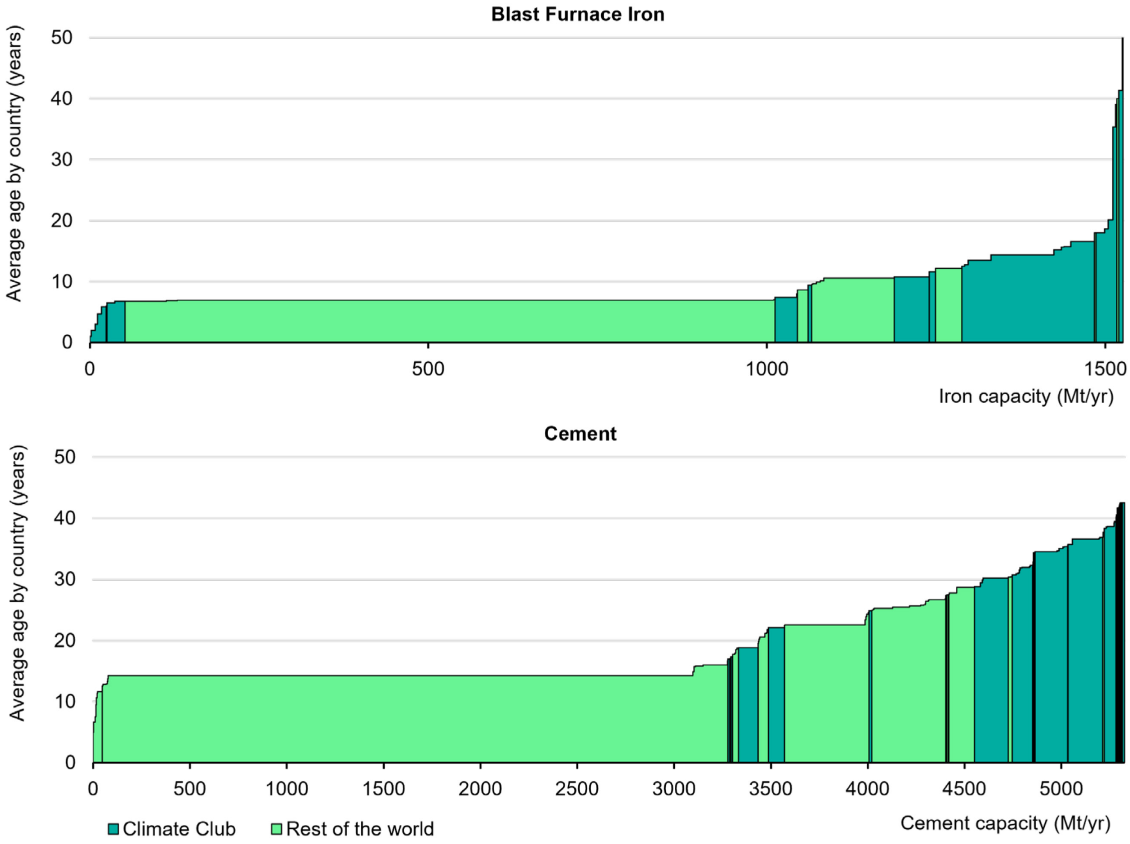
Key message: There is a narrowing window to bring near-zero emissions technologies to market, if countries wish to avoid considerable risk of stranded assets or otherwise “locked-in” emissions from high-emissions conventional assets. This is because current conventional steel and cement production assets are ageing, with a large portion set to face an investment decision within the next 5 to 10 years. Any re-investments in these assets within the next few years, or alternatively, replacement of them, mean they will still be in operation mid-century. To ensure there is a strong business case for near-zero emissions technologies in the face of these impending investments, near-term support to accelerate innovation is crucial. Supply-side measures are also important to redirect investment to enable near-zero emissions, or otherwise near-zero emissions capable, facilities.

Governments are facing both a significant challenge and opportunity with regards to near-term investments in their domestic industrial capacity. Globally, the current stock of industrial assets is ageing. For Climate Club members, this is especially pertinent. By 2030, roughly 40% of the global cement production fleet will be coming to the end of an investment cycle; for Climate Club members, this figure rises to close to 100% of their production. Iron production assets face a similar challenge, while being a slightly younger fleet than cement. By 2035, roughly 15%

of the global blast furnace fleet will be coming to the end of an investment cycle; for Climate Club members, this is about 50% of blast furnace iron production.

It is therefore important that near-term investment be re-directed towards near-zero emissions production and away from business-as-usual reinvestment in high-emissions facilities without the possibility to later transition to near-zero emissions, to avoid considerable risks of stranded assets or locked-in emissions. This is particularly significant since the industry transition has reached a critical point where mid-century is just one investment cycle away for the steel and cement sectors. The investment decisions being made today are for facilities that will mostly still be in operation by mid-century.

Average age of key emission-intensive assets in the steel and cement sectors by membership in the Climate Club and rest of world



Notes: Capacity is aggregated by country and is represented using the weighted average age of capacity in the country in which it is located. For blast furnaces, the plant "age" is equivalent to the number of years since the most recent re-lining; consequently, the time since plants were first built may be longer than considered here in some cases. Capacity and average age data estimated from a range of available data from 2022 for cement and from 2024 for blast furnace iron. For cement, capacity data is from the United States Geological Survey and the Global Cement Directory, clinker-to-cementitious material ratios are from the Global Cement and Concrete Association and average ages of assets are based on the Global Infrastructure Emission Database. For steel, capacity data and average ages of assets are from the Global Energy Monitor Global Blast Furnace Tracker and Global Steel Plant Tracker. Climate Club membership is as of March 2025.

Despite the increasing need for them, near-zero emission technologies still face significant barriers, especially cost, that limit widespread commercial deployment, putting industry at risk of locking-in future emissions during this next investment cycle. The current business-as-usual case is still high-emissions conventional production, driven largely by high production costs and lack of commercial-scale technology demonstrations of near-zero emissions production, leading to a risk and cost premium that may dissuade investors. In the absence of policy interventions aiming to quickly prove technologies at commercial scale and bring down costs, this economic equation is unlikely to change.

Increased support for near-zero emissions production and its value chains is therefore needed to accelerate proof-of-concept demonstrations and strengthen their business case in time for these upcoming investments. In this way, governments can help de-risk early technology deployments while simultaneously driving down costs, making near-zero emissions production a practical option for investors. This can be supplemented by targeted supply-side measures that further encourage investment in near-zero emissions production and help redirect investment or reinvestment away from high-emissions conventional production.

Progress to date and lessons learned

Early investments in near-zero emissions material production are emerging, but not at the required pace

Key message: Private sector companies are poised to bring near-zero emissions production to market, but many announcements lack clarity on achievable emission levels and are regionally concentrated. While announced supply has been increasing steadily in recent years, it still falls short of the pace required for achieving net zero emissions by mid-century. Projects that have reached final investment decisions are often supported by supply-side measures that have helped to mobilise private sector funding.

In recent years, there have been numerous announcements for private sector-led projects to spur early developments of near-zero emissions production. Innovation progress for near-zero emissions production technologies is tracked through IEA resources such as the ETP Clean Energy Technology Guide and the Clean Energy Demonstration Projects Database. Projects are also tracked in resources from several other organisations, such as LeadIT's Green Steel and Cement trackers, Mission Possible Partnership's Global Project tracker, and Agora's Global Steel Transformation Tracker.

