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HOW INTERNATIONAL COLLABORATION CAN ENABLE THE GREEN TRANSITION

Peter Hill, **Virginia Sentance**, **Simone Gasperin**, **Alice Coffey** and **Klara Rehm**

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SUMMARY

CLEAN TECHNOLOGY DEPLOYMENT LAGS DESPITE TECHNOLOGICAL AND POLITICAL PROGRESS

Despite rapid progress in the development of clean energy technologies, global deployment is far too slow to meet climate goals. Clean industrial supply chains are struggling to scale because supply and demand are poorly aligned across countries, investment risks remain high, and existing international cooperation is not designed to address these challenges at the necessary scale.

Many clean industrial technologies depend on highly specific conditions. Low-cost renewable energy, suitable land, water, infrastructure and access to raw materials are often vital, and are concentrated in a small number of countries. By contrast, demand for low-carbon industrial products such as fertilisers, steel and fuels is concentrated in advanced economies, typically with limited access to these resources. This geographic mismatch makes projects risky and expensive, particularly when demand is uncertain and markets are still emerging.

EXISTING INTERNATIONAL COOPERATION COMES WITH LIMITATIONS

At the same time, geopolitical tensions and uncoordinated industrial policies are fragmenting global supply chains. Governments increasingly prioritise domestic production and supply chain security, but acting alone raises costs and limits the ability to scale clean technologies efficiently. Meanwhile, private investors remain cautious, particularly in capital-intensive sectors that depend on shared infrastructure and long-term policy stability.

Existing international approaches are not solving these problems. Multilateral processes – such as COP – are important for setting goals, but they are not well suited to mobilising finance, coordinating infrastructure decision-making, or creating reliable markets for new clean technologies. More flexible forms of cooperation exist, but they often lack binding commitments and fail to align the interests of producer and consumer countries.

MOVING FROM NATIONAL FRAGMENTATION TO DURABLE INTERNATIONAL COOPERATION THROUGH TECHNOLOGY-SPECIFIC COUNTRY PARTNERSHIPS

Scaling clean industrial technologies requires a shift from fragmented national strategies to targeted, durable international cooperation on technology-specific country partnerships. These partnerships would link countries with strong potential to produce clean industrial products to countries with growing demand, aligning policies, finance, infrastructure and standards across borders.

GREEN AMMONIA AND GREEN STEEL AS TEST CASES

Green ammonia and green steel are well positioned for this new model of partnership. Green ammonia is critical for decarbonising fertiliser production, shipping and hydrogen transport, but it faces high costs and uncertain demand. Green steel is essential for clean energy and infrastructure, but it remains expensive in countries with high energy costs. In both cases, coordinated international partnerships could reduce risk, unlock investment and accelerate market formation.

For green ammonia, partnerships can combine demand-side support, long-term offtake agreements and shared infrastructure investment to bridge the cost gap and give producers confidence to invest. For green steel, partnerships can enable the international trade of green reduced iron, allowing energy-intensive production stages to take place where they are cheapest while steelmaking and manufacturing are retained in consumer countries.

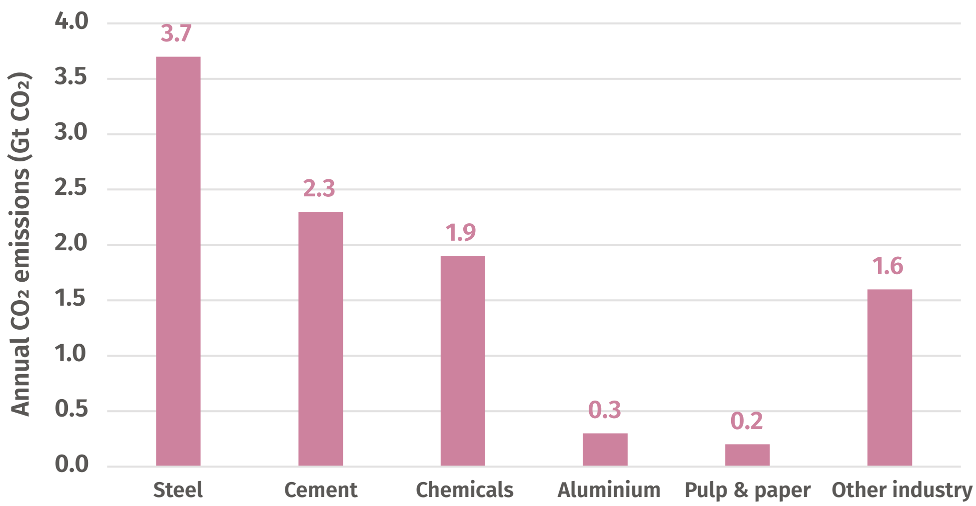
1.
THE CASE FOR NEW INTERNATIONAL PARTNERSHIPS IN CLEAN ENERGY TECHNOLOGIES

1.1 GLOBAL CONTEXT

At the current rate of decarbonisation, we won't reach the target of limiting global warming below 1.5°C compared to pre-industrial levels. While clean energy deployment has accelerated and net zero commitments are now widespread, current policies and investment patterns fall well short of what is required to deliver Paris-aligned emissions reductions (IEA 2024a; IPCC 2022). This gap is particularly acute in energy- and emissions-intensive industrial sectors, which account for a large share of global emissions but have seen comparatively limited progress in the deployment of low-carbon production routes.