Of these projects, the most transformative are those that involve producing near-zero emissions iron-based steel and near-zero emissions cement (the latter either via near-zero emissions clinker or innovative cements from alternative raw materials that wholly replace the need for clinker). Here, some early commercial facilities are set to come online starting in 2025, helping to bring such technologies to market and serve as critical proofs-of-concept for de-risking future investment. As outlined below, efforts are also underway to produce near-zero emissions scrap-based steel; however this cannot meet all of expected future steel demand due to constraints in global scrap availability. An increasing number of projects are also exploring increased use of supplementary cementitious materials; however these are unlikely to fall into the category of near-zero emissions cement unless they can fully eliminate emissions-intensive clinker production.

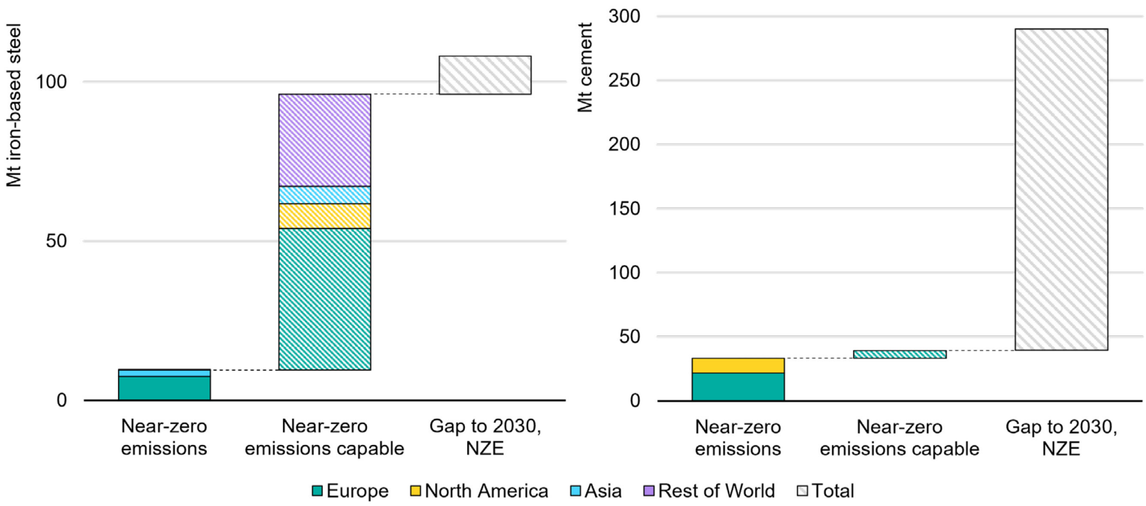
In the case of steel, roughly 10 Mt of planned iron-based steel capacity is near-zero emissions production that is supported with final investment decisions and clear technology descriptions, based on public announcements. However, this constitutes just under 10% of the nearly 110 Mt of near-zero emissions production in 2030 in the NZE Scenario. Consequently, accelerated efforts in the coming years are needed to close this gap, although there are indications that momentum is growing.

Publicly announced near-zero emissions capable production accounts for an additional 85 Mt of iron-based steel capacity. In contrast with near-zero emissions capacity, these projects often lack clarity around technology details and timelines. In many cases, projects have not achieved a final investment decision, creating uncertainty around these developments. Furthermore, for some facilities, production is only partially decarbonised through natural gas-based DRI, with unclear timelines for transitioning to fully hydrogen-based production. Such near-zero emissions capable projects can significantly reduce emissions but are ultimately insufficient unless converted to near-zero emissions. Despite these factors, near-zero emissions capable projects could readily confirm their near-zero emissions compatibility in the near term as further project details emerge or conversion timelines are shifted forward. This could result in as much as 95 Mt of near-zero emissions iron capacity in 2030.

For near-zero emissions cement, progress has been even slower than for steel. To date, the roughly 35 Mt of publicly announced near-zero emissions cement production accounts for slightly above 10% of the nearly 300 Mt of capacity in 2030 in the NZE Scenario. Moreover, near-zero emissions capable production adds just over 5 Mt of further capacity. While the project pipeline has increased considerably in recent years, a gap of approximately 250 Mt of cement production remains to the NZE Scenario. In many cases, CCS only covers partial emissions at cement facilities, whereas expanding coverage to all emission sources at capture rates greater than 90% will eventually be needed for achieving near-zero emissions production.

Announced projects to date also lack regional diversity. Most global capacity for near-zero emissions production is planned in Europe: 80% for steel and 65% for cement. The outlook for near-zero emissions capable steel production is somewhat more promising. Here, half of announced capacity is planned for outside of Europe, suggesting that near-zero emissions production will become more regionally diversified. Meanwhile, announced near-zero emissions capable capacity in the cement sector is concentrated in Europe, reflecting an uneven pace of transition across regions.

Announced capacity for near-zero emissions and near-zero emissions capable iron-based steel production and cement production relative to the Net Zero Emissions by 2050 Scenario in 2030



Notes: NZE = IEA Net Zero Emissions by 2050 Scenario. “Announced capacity” is estimated based on publicly available project announcements. “Near-zero emissions” refers to projects that, once operational, will be near-zero emissions from the start, as defined in the IEA report Achieving Net Zero Heavy Industry Sectors in G7 Members. Projects need to have achieved a final investment decision and provided clear details confirming near-zero emissions production to be included here. “Near-zero emissions capable” refers to projects that will achieve substantial emissions reductions from the start – but fall short of near-zero emissions initially – with plans to continue reducing emissions over time such that they could later achieve near-zero emission production without substantial additional capital investments in core process equipment; project announcements that are still only at the concept stage are also included in this category due to the higher uncertainty surrounding their completion. Project announcements that have not achieved a final investment decision are also included in this category due to the higher uncertainty of their completion. Production from announced projects shown here excludes near-zero emissions steel from 100% scrap.

Ultimately, all near-zero emissions technologies play a critical role in the industry transition, including facilities that use scrap-based EAF steel. Reaching near-zero emissions for scrap-based production largely involves switching to already commercially available low-emissions electricity sources, but it also requires important innovations to nearly eliminate other smaller direct and supply chain residual emissions. While not included in the earlier totals for near-zero emissions capacity, some announced projects are undertaking innovations on residual emissions and thus could potentially meet the emissions intensity threshold for near-zero emissions scrap-based production, such as SSAB's planned Luleå facility in Sweden. Additionally, while global scrap collection rates are already very high – around 85% – innovation may also be helpful to further improve recovery, sorting and elimination of contaminants to increase scrap use even further. Still, support remains critical for tackling the major challenge of decarbonising iron-based steel production, as global availability of scrap ultimately has limitations.

Governments are rolling-out a variety of supply-side measures

Key message: Governments can play a decisive role in securing a strong business case for near-zero emissions material production. Early measures have already shown success in incentivising investment in near-zero emissions production and reducing high-emissions production, but so far have not been at sufficient scale and coverage to drive widespread market shifts globally.