FIGURE 1.1: IN SEVERAL KEY INDUSTRIAL SECTORS FOR ADVANCED NATIONS, CO_2 EMISSIONS ARE HARD TO ABATE

Industrial sector CO_2 emissions (global, 2023 estimates)



Source: IEA (2024b)

The challenge is not one of technological availability alone. Across power generation, fuels and industrial processes, many of the technologies required for deep decarbonisation already exist or are approaching commercial readiness. However, project-level evidence suggests that deployment is failing to scale. Tracking of announced clean industrial and hydrogen projects indicates that a substantial share remains at early development stage, with many projects delayed or failing to reach final investment decision (Mission Possible Partnership 2025). This pattern points to systemic barriers that extend beyond individual technologies or firms.

Hard-to-abate industrial sectors illustrate these constraints most clearly. Long asset lifecycles, high upfront capital requirements and dependence on shared infrastructure slow the pace of transition and increase exposure to policy and market uncertainty. The World Economic Forum estimates that achieving deep decarbonisation across these sectors will require additional investment of around $30 trillion by 2050 (World Economic Forum 2024), encompassing both production assets and the energy, transport and processing infrastructure that underpins them. Yet current capital flows remain misaligned with this requirement, particularly outside a narrow group of advanced economies.

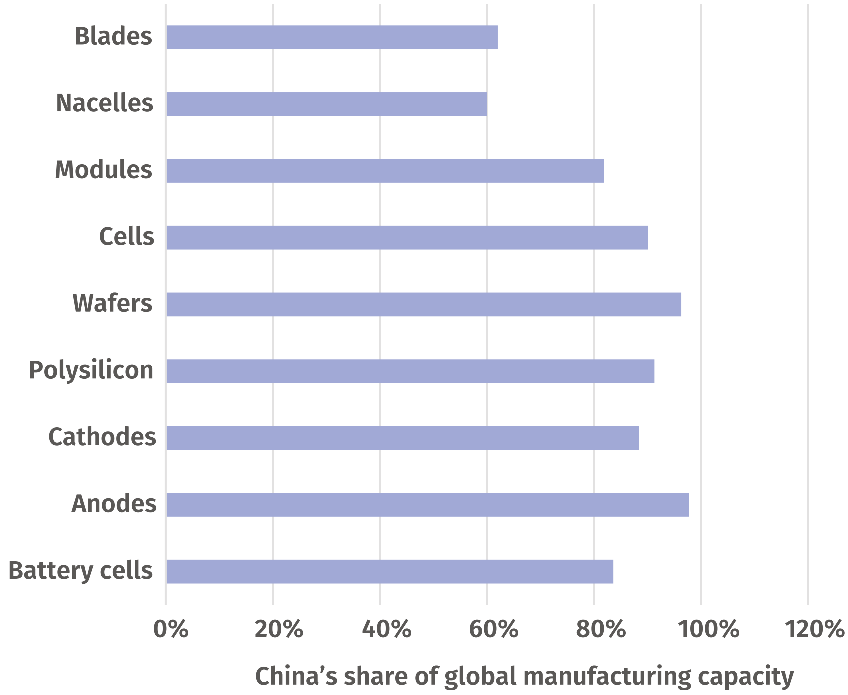
1.2 DRIVERS OF SLOW DEPLOYMENT

The gap between climate ambition and clean technology deployment is the result of features which constrain the development of clean energy supply chains.

- **Supply of clean technologies is constrained by infrastructural and geographical conditions.** Many clean industrial technologies depend on highly specific conditions (see section 2.2.2 for further detail), including access to low-cost renewable electricity, suitable land, water availability and high-quality raw materials. These conditions are unevenly distributed and often located far from established industrial hubs where demand is concentrated.
- **Demand for clean technologies is still insufficient or uncoordinated.** Demand for low-carbon industrial products is often insufficiently developed or coordinated to provide the certainty required to unlock large-scale investment. As a result, production potential and demand are both geographically and systemically misaligned, creating coordination challenges that markets alone struggle to resolve.
- **Capital expenditure and operating costs remain prohibitively high for most private actors operating in clean technology supply chains.** Under existing cost structures for capital and operating expenditures, there is little economic incentive for investors to allocate capital into these nascent technologies. This is especially pronounced in emerging and developing economies, where policy uncertainty, trade exposure and infrastructure constraints continue to sustain higher risk premiums despite strong underlying resource and industrial potential.
- **Geopolitics incentivises concentration.** Clean technology manufacturing supply chains are emerging in a political environment where governments view strategic sectors as integral to economic security and industrial competitiveness (IEA 2023; Gasperin et al 2026). This has strengthened incentives for onshoring and reshoring, often at the expense of broader cooperation. Global supply chains remain highly concentrated, with China dominating large segments of solar PV, batteries, electric vehicles, wind turbines and other strategic clean energy technologies. In response, advanced economies have introduced more interventionist industrial policies, including the United States' Inflation Reduction Act and the European Union's Industrial Accelerator Act. While these measures can strengthen domestic resilience, they also risk fragmenting global supply chains when pursued without coordination.

FIGURE 1.2: CHINESE DOMINANCE IN CLEAN ENERGY SUPPLY CHAINS

China's share of global manufacturing capacity in selected products (year 2023)



Source: Authors' elaboration from IEA (2024c)

1.3 LIMITATIONS OF EXISTING APPROACHES

Despite growing political attention and a proliferation of policy initiatives, existing approaches have struggled to overcome the constraints described above.

- **The private sector cannot absorb system-level risks alone**. Firms face exposure to global price competition, policy volatility and infrastructure dependencies that lie beyond their control. In the absence of clearer policy signals, risk-sharing mechanisms and coordinated frameworks, private investment has remained cautious, particularly in internationally exposed and capital-intensive sectors.
- **Multilateral governance frameworks have limited capacity to deliver effective implementation**. While international institutions and forums such as COPs remain important for political alignment and agenda-setting, they have been less effective in mobilising capital, harmonising standards or coordinating cross-border infrastructure for nascent technologies.
- **Alternative cooperation formats have expanded but remain partial**. In response to perceived multilateral inertia, governments have turned to more flexible plurilateral arrangements, including initiatives such as the Clean Energy Ministerial and Just Energy Transition Partnerships (JETPs). These formats can enable more targeted collaboration, but they do not sufficiently seek to build connections between producer and consumer economies and so have limited ability to overcome binding constraints.

Collectively, these limitations explain why existing tools have struggled to translate ambition into deployment.

1.4 TOWARDS A NEW MODEL OF INTERNATIONAL COOPERATION

Addressing the systemic challenges facing clean industrial deployment requires forms of international cooperation that are more targeted than previous approaches. To address the constraints which are holding back progress, advanced economies should pursue **strategic country partnerships with producer countries focussed on specific clean industrial technologies.**

These partnerships should be designed to link producer countries with strong resource and production potential to consumer markets with growing demand for low-carbon materials, creating durable cross-border supply relationships. Such arrangements can strengthen energy security and supply-chain resilience in importing countries while supporting industrial development and value creation in producer economies. By aligning investment, infrastructure development and long-term demand across borders, they can also contribute to wider economic competitiveness and reinforce shared strategic interests, including national security considerations.

For the UK, the EU and other developed economies, such partnerships provide a means of securing reliable access to low-carbon materials and energy carriers that are essential for industrial decarbonisation, while reducing exposure to concentrated supply chains and geopolitical risk.

For producer countries, especially those with strong renewable resource endowments or access to critical inputs, they offer a pathway to industrial development, value creation and participation in higher-value segments of clean technology markets. Structured effectively, and with consumer countries mobilising capital at scale, these partnerships can deliver mutual benefit, strengthening energy resilience, national security and economic competitiveness in importing countries while supporting sustainable industrial growth in exporting economies. Over time, they can also support deeper diplomatic engagement around shared economic and strategic interests.

Across technologies, effective partnerships share a set of common principles. Coordinated policy and regulatory frameworks are essential to unlock longer-term investment in capital-intensive projects. Governance arrangements must provide clear institutional responsibility, long-term policy signals and collaboration across industrial, trade, climate and foreign policy. Interoperable standards and regulatory frameworks are also critical, enabling cross-border trade in low-carbon products and supporting the development of transparent and efficient international markets.

At the same time, these partnerships should adopt a technology-specific focus, marking a departure from and innovation upon previous models. Clean industrial value chains differ significantly in their production requirements, infrastructure needs, cost structures and exposure to international competition. A technology-specific focus also better enables the inclusion of the private sector in the partnership.

The application of this approach to green ammonia (chapter 2) and green steel (chapter 3) illustrates how technology-specific partnerships can respond effectively to different technologies and green product markets.

2.
COUNTRY PARTNERSHIPS IN PRACTICE: GREEN AMMONIA

2.1 THE CONTEXT

Green ammonia occupies a distinctive position in the clean energy and industrial transition. Its most immediate role lies in fertiliser production. Fertiliser accounts for approximately 80 per cent of global ammonia consumption and underpins global food systems (The Royal Society 2020). Given its implications for food security, trade balances and price stability, decarbonising its production intersects with both industrial and geopolitical priorities.

Beyond fertilisers, green ammonia is increasingly recognised as a viable zero-carbon fuel for deep-sea shipping (The Royal Society 2020). Maritime transport faces particularly acute decarbonisation constraints due to energy density requirements and the long lifetimes of vessels. Ammonia offers a pathway that can be combusted without direct carbon dioxide emissions. At the same time, ammonia also provides a practical 'carrier' for international hydrogen trade, allowing green hydrogen produced in resource-rich regions to be transported to industrial demand centres using established bulk shipping technologies at reduced carbon emissions.