To date, near-zero emissions steel and cement projects that are advancing towards operation have been supported with public funding, or facilitated by accelerated approval processes intended to establish feasibility through these first-of-a-kind deployments. Examples of flagship projects that have received government support include those from Stegra, Hybrit, and Hydnum Steel, on the steel side, and Heidelberg Materials, Lafarge, and Sublime Systems for cement. As near-zero emissions production proceeds to market, government support will continue to play a decisive role in securing a business case for these technologies, especially in regions and applications where progress has lagged to date. Policy measures have begun to emerge and can offer examples of plausible supply-side policy approaches to the industry transition. In all cases, care should be taken when choosing and designing policies to ensure a level playing field for near-zero emissions producers.

Targeted supply-side measures can be particularly effective at this early stage of market development and have been used by a number of governments to ensure deep decarbonisation technologies are strongly incentivised. Some examples of existing policies are listed below, and each type of policy measure is further detailed in the next section, along with their advantages and disadvantages:

- **Direct subsidies and tax credits** such as Canada's Clean Economy Investment Tax Credits, Italy's Piano Transizione 5.0, and the United States' 48C Advanced Energy Project Credit are helping mobilise private capital while addressing the capital cost barriers of transitioning to near-zero emissions production. The United Kingdom's Industrial Energy Transformation Fund aims to advance innovation for large-scale deployments, in addition to providing capital support.
- **Contracts for difference programmes** help to de-risk and secure the higher investment associated with near-zero emissions production. This subsidy typically addresses operation expenses, such as Canada's CCfD mechanism through the Clean Growth Fund, but can also be agnostic of capital or operating expense, such as in Germany's CCfD programme (see box below).
- **Regulatory measures** targeting scale-up of near-zero emissions production have been slower to emerge but can complement incentives like those described above. One proposal that has entered discussions is a tradeable certificate scheme for near-zero emissions production. At the same time, regulatory measures that aim to limit capacity growth of emissions-intensive assets have become more common, with recent examples such as Malaysia's moratorium on new steel capacity, China's Notice on suspending steel production capacity replacement work, and Indonesia's moratorium on new cement capacity.
- **Innovation funding programmes** are being used by several governments to support a pipeline of innovative technologies that can help lower costs and emissions over time. Examples include Australia's Energy innovation Fund, India's Scheme for Pilot projects on use of Green Hydrogen in the Steel Sector, Japan's Green Innovation Fund, and Türkiye's Green Industry Project. Due to the relatively smaller scale of these programmes, in some cases they can be designed to be revenue neutral. For example, the European Union's Innovation Fund is largely funded by revenue from the EU ETS, while Japan has taken another approach to generate funding using their Climate Transition Bond scheme.
- **Policies that target scale-up of enabling infrastructure** can be effective in enabling the industry transition. Policies to date have taken a broad range of forms, including tax credits like the United States' 45Q Tax Credit for Carbon Sequestration and 45V Clean Hydrogen Production Tax Credit, and regulatory measures like Canada's Clean Electricity Regulations and the European Union's Net-Zero Industry Act.
- **Energy efficiency measures** provide much weaker direct support for near-zero emissions production but can contribute to reducing emissions and lowering costs towards achieving low or near-zero emissions production. Policy examples include Egypt's Industrial Energy Efficiency Project, Indonesia's National Energy Efficiency Award, and India's Perform, Achieve and Trade mechanism (which has been in place for over a decade although is now being superseded by the Carbon Credit Trading Scheme for emissions-intensive industries).

Economy-wide policies can also strengthen the business case for near-zero emissions production, signalling the decarbonisation trajectory of the economy. Policies like carbon pricing tilt the investment landscape towards lower-emission technologies, making near-zero emissions production a potentially safer and more cost-effective investment in the long-term. Mechanisms like carbon border adjustment schemes aim to help minimise the risk that suppliers could be priced out of domestic markets, but should be implemented co-operatively to avoid potential negative impacts on global trade markets. See the Demand-side measures section above for examples of these types of policies adopted to date. Notably, in the absence of other measures, economy-wide policies alone are unlikely to overcome current market barriers and secure a sufficiently strong business case for near-term investment in higher-cost early deployment of near-zero emissions production. It is therefore essential to also consider the types of targeted supply-side measures noted above to bolster support provided by carbon pricing.

Policy spotlight: Germany's Carbon Contracts for Difference programme

Announced in 2023, Germany's Carbon Contracts for Difference (CCfD) programme was designed with the aim of building a stronger business case for investment in and scale-up of transformational clean energy technologies used in the industrial sector by removing some of the risk and volatility in energy and carbon prices. The programme provides energy and carbon price guarantees over 15 years for selected projects that can achieve a 90% emissions reduction by the end of the funding period, and a 60% reduction within 3 years. Eligibility is extended to projects across a wide range of sectors and technology types to demonstrate their feasibility. This allows the programme to bridge the current funding gap to conventional production and create favourable conditions for investment in transformational near-zero emissions technologies.

Germany's CCfD programme has several features that help to balance emissions reductions and cost to the public. First, CCfDs are offered on an auction basis to ensure public funding is spent efficiently. Second, there is an upper bound to the amount of funding that can be allocated to each company and through each auction. Third, there is a mechanism in place to claw back funds from a recipient in a case where the benchmark cost of conventional production rises above the strike price for near-zero emissions production set out within the CCfD. Fourth, only 90% of the cost premium is covered by CCfDs, meaning the recipient still bears some risk, which creates an impetus to spend funding efficiently.

Where possible, the programme design used the reporting and monitoring aspects of the EU ETS to minimise administrative burden. Notably, data from the EU ETS was used to provide benchmarks for determining emissions reductions. Working alongside existing policy frameworks also required overcoming some challenges: rigorous European state aid rules allow funding of either capital or operating costs, but not both, meaning Germany needed to get exemptions for its CCfD policy, which can fund both types of expense.

The CCfD programme is seen as complementary to Germany's strategy for public procurement of near-zero and low-emissions materials, by kick-starting supply that can then be bought in lead markets created through public procurement. To enable private sector markets, the policy has a clause that ensures companies can only collect a price premium once, either through CCfD programme funding or from the market. Through the programme buyers have access to cost-competitive low- and near-zero emissions materials, spurring market demand.

The first auction took place in 2024, with EUR 2.8 billion awarded to 15 industrial companies. The projects have the potential to avoid up to 17 Mt CO_2 equivalent (CO_2-eq) over the 15-year term of the contracts. There were no awards for steel or cement in this round, primarily due to the large scale of these facilities, combined with a EUR 1 billion spending limit per project.

Policy options to accelerate progress

Key message: Countries have a variety of policy options that they can adapt to their specific domestic circumstances to accelerate the coherent scale-up of near-zero emissions production and redirect investment away from high-emissions conventional production, including tax credits and incentives, regulations on production, innovation funding, and measures for enabling infrastructure. While broader emissions reductions measures are also useful to create a favourable environment for decarbonisation, supply-side measures targeted specifically at near-zero emissions steel and cement are critical for mobilising early deployment.

To achieve government objectives for net zero emissions, supply-side measures are needed to complement and reinforce demand-side measures, helping to secure the investment needed to get near-zero emissions production off the ground and provide guardrails to efficiently transition away from emission-intensive production. Governments have an array of supply-side policy options at their disposal and may draw learnings from the policy examples implemented to date in other jurisdictions. Each jurisdiction will have different domestic circumstances, and so governments may look to implement tailored supply-side measures to complement their demand-side strategy, underpinning an effective and comprehensive industrial decarbonisation strategy that can best align with the regional circumstances.