Conventional ammonia production accounts for around 1.8 per cent of global carbon dioxide emissions (Royal Society 2020)[1]. Substituting green ammonia for conventional supply therefore delivers immediate abatement in an established industrial market, while also enabling longer-term transitions in shipping and hydrogen logistics.

Despite this potential, green ammonia remains constrained by the limited availability of green hydrogen[2], on which its production depends. In 2023, less than 1 per cent of global hydrogen was produced via renewable electrolysis, creating a bottleneck that is expected to intensify as demand expands (IEA 2024d).

These characteristics place green ammonia at the intersection of the systemic challenges outlined in chapter 1. Competitive production depends on geographically specific conditions (such as access to low-cost renewable energy) which are not present in the industrial and maritime hubs where demand is concentrated. This makes green ammonia a particularly instructive case for examining how technology-specific country partnerships could help realign supply, demand and investment across borders.

2.2 THE CHALLENGE

2.2.1 Rising demand without reliable sources of supply

Global ammonia demand is set to rise, led by fertilisers and emerging uses in shipping fuels and hydrogen logistics. In both the EU and the UK, policy pathways to net zero imply increasing reliance on green ammonia through 2050.

1 For context, international aviation currently accounts for approximately 2.5 per cent of global emissions.
2 Green hydrogen is produced through electrolysis powered by renewable energy.

- **EU**: The REPowerEU plan targets 10 million tonnes (Mt) of domestically produced and another 10 Mt of imported renewable hydrogen by 2030, much of which is expected to arrive as ammonia. FuelEU Maritime will tighten marine fuel greenhouse gas (GHG) intensity, reaching approximately 80 per cent cuts by 2050, driving uptake of green ammonia-based fuels. Europe faces considerable limitations in producing sufficient renewable energy at low cost to meet its domestic green hydrogen targets (Hydrogen Europe 2024).
- **UK:** Fertiliser dominates current ammonia use, but the Hydrogen Strategy identifies 75–95 TWh/year of hydrogen-derived fuels for shipping by 2050, equivalent to 15–20 Mt/year of ammonia (UK Government 2021). Ammonia is also expected to be a key hydrogen carrier for imports into industrial clusters.

Both jurisdictions anticipate growing import dependence from the 2030s onwards. This reflects the difference in cost between domestic production and imported green ammonia. As a result of significantly higher electricity prices, producing green hydrogen domestically is projected to be double the cost of importing ammonia from regions with abundant low-cost renewables (for example MENA, Australia) (UK Government 2021).

2.2.2 Production depends on highly specific country conditions

There is a widening gap between projected demand and feasible green ammonia production. Capacity is growing – announced green hydrogen projects reaching final investment decision (FID) doubled from 2023–24 – but is still insufficient (IEA 2024d). Demand for ammonia in Europe alone stood at 17.1 Mt in 2025 with a forecasted demand-capacity gap of 12.9 Mt in 2050 (Haveresch and Gallardo 2024).

Projections suggest renewable ammonia capacity could exceed 15 Mt by 2030, expanding further towards 2040 (IRENA and AEA 2022). As of November 2025, 144 projects have reached FID, with early movers including Saudi Arabia (NEOM/ACWA), Oman (Duqm), Morocco (OCP), Egypt (SCZONE), Australia, Chile, Namibia (Hyphen), Brazil, and South Africa. However, more than 860 others remain at pre-FID stage.

Production will concentrate in countries with the right combination of natural resources, infrastructure and policy frameworks.

1. **Very low-cost renewables.** High-quality solar and wind enable low and high utilisation.[3] Some regions are projected to reach cost parity with grey hydrogen by 2028, with potential green hydrogen costs as low as $1.5/kg (Cordonnier and Saygin 2022).
2. **Infrastructure compatibility.** Green ammonia production benefits from access to ports, pipelines and bulk handling facilities that can accommodate ammonia safely at scale. Unlike hydrogen, which requires high-pressure compression or cryogenic liquefaction, ammonia can be stored and transported under moderate pressure or at low temperatures, enabling the reuse or adaptation of existing infrastructure. Where such infrastructure is available, capital requirements for green ammonia are lower and deployment can proceed more rapidly.
3. **Supportive policy and regulation.** Bankable land tenure, grid/offtake arrangements, streamlined permitting and common-user infrastructure enable faster progress.[4] International alignment on safety standards and regulations will be essential for large-scale, cost-effective global trade.

3 Levelised Cost of Hydrogen (or ammonia) is a metric used to assess the average cost of producing hydrogen (or ammonia) over the lifespan of a production facility.

4 'Common-user infrastructure' refers to shared facilities and services that multiple companies or projects can access, rather than each developer building and operating their own separate infrastructure.

These specific conditions mean a small number of countries and regions are projected to supply most green ammonia and in turn green hydrogen – and certainly most traded volumes – by 2050.

Which countries will dominate this future production is yet to be determined. IRENA's 2050 Outlook predicts Australia, North Africa (primarily Morocco, Egypt, Tunisia), the United States, India, Russia and Chile as the largest net exporters, with the potential for other Emerging Markets and Developing Economies (EMDEs) to also emerge as hubs for low-cost, low-emissions hydrogen production. A new 'industrial sunbelt' – including countries such as India, Egypt, Brazil and Mexico – with abundant solar potential to capture clean industry projects could dominate future production (Mission Possible Partnership 2024).

2.2.3 Why current approaches are not delivering scale: insufficient and limited coordination

Although international interest in green ammonia is growing, the scale and structure of current cooperation remain inadequate. Many initiatives focus on bilateral agreements or non-binding Memorandums of Understanding (MoU) that lack commitments on offtake, infrastructure or finance. For producers, this results in high capital costs and limited clarity on demand, complicating willingness to invest. For consumers, it creates uncertainty around future supply, cost and standards. The absence of mechanisms that systematically align producer and consumer interests is one of the greatest constraints to market development in green ammonia.

The slow pace of deployment reflects a combination of reinforcing constraints rather than a single barrier. On the demand side, policy frameworks remain fragmented across sectors and jurisdictions, with limited clarity on standards, certification and the role of ammonia in decarbonisation pathways. This weakens price signals and discourages long-term contracting.

On the supply side, green ammonia projects are capital-intensive and highly exposed to early-stage risk. Developers require long-term revenue certainty to secure financing, yet prospective buyers in fertilisers, shipping and refining are reluctant to commit to multi-decade contracts in a rapidly evolving market. This mismatch between producer and consumer time horizons is a core feature of the market failure.

Infrastructure constraints compound these challenges. Large-scale production depends on coordinated investment in renewables, transmission, hydrogen handling, desalination and export facilities. These assets often exceed the scope of individual projects and require public planning, shared financing structures and political backing. In the absence of such coordination, projects struggle to progress beyond early development.

2.3 THE SOLUTION

Scaling green ammonia as a globally traded low-carbon commodity requires coordinated action by producer and consumer governments to address the market failures identified above. Green ammonia therefore represents a clear case where technology-specific country partnerships can provide a practical framework for progress.

Early examples illustrate how these tools can be deployed in practice.

THE EXAMPLES OF H2GLOBAL AND HYPHEN HYDROGEN ENERGY

H2Global is a demand-side market-building mechanism designed to address the systemic mismatch between green ammonia producers and early buyers. Established with substantial funding from the German government, initially capitalised at €4–4.5 billion, it seeks to bridge the cost gap between renewable hydrogen derivatives and conventional fossil-based alternatives.

The central challenge it addresses is one of timelines. Producers require long-term price and volume certainty to finance capital-intensive projects, while buyers in sectors such as fertilisers, refining and shipping prefer short-term commitments due to expectations of falling costs and evolving technology choices. This mismatch has been one of the primary barriers to the emergence of a liquid international market for green hydrogen derivatives.

H2Global introduces a dual-auction structure to reconcile these competing needs. A government-backed intermediary signs long-term purchase contracts with producers at fixed prices, creating bankable revenue streams that support project finance. It then resells the product through shorter-term auctions to buyers, reflecting demand-side preferences for flexibility. Public funding underwrites the difference between the long-term purchase price and the short-term resale price, rather than subsidising a fixed proportion of output, allowing fiscal exposure to adjust as market conditions evolve.

Beyond individual transactions, H2Global plays a broader role in market formation. By aggregating demand, standardising contract structures and providing transparency on pricing and volumes, it helps establish common commercial practices for the trade of green molecules. It supports early price discovery, contributes to the development of sustainability criteria and signals durable policy commitment from importing regions. This combination of public funding and market-based contracting strengthens confidence among producer countries and investors considering large-scale investment in renewable generation and export infrastructure.

The **Hyphen Hydrogen Energy** project in Namibia provides a producer-side illustration of how country partnerships can enable large-scale green ammonia production in an emerging economy. The project is a joint venture between the German renewable energy developer Enertrag and investor and project developer Nicholas Holdings. It is developed in partnership with the Namibian government, which has granted Hyphen the rights to develop the project. SDG Namibia One brings together the state, local institutions and international investors to mobilise blended finance for shared infrastructure.

The project is designed to produce up to 2 million tonnes of green ammonia per year in its first phase, supported by approximately 5 gigawatts of solar and wind generation and 3 gigawatts of electrolysis capacity. Its scale reflects both Namibia's exceptional renewable resource base and a strategic ambition to position the country as an early exporter of green hydrogen derivatives to Europe and Asia.

A defining feature of Hyphen is its integrated infrastructure model. Public authorities coordinate land allocation, permitting, transmission links, desalination capacity and port upgrades, ensuring alignment between public infrastructure and private investment. Through SDG Namibia One, the state holds a 24 per cent equity stake and channels concessional and commercial capital into common-user assets such as desalination plants, pipelines and port facilities. This reduces project risk, lowers system-wide costs and creates a platform for additional projects to develop in parallel.