For private sector stakeholders, many of the policies listed here are seen as critical levers. This is evidenced in the 2024 Buyer Questionnaire, where participants identified what policies would be most helpful to accelerate private procurement for lower-emission steel and concrete. Of the listed policy options, supply-side measures were highly supported, including tax incentives, credits, and subsidies (70%); carbon pricing (50%); and support for clean energy infrastructure (35%). Together, these accounted for three of the four most supported policies from participants (the fourth being embodied carbon limits). Benefits from such measures, while targeted at producers, could be passed on to buyers to stimulate private procurement. Like the section on demand-side policies, the table below summarises key policy options and refers to the IEA's Policy Toolbox for Industrial Decarbonisation for more detailed information.

In addition to the measures themselves, definitions and standards for near-zero emissions and low-emissions materials are fundamental to underlie the supply-side policies discussed here. For producers, these provide clarity to help establish a business case. They also provide transparency to help guide investors looking to support credible transition activities. In turn, this can prompt the private sector to mobilise investments, serving as an important facilitator for a co-ordinated shift in steel and cement production.

Key supply-side policy options for near-zero emissions steel and cement

Policy option	Description
Tax credits, grants, and loans	Public incentives provided to producers to install near-zero emissions technologies at their facilities. This can be in the form of tax credits, public guarantees, equity investment, concessional loans or direct grants that help overcome high cost and risk of early deployments. Benefits: mobilises private finance at early stages of the industry transition; can promote transparency if designed to require public knowledge-sharing. Limitations: potential for high public cost if private finance is not strategically and sufficiently leveraged; possible risk of anti-competitiveness if only awarded to a limited number of recipients.
Contracts for difference	Contractual agreements that provide a guarantee to cover the cost differential of carbon abatement and/or related energy inputs, relative to some baseline for a fixed period, typically between 10 to 20 years. Acts as a hedge through which the government absorbs price uncertainty related to near-zero emissions production. As a direct subsidy to suppliers, this mechanism ensures the cost to producers of near-zero emissions production is equal or close to that of conventional

Policy option	Description
Contracts for difference (continued)	production and can facilitate investment in near-zero emissions production facilities. Benefits: guarantees cost-competitiveness with conventional production; provides longer-term price certainty to support investment decisions; can be awarded through auctions to optimise funding efficiency; can promote transparency if designed to require public knowledge-sharing. Limitations: can be relatively expensive for governments, who would directly subsidise the additional costs for selected projects, and thus can likely only cover a limited number of projects; can create financial risk for governments if CO_2 and/or energy prices fluctuate outside of expected ranges; auctions may not be feasible in jurisdictions with smaller markets.
Near-zero emissions production mandates or certificate trading schemes	Requires a minimum and growing share of near-zero emissions material production that must be met in a market by establishing selling requirements on the supplier side. Certificate trading schemes can provide flexibility for this to be achieved in an efficient way in the market. In these tradeable permit systems, producers must hold certificates indicating that a specified portion of their product was produced with near-zero emissions. Compliance credits can be purchased from suppliers who go above and beyond compliancy requirements. Design could draw on learning from zero emissions vehicle standards. Benefits: funding originates from the industry rather than public subsidies; can be implemented flexibly using a tradeable permits system (similar to a zero emissions vehicle mandate); certificate trading schemes spread cost of early deployments across the industry; thresholds could be progressively tightened over time and calibrated to align with domestic circumstances; could incentivise early deployment of near-zero emissions production; would push producers to develop a decarbonisation plan; provides long-term predictability for investments. Limitations: could lead to higher average production costs in the regulated market, possibly creating competitiveness challenges for exports and also potentially for domestic purchasing as stringency increases and if border measures are not applied to imports (e.g. importers purchase and redeem permits from domestic suppliers with excess permits); requires a clear emission measurement methodology with third-party validation.
Regulations on emissions-intensive production	Regulations that ensure the gradual reduction of emission-intensive production over time. One form could be to specify a date after which all high-emissions facilities must be retrofit to incorporate near-zero emissions technologies or retired, and/or after which no new high-emissions facilities can be built (sometimes called moratoriums or sunset clauses). Another form could be a progressively tightening emissions limit to allow a consistent pace of decarbonisation (see “carbon product requirements” policy in the demand section). Benefits: helps reduce risk of carbon lock-in; ensures emissions are reduced at the required trajectory; provides long-term predictability for investments. Limitations: risk of carbon leakage; may lead to reduction of production instead of emissions intensity of production to be compliant, particularly if suitable near-zero or low-emissions technologies are not yet ready on the market; can increase production costs that may lead to higher purchase prices for buyers; does not directly incentivise near-zero emissions production.

Policy option	Description
Retrofit-ready requirements	Regulations that set out specifications for new installations or refurbishments to ensure that a facility can be readily converted to near-zero emissions production at a later date when innovative technologies become available. Specifications could be related to technical readiness (e.g. sufficient space for new equipment, access to CO_2 transportation and storage infrastructure, access to non-emitting energy, sufficient secondary heat generation and ancillary system capacity) or economic readiness (e.g. minimum plant efficiency, level of flue gas treatment, requirements for cooling and ancillary systems, heat integration potential). Performance can be verified through engineering reports (e.g. FEED). Benefits: reduces risk of carbon lock-in; reduces risk of stranded assets; gives companies cash flow relief. Limitations: may require higher overall initial investment to make facility retrofit-ready, which may lead to higher prices for customers; may be challenging for policy makers to create robust requirements and verify what constitutes retrofit-ready.
Research, development and demonstration funding	Direct funding provided to develop innovative near-zero emissions technologies that have not yet reached the market. This can be especially important for large-scale demonstrations where financial risk is greatest for the private sector. These programmes target a range of technology readiness levels from R&D through to large-scale demonstrations. Benefits: can accelerate technology development, helping technologies reach commercialisation and lowering costs; can leverage private funding at early stages and fill funding gaps. Limitations: unlikely on its own to yield substantial near-term emissions reductions; needs a robust innovation environment to be implemented; requires balance of innovation support across technologies and readiness levels.
Enabling infrastructure funding and coordination	Direct funding or other measures that facilitate large-scale development of enabling infrastructure (such as CCS, hydrogen production, and renewable energy) to encourage deployment of near-zero emissions production. Targeted support for industrial hubs can support congruent scale-up, minimise capital investment, and facilitate supplier co-ordination. Benefits: helps create a push for industry decarbonisation projects; can accelerate construction timelines for near-zero emissions production; avoids the "chicken-and-egg" problem for industry. Limitations: may require upstream operators to take on risk if offtakes are not yet established; can be high cost to the public if private funding is not properly leveraged; long development timelines necessitate early planning.
Carbon pricing schemes	Market-based mechanism (emissions trading system) or levy (carbon tax) that makes emission-intensive production more costly (and thus near-zero emissions production more competitive) by incorporating the externality cost that CO_2 emissions generate. Although carbon pricing is a broad measure to reduce emissions by various strategies, it is an important supply-side backstop that provides predictable and long-term stability and can trigger investments in near-zero emissions production. Furthermore, it offers a clear market signal for emissions reductions. Domestic producers subject to a carbon price may be at a disadvantage compared to producers in jurisdictions with lower carbon prices (or none). Here,

Policy option	Description
Carbon pricing schemes (continued)	measures to help secure a level playing field internationally can complement carbon pricing. An example includes placing a carbon tariff on imports from jurisdictions with lower policy stringency and/or higher emissions intensity. Benefits: economically efficient and technology-neutral way of reducing emissions; price and/or free allocations can be progressively tightened over time to facilitate a continued transition; could use revenue recycling to support investments in the industry transition; measures such as carbon border adjustments could encourage other countries to adopt carbon pricing or similar decarbonisation measures. Limitations: may not incentivise the industry transition at the desired pace if not sufficiently stringent; does not provide targeted support for industry; on its own, and particularly in the near term when carbon prices are still relatively modest, unlikely to create sufficient incentive for early deployments of near-zero emissions technologies due to the high cost and risks involved; can be politically challenging to adopt in certain regions; could lead to carbon leakage in the absence of complementary measures to create a level playing field; for complementary measures like border carbon adjustments, trade implications and impacts on supply are unclear and implementation can be complex.

Potential role of a collective pledge in decarbonising industry

Key message: As demonstrated by similar efforts in other sectors, an international collective government pledge could facilitate global demand- and supply-side action in industrial decarbonisation by aggregating and amplifying individual market signals, and by providing a clear political signal on the direction of decarbonisation. While some initial steps have been taken on government pledges related to industrial decarbonisation, particularly on the demand-side, a stronger collective signal by a larger number of governments would have a greater impact.

Policies take time to develop, so government demand- and supply-side commitments could help provide a valuable signal to global markets in the near term. Aggregating commitments by multiple governments into a collective pledge can create an even stronger signal and give certainty for market players that operate across borders. The signal would be stronger still if private sector initiatives work to aggregate commitments in parallel. With greater certainty of a larger market, buyers can limit risk from exposure to near-zero emissions materials in their procurement portfolio by sharing offtake from first-of-a-kind projects with other buyers, while suppliers can leverage this combined purchasing power and policy certainty to secure more and longer-term offtake agreements and justify capital investments. This can help reduce barriers to market entry and promote better alignment of standards, accelerating action even further.

On the demand-side, some action is starting to emerge on government pledges related to industrial decarbonisation. The IDDI is among the leaders in this space, encouraging and aggregating commitments on public procurement into a collective pledge. Current membership consists of ten countries covering around 21% of global steel demand and 18% of global cement demand. To date, five IDDI member countries – Canada, Germany, the United Arab Emirates, the United Kingdom, and the United States – have signed on to the IDDI Green Public Procurement Pledge, pledging to adopt time-bound commitments for procurement of low-emissions materials for public construction projects. Such pledges could have a substantial impact on emissions from public procurement, considering that these governments together procure more than 30 Mt of steel and 55 Mt of cement. A further two countries – Austria and Japan – have signed a statement of intent to work towards key aspects of the IDDI pledge. These commitments were affirmed at COP29, which also saw the IDDI, FMC, and Net-Zero Government Initiative launch a Joint Call to Action for other governments to join the IDDI pledge at a level in line with their national circumstances, as well as to undertake other actions to enable low-emissions procurement. India, which is also a member of the IDDI, launched a public consultation in late 2024 for public procurement of lower-emissions steel, although it has not made a formal pledge through IDDI. Taken together, these efforts are a promising start, but would have more impact if a greater number of countries joined and if pledges increased in ambition to also include procurement of near-zero emissions materials.

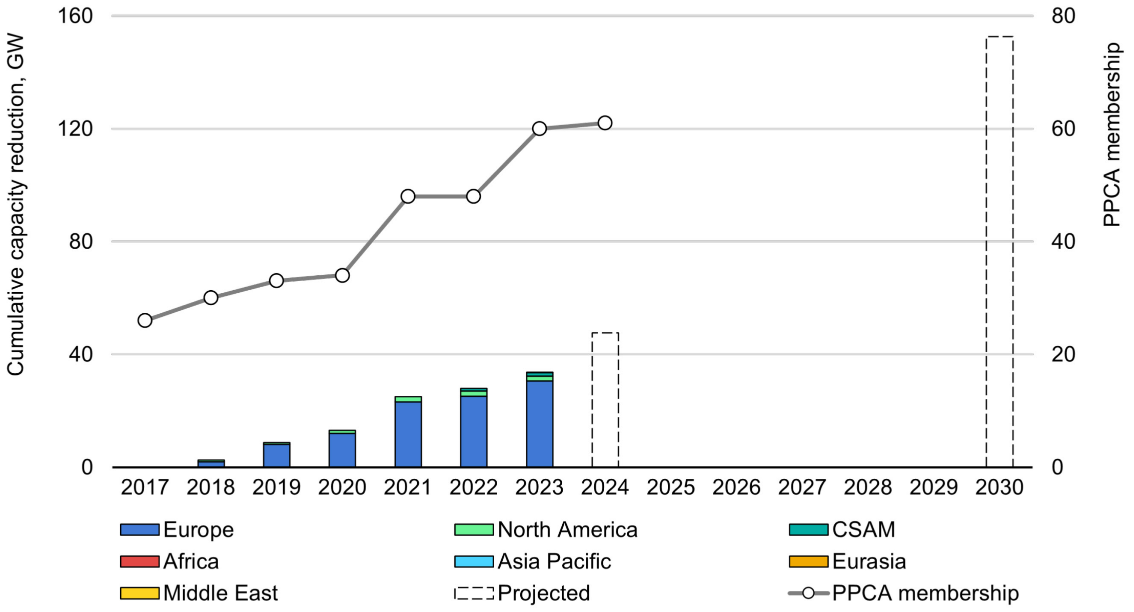
Supply-side pledges for the industry transition have been less discussed to date at the international level. To help start the conversation, the OECD Steel Committee Secretariat has developed a forthcoming 2025 report, titled *The Carbon Capacity Nexus: A Framework for Supply-Side Industrial Emission Reduction Pledges*. The framework proposal introduces how policy makers and industry stakeholders may design actionable supply-side commitments that relate emission reductions to capacity adjustments, using the steel sector as a replicable example. This includes the possibility of commitments and pledges that focus not only on scale-up of near-zero emissions capacity, but also on reducing reliance on emissions-intensive capacity, including by addressing the underlying causes that contribute to growth and maintenance of high-emissions capacity. As countries face unique opportunities to adjust their production capacities, this framework emphasises the different decarbonisation trajectories, requirements, and policy mixes available to governments as they work towards national commitments and possible collective pledges.

Collective government pledges for decarbonisation have been effective in creating global momentum for action in other sectors. However, a comparable high-level global rallying point for the industry sector transition does not yet exist, although pledges like that of the IDDI on public procurement of low- and near-zero emissions materials could serve as seeds for a broader global commitment. The co-ordinated pledges initiated in recent years relating to various parts of the energy sector could provide learnings for a potential collective pledge targeting the industry transition. Pledges include the Global Renewables and Energy Efficiency Pledge launched at COP28, the Global Energy Storage and Grids Pledge launched at COP29, the Global Methane Pledge launched at COP26, the Clean Energy Transition Partnership joint statement to end international public support for unabated fossil fuels launched at COP26, the EV30@30 campaign pledge, and the Beyond Oil & Gas Alliance Declaration.