International engagement underpins the project's viability. Germany has designated Hyphen a strategic foreign hydrogen project, signalling political support from a major import market. Early offtake discussions with European and Asian buyers covering more than 1 million tonnes per year help anchor demand and enhance bankability. Together, these elements illustrate how producer and consumer interests can be aligned through coordinated planning, blended finance and long-term political commitment.

TABLE 2.1: COMPARATIVE ASSESSMENT OF COUNTRY CONDITIONS FOR COMPETITIVE GREEN AMMONIA PRODUCTION AND EXPORT POTENTIAL

Country	Resource availability	Transport infrastructure	Export focus	Current green H_2 status	Financial risk/ cost of delivery	UK/EU relationship
Algeria	Strong solar and land availability.	Gas infrastructure. Involved with the SouthH_2 Corridor hydrogen pipeline concept targeting up to 4Mt import capacity by 2030.	Clear export focus in National Hydrogen Strategy (2023).	National Hydrogen Strategy (2023) targets 1Mt of H_2 by 2040.	Uncertainty around CAPEX and limited project pipeline.	Strong EU partnership on energy and security, part of European Neighbourhood Policy with recent disputes over trade and migration. UK relation more on security.
Australia	Vast land with excellent solar and wind.	Mature ports/export infrastructure. LNG export experience transferable.	Explicit export ambition within National Hydrogen Strategy.	National Hydrogen Strategy (2024) targets 15Mt/yr (stretch 30Mt/yr) by 2050. Green H_2 hubs at Pilbara, Gladstone, Hunter Valley.	Government subsidies and tax credits but potential financing constraints due to high CAPEX.	Strong UK and EU ties with existing clean technology links. Co-presiding over COP31 negotiations.
Brazil	Strong solar and wind – over 89 per cent of power renewable (hydro dominant).	Northeastern ports (Ceará, Pernambuco) emerging as H_2 hubs with MoUs. All at early stages of development.	Targeting domestic use for steel, fertiliser and other applications, as well as export.	National Hydrogen Program (2021); Hydrogen Law passed 2025. Flagship industrial green hydrogen plan paused.	Financial challenges and uncertainty of governmental support.	Joint initiatives as part of Clean Energy Pact, recent announcement of Mercosur trade agreement with EU.
Morocco	Good solar and wind resources “Morocco Offer” (2024) - earmarked 1 million hectares for renewable-H_2 projects.	Strong port infrastructure (Tangier, Casablanca). 14km from Europe, giving it a strategic export position.	Clear export focus in National Hydrogen Roadmap with limited projected demand for domestic use.	Hydrogen Roadmap (2021) aims to produce green ammonia to replace ammonia imports for fertilisers.	Costs moderate; scaling required to meet projected export demand.	Reliable EU and UK partner for clean energy, green hydrogen, ammonia etc. Includes UK-Morocco Clean Energy Innovation Facility and EU-Morocco Cooperation Programme.
Namibia	World-class solar/wind in Namib desert.	Ports exist but upgrades needed. Walvis Bay terminal upgrades planned.	Strong orientation on export corridors in National Hydrogen Strategy.	Hyphen project: 10GW RE + 3GW electrolysis, backed by Germany/EU; ~300 kt H_2/yr planned.	Large CAPEX making offtake agreements key to further development.	Important EU partner for green energy and raw materials with funding funnelled through Global Gateway initiative.
South Africa	Good solar and wind resources. 2021 Hydrogen Society Roadmap envisions deploying 10GW of electrolysis capacity (mostly in Northern Cape) by 2030.	Ports exist but upgrades are needed.	Hydrogen Society Roadmap includes a dual focus on domestic decarbonisation and export ambitions.	Hydrogen Society Roadmap (2021) outlines deployment towards 500,000 tonnes of green hydrogen per year by 2030.	Grid and finance constraint on Northern Cape transmission network.	EU is South Africa’s largest trade and investment partner. EU- South Africa Clean Trade and Investment Partnership, UK Infrastructure Partnership and JETP links.

Source: Authors’ elaboration.
Green=high potential; yellow=medium potential; red=low potential.

2.3.3 Potential partner countries

Table 2.1 above assesses a list of countries against several criteria to rate their overall suitability as potential producer and exporter countries of green ammonia.

2.4 POLICY RECOMMENDATIONS

Green ammonia faces a multi-stage market failure: first, projects cannot reach final investment decision due to high costs and demand uncertainty; second, sustained investment will not flow without enabling policy frameworks and market conditions, including clear demand signals.

Scaling supply therefore requires policy action in three related domains.

1. **Deploying public finance mechanisms to enable early project investment to secure supply**. These are essential to close the price premium on green ammonia and create bankable demand for early projects.
2. **Creating durable market conditions through long-term offtake agreements.**[5] These can play a central role in reducing risk of limited revenue and creating early supply.
3. **Providing the market infrastructure to underpin both supply and demand.** This includes physical and regulatory infrastructure.

These levers should be the focus of the UK and EU's clean technology partnerships with third countries.

2.4.1 Public finance mechanisms enable early investment to secure supply

Governments should initially focus on enabling early projects to reach FID by de-risking production while facilitating the following.

- The establishment (or expansion) of an H2Global style double auction mechanism for ammonia that signs long-term purchase contracts with producers (eight–10 years) while reselling volumes on shorter-term contracts to buyers. This support should be time-bound, with declining public exposure as costs fall and market liquidity improves.
- The creation of aggregate demand across anchor sectors (fertilisers, chemicals, shipping for fuels) to generate sufficient scale for early projects and avoid fragmented bilateral contracting (for example by deploying an intermediary to sign bundled offtake agreements with producers and allocate volumes to end-users).
- The coordination of these mechanisms with partner countries to send a credible signal of future import demand and reduce investor risk in export-oriented projects. This may include linking policy commitments, contracting frameworks, deployed public finance and risk-sharing.

When implemented through partnerships with producer countries, public finance mechanisms also send a credible signal that future import demand will materialise, strengthening confidence in large-scale export-oriented investment.

2.4.2 Creating durable market conditions through long-term offtake agreements

Once initial supply is unlocked, governments must anchor sustained demand to support continued investment.

- Support long-term offtake commitments in strategic sectors where green ammonia is a like-for-like substitute, providing predictable revenues for producers. This should apply a phased approach, starting with sectors that are initially able to absorb the green premium and scaling into larger, more price-sensitive markets as costs decline.

5 An offtake arrangement is a contract committing a buyer to purchase future production, used to secure demand certainty and underpin investment.

- Reduce risk for private offtakers, such as by using government export finance to provide political risk insurance, currency guarantees and concessional finance for green ammonia projects.
- Link offtake agreements to co-investment arrangements, such as with multilateral development banks, to enable infrastructure in producer countries.

2.4.3 Providing market infrastructure which supports investment

Financing and contractual mechanisms to underpin supply and demand can only go so far if the wider market infrastructure isn't supportive. They will be most effective when combined with coordinated investment in enabling infrastructure within producer countries. Public planning and blended finance should enable shared infrastructure such as renewable generation, transmission, desalination, hydrogen handling and export-ready port facilities.

Similarly, supportive governance arrangements and regulatory alignment remain essential. Interoperable standards for safety, sustainability and certification reduce transaction costs, enable cross-border trade and provide clarity for early movers. Without such alignment, even well-financed projects risk being constrained by regulatory fragmentation and uncertainty.

3. COUNTRY PARTNERSHIPS IN PRACTICE: GREEN STEEL

3.1 THE CONTEXT

Steel matters for decarbonisation both as a final product and in terms of how it is manufactured. Accounting for around 10 per cent of global emissions (IEA, IRENA and UNCC HLC 2023), steelmaking represents one of the largest industrial decarbonisation challenges. At the same time, steel products underpin the deployment of renewable energy infrastructure, electricity networks, transport systems and industrial equipment. For both reasons, it is important to accelerate the production of green steel.

Steel is produced through two main routes: primary and secondary. Primary steelmaking relies on ironmaking from processing iron ore, traditionally via the blast furnace-basic oxygen furnace (BF-BOF) route, which produces virgin steel but is highly emissions-intensive, releasing around 2 tonnes of CO_2 (tCO_2) per tonne of steel, due to the inherent chemical reduction of iron ore with coke (Hasanbeigi 2022). An alternative primary route is direct reduced iron (DRI), where iron ore is reduced into solid sponge iron and then melted in an electric arc furnace (EAF) to produce virgin steel. Today, most DRI is produced using natural gas or coal gasification, which lowers emissions relative to BF-BOF but remains highly carbon-intensive.

TABLE 3.1: MAIN STEELMAKING PROCESSES

<table>
<tr><th>Production processes</th><th>Input raw material</th><th>Ironmaking</th><th>Steelmaking</th><th>Semi-finished products</th><th>Hot-rolled products</th><th>Finishing operations</th></tr>
<tr><td rowspan="4">Primary steelmaking</td><td>Coal</td><td rowspan="3">Pig iron from blast furnace</td><td rowspan="2">Basic oxygen furnace</td><td rowspan="6">Blooms
Billets
Slabs</td><td rowspan="6">Long products
Rails
Structural shapes
Welded tubes
Seamless tubes
Wire rods
Bars
Rebar
Flat products
Coils
Plate</td><td rowspan="6">Cold rolling
Metal coating
Painting</td></tr>
<tr><td>Limestone</td></tr>
<tr><td>Iron ore</td><td>Electric arc furnace</td></tr>
<tr><td>Iron ore</td><td>Sponge iron from DRI process</td><td>Electric arc furnace</td></tr>
<tr><td colspan="4"></td></tr>
<tr><td>Secondary steelmaking</td><td>Scrap ferrous material</td><td>[None]</td><td>Electric arc furnace</td></tr>
</table>

Source: Authors' elaboration from Worldsteel (2025a)

Secondary steelmaking bypasses ironmaking altogether by melting scrap steel in EAFs. Its emissions are much lower (around 0.4 tCO_2 per tonne in Europe and North America (E3G 2025)) and largely depend on the electricity mix, though scrap quality constraints limit its use for certain industry applications, such as flat products used in automotives.