While each of these pledges has its own specificities, there are several common aspects that have helped contribute to their success. One element is an easily communicable headline statement, often with a quantitative and time-bound element, that governments commit to (e.g. tripling renewables capacity by 2030, deploying 1 500 GW of energy storage by 2030, reducing methane emissions at least 30% by 2030). Underlying this are often several tangible actions that governments can take to realise the high-level objective, providing both guidance and accountability for taking the pledge forward. Together, these can create a simple yet powerful political signal. The extent of follow-up after the initial launch varies, ranging from welcoming additional governments to join the pledge, to detailed collaborative work to help facilitate action towards its objectives.

The Powering Past Coal Alliance (PPCA) is an example of a collective pledge that has shown demonstrable progress, and is analysed here in as an illustrative case study. A coalition of governments launched the PPCA in 2017 at COP23, with the objective to amplify national commitments to end unabated coal power generation and accelerate progress towards this end. At its inception, 20 countries had joined the pledge; as of the beginning of 2025, membership from national governments had grown to 61, covering over 300 GW of coal-fired power generation, or roughly 15% of total global capacity. By the end of 2023, PPCA members had reduced their total coal power capacity by 10%, or 35 GW, and have planned retirements dates for well over 100 GW of further capacity by 2030. Notably, the United Kingdom, as co-chair of the PPCA, achieved coal-free status in 2024 after retiring almost 15 GW of coal-fired generation capacity.

Reduction in coal-fired power generation capacity in countries that have taken up the Powering Past Coal Alliance pledge, 2017-2030



Notes: PPCA = Powering Past Coal Alliance. CSAM = Central and South America. Capacity reduction represents the total reduction in installed coal-fired power generation capacity starting the year following each country's membership in the PPCA. PPCA membership includes all national governments as of March 2025.
Source: IEA analysis based on data from Global Energy Monitor and S&P Global

PPCA member countries have used different policy strategies to move towards the mutual goal of becoming coal-free. For example, Chile executed bilateral agreements with power plant company owners for the gradual phase-out of coal-fired power generation, following the conclusion of an Energy Decarbonization Working Group established in 2018. This has since resulted in plans to retire or reconvert 20 of 28 total coal-fired power generation facilities in Chile by 2025. In 2023, Canada released its draft Clean Electricity Regulations that aims to set an emission intensity limit on new power generation facilities, including coal-fired power. In another recent example, France introduced in early 2024 a tax credit for clean energy equipment to incentivise a growing market share of renewable electricity and contribute to displacing coal. In Colombia, the government is taking steps to reduce coal use by phasing coal into its carbon tax scheme beginning in 2025, making coal-fired power generation less economical. With a potential collective industrial decarbonisation pledge, countries could take a similar approach of adopting a policy strategy that best suits their domestic circumstances.

While much of the actual coal power capacity reductions to date have been in advanced economies, momentum is also building in emerging markets, which account for 40% of the PPCA membership. Even though their membership in the PPCA has not yet translated to significant capacity reductions, it has affirmed a commitment to avoid where possible installing new coal-fired power generation and to support clean power generation. Furthermore, these economies have started to implement firm policies and investments, which are likely to trigger a decline in coal capacity in the coming years. Examples include Panama's renewable energy auctions, energy transition investments in North Macedonia, and Mauritius' implementation of its Renewable Energy Roadmap 2030.

Despite its success, there are limitations to the PPCA, including in terms of global coverage and bringing on board a broader range of EMDEs. Of the 61 signatories, 57 are either advanced economies or countries who were coal-free or near coal-free when they joined. Outside of the PPCA, countries are still installing new coal capacity, especially rapidly industrialising emerging economies. Given the differing rates of industrialisation worldwide, globally co-ordinated pledges for the industry transition could include targeted support for EMDEs to help advance a globally coherent transition.

Opportunities for a collective industry pledge on demand and supply under the Climate Club

As a high-level initiative for co-operation on industrial decarbonisation, the Climate Club has the opportunity to provide an important forum to discuss collective action, including exploring the possibility of a collective pledge. Such an international pledge has the potential to trigger a transformation of how steel and cement are produced, used and managed, facilitating a sustainable transition towards achieving internationally agreed government objectives for net zero emissions, while creating new market opportunities. As discussed further in the introduction, there is strong rationale to consider international co-ordination of demand- and supply-side action for industrial decarbonisation. Furthermore, the Climate Club could have a substantial collective impact given that, as of mid-March 2025, it accounts for just over 25% of global production and demand for steel, and 20% for cement, together resulting in around 850 Mt CO_2 emissions.

Discussions on collective pledges are likely to be complex, but they are nonetheless likely to be of high value to global industrial decarbonisation efforts. The year 2025 may provide an opportunity, as many governments are asked to revise their Nationally Determined Contributions (NDCs) for the next round of submissions. Discussions in the Climate Club on the industry transition, including on demand- and supply-side measures for scale-up of near-zero emissions materials and addressing high-emissions capacity, may be able to assist in the development and implementation of ambitious NDCs, and of steps towards meeting the commitments of the Paris Agreement more broadly. As governments are considering opportunities to increase ambition, robust implementation plans will be a key determinant of progress, including for the industry sector. The more governments can work together on the industry transition, the higher the likelihood of a smooth, affordable and effective transition while maintaining robust and competitive industrial markets. In this way, discussions on collective pledges and governments' own work on their NDCs can be complementary and reinforcing, even as the two processes remain distinct.

In discussions on pledges, it may be useful at the outset to acknowledge both the common interests of all members (e.g. progress on climate goals, resilient and competitive industries) and the unique circumstances that each brings to the table (e.g. different strengths on particular technologies for decarbonisation, being at different stages of the transition, different capabilities). Viewing these as strengths, and searching for synergies and complementarity, could aid the dialogue towards collective pledges that are ambitious and attainable. Parallel discussions on international technology collaboration, technical assistance and finance (including those ongoing in other workstreams of the Climate Club) can help identify ways forward on raising collective ambition together. Moreover, with the right combination of supply and demand-side measures – both domestically and internationally – early adoption of near-zero and low-emissions technologies may in fact provide a competitive advantage for first movers as the transition progresses.

In this section, at the request of the Climate Club, the IEA has developed a proposal for a collective pledge for consideration and discussion within the Climate Club, as well as considerations for its potential design and for how it could be implemented through clear and concrete policy measures. The pledge aims to address demand-side and supply-side challenges faced by global steel and cement markets in the transition towards near-zero emissions production while addressing high-emissions production. It serves as a concrete example of some of the various types of pledge options elaborated by the OECD in its forthcoming 2025 report titled *The Carbon Capacity Nexus: A Framework for Supply-Side Industrial Emission Reduction Pledges*.

The pledge is not intended to be exhaustive of all strategies, technologies and policies for industry decarbonisation – rather it focuses on targeted demand- and supply-side considerations where it is deemed that international co-ordination will be particularly valuable and could use more focused efforts. Climate Club members may wish to consider in parallel other complementary and reinforcing policies, including those to increase material efficiency and circularity, industrial decarbonisation roadmaps and broader policy measures like carbon pricing. Furthermore, the pledge proposal focuses on steel and cement specifically, but similar considerations could also be applicable to other industrial sectors.

The pledge proposal is intended to complement the work of other international initiatives by raising ambition to achieve shared objectives for industrial decarbonisation and, where relevant, helping in turn to drive increased engagement in other international activities. For example, the pledge could aid in achieving aspects of the Breakthrough Agenda's goals around steel and cement, including those around demand creation and innovation. Climate Club members might also consider ways that collaboration through other existing intergovernmental platforms could aid in achieving the pledge objectives, for example through Mission Innovation and the Clean Energy Transition Partnership.

It should be noted that the pledge proposal is intended only to provide a possible example as a starting point for discussion. Climate Club members are invited to discuss this example and jointly consider modifications, as well as the extent to which they may be willing to commit to such a pledge. Ultimately, any pledge and its underlying details rest with the Climate Club members to develop and agree upon, based on their combined considerations and collective ambitions.

Illustrative pledge proposal for discussion

The following is an illustrative example pledge on industrial decarbonisation, accounting for demand and supply challenges, that could be considered and discussed by Climate Club members. As noted above, it is purely illustrative, as such a pledge rests with Climate Club members, and there is no such commitment at this point.

Climate Club members could pledge to work together and develop supporting policies to contribute to reaching a share of 35% near-zero emissions steel and 25% near-zero emissions cement globally by 2035.

To bolster the high-level pledge, members could pledge to take further concrete actions. Here, it would be up to Climate Club members to decide together if the pledge implies committing to work on all of these actions collectively, or rather whether members would choose which of these supporting actions to commit to individually (see further below). Key areas of concrete action could include the following:

- **Creating near-zero emissions material demand:** including through setting ambitious targets for public procurement of near-zero emissions materials, and aggregating such signals internationally, e.g. through signing up to or increasing ambition within the IDDI Green Public Procurement pledge; and through developing policy mechanisms to support increased private sector purchases (e.g. contracts for difference, government-facilitated product emissions labelling and certification systems).
- **Scaling-up of near-zero emissions material production:** including through measures to enable deployment domestically, such as finance mechanisms to enable first-of-a-kind "lighthouse" projects; policies to facilitate broader early commercial deployment (e.g. subsidies, capital investment, permitting support, minimum market share regulations); and supporting the development of sufficient enabling infrastructure (e.g. low-emissions hydrogen production, CO_2 transport and storage). Additionally, this may include actions to co-operate internationally to support near-zero emissions production scale-up, such as targeted international capital financing and technical support specifically to support near-zero emission production and/or enabling infrastructure in EMDEs, including "lighthouse projects"; sharing RD&D costs and learnings among multiple governments for a portfolio of collaborative near-zero emissions

technology demonstrations in different regional contexts; and international partnerships along the value chains (e.g. cross-border materials purchase/offtake agreements, trade deals, or collaborative developments, including for low-emissions energy inputs and intermediates such as near-zero emissions iron).

- **Encouraging new capacity additions to be near-zero emissions capable:** including through policies requiring that all projects built after a particular date, including those based on conventional technologies, have clear plans and technical capabilities for transitioning production to near-zero emissions without requiring a major reinvestment (if they are not already near-zero emissions from the start); and through ending international public financial and in-kind support of high-emissions production not related to the implementation of transition plans aligned with achieving net zero emissions by 2050.
- **Reducing production and use of high-emissions materials:** including through financial incentives or regulatory policies that facilitate the replacement or retrofit of existing conventional facilities towards near-zero emissions technologies at the end of planned investment cycles; through developing a clear and ambitious schedule to reduce high-emissions production; removal of subsidies for emissions-intensive production; engaging in international discussions on possible collaborative actions to reduce overcapacity; or, on the demand-side, setting a date after which the government will no longer procure, and/or buyers within the country can no longer purchase, high-emissions steel and cement.

Considerations around a collective pledge

The illustrative pledge suggested above is designed for Climate Club members to send a clear, ambitious, collective signal to markets. The "headline" pledge is intended to be concrete and quantitative, allowing for monitoring and reporting on progress against milestones, yet simple to understand and communicate. Meanwhile, the underlying concrete actions provide detail on how governments could implement the pledge.

Several considerations are relevant for discussions surrounding this type of pledge, including how members may commit to the pledge, and the specific content of the pledge.

Method of commitment and adaptability

Any pledge needs to account for the different circumstances of different countries. In particular, parallel conversations on international assistance and finance will be important to strengthen possibilities for EMDEs to participate in such a pledge and ensure that commitment to such a pledge can be aligned with broader sustainable development objectives. Such activities are indeed occurring in parallel in the Climate Club, including through the Global Matchmaking Platform. Members might also consider signing up to the COP29 Global Pledge on Scaling International Assistance for Industrial Decarbonisation, and consider options mentioned in the pledge for international finance or partnership on lighthouse projects.

Furthermore, there could be different ways in which Climate Club members commit to such a pledge. On one side of the spectrum, members could collectively agree to the pledge overall, with international assistance and collaboration helping make this possible for all members. On the other side, individual members could elaborate their level of commitment to the different actions underlying the pledge. This could include the possibility to “sign-up” to certain actions, but not necessarily all of them, to allow members to adapt components to their own circumstances (e.g. dates, percentages, quantities) and perhaps elaborate detailed policy plans. The former option may provide a stronger unified signal, while the latter could enable more flexibility for members at the same time as providing additional accountability and commitment to specific actions that each is ready to pursue.

In considering which of these routes to select, it should be noted that the supporting actions listed are intended to be complementary, with each pulling a different lever for driving the industry transition and therefore having the biggest impact when taken together. Action on demand would help ensure a market by directly addressing the price premium and can deliver key market pull for bringing near-zero emissions supply online. Addressing near-zero emissions material supply can spur capacity scale-up to help ensure supply is available at the scale needed to meet demand. Encouraging any new investments, if they are not already near-zero emissions from the start, to be near-zero emissions capable would help manage the risk of carbon lock-in, stranded assets, and excess capacity throughout the industry transition. Reducing high-emissions conventional supply from existing assets could help ensure the progressive transition from high-emissions production to near-zero emissions production at a controlled pace.

While the industrial structure of each country – for example the age of its industrial assets and the extent to which its capacity is growing – may impact the relative significance of each action within each country’s transition, in general, all of the actions could play a useful role. Meanwhile, components of the actions that target other jurisdictions, such as international finance, can help bolster the collective ambition and scope of the pledge overall. Each action will come with its own challenges, and some countries may find certain actions more amenable than others due to their own unique circumstances. A middle-ground option could be to increase the degree of commitment to all of the actions over time – a smaller coalition of first-mover governments could focus on a particular action first, while others may come later, or choose to first target a different action. Alternatively, the Climate Club might collectively focus on certain actions initially, such as those that members regard as currently requiring the greatest attention in international dialogues.

Content of the pledge

In addition to the broader considerations around commitment to the pledge noted above, there are several details related to the pledge content that would require consideration. These are interlinked with the consideration of whether components of the pledge are collective by all members – in which case members would need to decide together on these elements – or whether some elements of the pledge are an aggregation of individual members' commitments – in which case individual members could decide on elements themselves.

These considerations include the following:

- **Quantitative target for near-zero emissions materials**: the shares of near-zero emissions steel and cement for Climate Club members in the above proposal are in line with the ambition of the IEA's Net Zero Emissions by 2050 Scenario, as a higher possible end of potential ambition. Here, the near-zero emissions steel target considers that it can be met via both iron- and scrap-based steel. The possibility to produce near-zero emissions steel fully from scrap is a key reason that the near-zero emissions steel 2035 milestone is more ambitious than that for cement: in theory, grids can be more readily decarbonised (as they are in decarbonisation scenarios), and innovations to reduce residual direct emissions from EAFs can be rolled out at a relatively rapid rate, which means that a comparatively larger portion of scrap-based steel can reach near-zero emissions. If they wish, some countries may set specific targets for each of near-zero emissions iron-based and scrap-based steel, given the importance of both in decarbonisation pathways.

  The Climate Club could choose to collectively work towards targets, such as these that are based on scenario analysis. Another option could be to aggregate the quantities that individual Climate Club members are willing to commit to in order to determine the collective share. The latter would imply that countries assess what is possible given their expected material demand and/or production, and the portion of this they would allocate as near-zero emissions.
- **Timing/year(s) for near-zero emissions materials:** the above proposal includes targets for 2035 to provide members time to develop sufficient supporting policies to achieve considerable deployment. Climate Club members could consider whether to also set a mid-term target (e.g. 2030), which could help push for higher mid-term ambition on early deployment. Including both targets may be stronger but would add an additional layer of complexity to the pledge.
- **Timing/year(s) for new near-zero emissions capable builds and reducing reliance on high-emissions materials:** with regards to dates by which new

investments, if not already fully near-zero emissions, are encouraged to be near-zero emissions capable and the timelines for ultimately reducing high-emissions production, Climate Club members could either collectively choose one target date/timeline, could individually pledge target dates/timelines, or could alternatively allow the pledge to provide a more indicative timeline (e.g. phase-down by mid-century). Members could also choose to set targets for when near-zero emissions capable production must transition to fully near-zero emissions.

- **Inclusion of low-emissions targets:** the current wording of the proposal focuses specifically on near-zero emissions materials, given that the Climate Club is designed to be a high-ambition forum. This would keep the end-point required for the transition squarely in sight and is consistent with the need to already have widespread near-zero emissions production by 2035 to get on a pathway to net zero by mid-century. It could be an option to also include low-emissions targets in the pledge, while still remaining focused on transformational technologies that could later be capable of near-zero emissions performance, in addition to the near-zero emissions target. This would have the advantage of clearly recognising that, in some cases, low-emissions production can be a step on the path to near-zero emissions production, and of providing more flexibility in the pathways that different countries target. A disadvantage of including low-emissions targets is that it would substantially increase the complexity of the pledge. Given that conceptions of what constitutes low-emissions production are more diverse, inclusion of low-emissions targets would make it more difficult to quantify what is required to meet the pledge and track collective progress towards it. Furthermore, a greater focus on low-emissions risks resulting in a less ambitious pledge and thus a weaker market signal overall. The impact would also depend in part on what level of low-emissions production were targeted, given that several proposed definitions of low-emissions materials have different levels or ratings of low-emissions within them (e.g. A to E rating).

Developing policies to implement pledges

As outlined above, high-level collective pledges can offer a powerful tool to mobilise action and send signals to markets on decarbonisation. However, pledges alone do not result in decarbonisation – rather they should be seen as one important initial step of many to be taken throughout the course of the policy-making process.

Once a pledge is made, follow-up with an implementation plan – ideally backed by a public commitment – would bolster the pledge and affirm action towards its realisation. This would involve the government evaluating how various policy measures could contribute towards achieving the pledge's objectives, which can include already existing policies but, in many cases, may require additional measures. This would likely feature both targeted demand-side and supply-side policy measures, along the lines of the policies outlined in this report. As noted previously, the IEA's Policy Toolbox for Industrial Decarbonisation can also be helpful in this regard, providing a snapshot of policy options and examples to aid governments in their strategy development. Climate Club members might also, if needed, make use of the Global Matchmaking Platform to seek technical assistance in developing their policy strategies. Once this step is complete, subsequent design and implementation of the chosen policy measures would follow.

Another important aspect of implementing such a pledge would be defining near-zero and/or low-emissions materials, as such definitions are critical enablers of demand- and supply-side policy measures. As international discussions on definitions continue, common ground is emerging around near-zero emissions intensity thresholds among the major proposals to date. Countries could move forward by looking into how existing international proposals may apply to their domestic circumstances and policy-making objectives. The IEA's principles for definitions, which were affirmed by Climate Club members, could be used as guardrails for such definitions. Continued international dialogue will be important to enable interoperability between definitions proposals and the underlying emissions measurement methodologies.

Of course, the policy-making process and commitment to collective pledges can be intertwined and may be an iterative rather than a linear process. For example, industry transition roadmaps or similar high-level strategies for net zero emissions could be useful stepping stones towards a committing to a collective pledge and carrying out its underlying actions. As Climate Club members contemplate the level of ambition for their pledge and work to define quantitative targets, country or regional roadmaps could be one approach to provide the means to define contextualised decarbonisation trajectories for their jurisdictions, for those who have not already undertaken such road-mapping exercises. In turn, these could be indispensable tools to establish appropriate milestones and credible targets for near-zero emissions steel and cement.

Organisations such as the Climate Club that are working towards a collective pledge could choose to also encourage, collate and track implementation plans. While this would require additional administrative efforts, it could help support the robustness of the pledges by providing better accountability and transparency.

Moreover, governments may consider possibilities to work together on policy development and implementation. This may include knowledge- and experience-sharing in fora like the Climate Club. It would also include discussions on the possibility to co-ordinate and align ambition of policy measures themselves, such as similar rates of subsidies under contracts for difference, comparable carbon prices, aligned emissions thresholds used in emissions intensity regulations, co-ordinated requirements within public procurement policies for near-zero and low-emissions materials, and co-ordination on similar timelines for reducing reliance on high-emissions production.

Finally, as policies are being implemented for the industry transition, it is important that complementary measures are provided to support workers and communities. One aspect of this includes programmes for capacity-building in the workforce related to near-zero emissions technologies and materials. In addition, targeted just transition measures can offer support for workers and communities that have been impacted by the industry transition.

Annex

Abbreviations and acronyms

CCfD	Carbon contracts for difference
CCS	Carbon capture and storage
CfD	Contracts for difference
COP	Conference of the Parties
CO_2	carbon dioxide
CSAM	Central and South America
DRI	Direct reduced iron
EAF	Electric arc furnace
EMDE	Emerging market and developing economies
ETS	Emissions trading system
EUR	Euro
FEED	Front-End Engineering Design
FMC	First Movers Coalition
IDDI	International Deep Decarbonisation Initiative
IEA GHG	IEA Greenhouse Gas R&D Programme
LCOP	Levelised cost of production
LeadIT	Leadership Group for Industry Transition
LESS	Low Emission Steel Standard
NDCs	Nationally Determined Contributions
NZE	Net Zero Emissions by 2050
OECD	Organisation for Economic Co-operation and Development
PPCA	Powering Past Coal Alliance
RD&D	Research, development and demonstration
RICS	Royal Institution of Chartered Surveyors
SBTi	Science-Based Targets initiative
S&P	Standard and Poor's
SSBP	Sustainable Steel Buyers Platform
UNIDO	United Nations Industrial Development Organization
USD	United States dollars

Units of measures

Gt	gigatonne
Gt CO_2	gigatonne of carbon dioxide
Gt CO_2-eq	gigatonne of carbon dioxide equivalent
GW	gigawatt
kg CO_2-eq	kilogramme of carbon dioxide equivalent
kW	kilowatt

Mt	million tonnes
Mt CO_2	million tonnes of carbon dioxide
Mt/yr	million tonnes per year
PJ	Petajoule
tcs	tonne of crude steel

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