Achieving near-zero emissions steel ('green steel') requires a shift to a fundamentally different production method – hydrogen-based direct reduced iron combined with electric arc furnaces, both powered by renewable electricity.

3.2 THE CHALLENGE

3.2.1 Global concentration and competitive pressures

Global steel production is highly concentrated and has become more so over the past two decades. While total output has expanded, production has shifted towards a small number of countries, particularly China and other large emerging economies, which now account for most global capacity. This reflects the capital-intensive nature of steelmaking.

At the same time, steelmaking in advanced economies has not disappeared. Absolute production has declined only modestly, and per-capita consumption remains high. This reflects the continued importance of steel to manufacturing, infrastructure and clean energy deployment. However, higher energy costs, ageing assets and competitive pressures constrain the ability of these economies to scale low-carbon production independently.

3.2.2 The continued need for primary steelmaking

One decarbonisation pathway would be to phase out blast furnaces entirely and rely solely on electric arc furnaces powered by renewable electricity. However, primary steelmaking remains critical for economies with advanced manufacturing sectors, which depend on reliable access to virgin crude steel for specific grades and applications. This is widely accepted in policymaking, as testified by the EU's Clean Industrial Deal (European Commission 2025), or by the UK's Industrial Strategy and Steel Strategy (UK Government 2025; DBT 2026a).

In addition, the physical availability of scrap is insufficient to meet global steel demand. As a result, primary steelmaking will need to persist and transition, requiring the greening of the ironmaking stage through DRI processes coupled with renewable hydrogen.

3.2.3 Cost constraints in green ironmaking and steel production

Installing DRI units and new EAF capacity is capital-intensive and often unviable without public support in the form of grants and subsidised financing. But operating costs present a more persistent challenge. Electricity prices strongly affect EAF competitiveness, while hydrogen-based routes are highly sensitive to renewable power costs, utilisation rates and infrastructure availability. As a result, both CAPEX and OPEX often require sustained support rather than one-off transition funding.

3.2.4 Trade frictions and strategic exposure

Trade policy and geopolitical considerations play an increasingly important role in shaping steel markets. Existing and emerging trade disputes, industrial policies and safeguard measures such as temporary trade restrictions influence investment decisions and market access, adding uncertainty to long-term planning. Recent tariff increases by the US and proposed tightening of EU import measures illustrate how protectionist dynamics are intensifying across major steel markets. These trends have been reinforced by high-profile political interventions in corporate transactions, most notably the blocking of Nippon Steel's proposed acquisition of

US Steel on national security grounds, underscoring the extent to which steel is now treated as a strategic asset rather than a purely commercial commodity.

Measures such as Carbon Border Adjustment Mechanisms (CBAM) aim to limit carbon leakage and protect domestic producers facing higher decarbonisation costs. However, while a CBAM may shield domestic markets from more carbon-intensive imports, it does not resolve underlying cost differentials between production routes or address the competitiveness of exports from jurisdictions facing higher carbon and energy costs.

At the same time, the strategic importance of steel for infrastructure, defence and manufacturing has heightened political sensitivity around supply chains. Governments are therefore balancing decarbonisation objectives against concerns over competitiveness, security of supply and industrial employment. These overlapping pressures complicate unilateral or purely domestic approaches to green steel deployment and reinforce the case for coordinated international strategies.

3.2.5 Limits of nationally bounded decarbonisation strategies

Most existing decarbonisation strategies focus on plant-level or national transitions, including incremental efficiency improvements, increased scrap use and pilot hydrogen-DRI projects co-located with existing assets. Germany has prioritised hydrogen-based DRI linked to domestic steelmaking, while the UK has temporarily embraced a transition from blast furnaces to EAFs without domestic DRI capacity.

Despite these differences, both approaches face the same underlying challenge: without recognising the fundamentals of operating costs and international cost asymmetries, domestic strategies risk delaying decarbonisation or locking in higher long-term production costs.

MARKET EXAMPLES: GERMANY'S DOMESTIC HYDROGEN-DRI TRANSITION AND THE UK'S CONSTRAINED PATHWAY TO GREEN STEEL

Germany has pursued one of the most ambitious domestic green steel strategies in Europe, centred on converting existing blast furnace capacity to hydrogen-based direct reduced iron. Major producers including thyssenkrupp, SHS and Salzgitter are planning to install DRI units integrated with electric arc furnaces, supported by over €7 billion in public funding under the Climate and Transformation Fund (E3G 2025).

These projects demonstrate the technical feasibility of large-scale hydrogen-DRI in an industrial setting. However, high electricity costs are making the transition to a fully integrated green steel production economically unsustainable, with some companies scaling back or postponing their investments.

Germany's approach illustrates the limits of a primarily domestic transition strategy in a country with a lack of abundant and affordable clean power generation capacity. As such, it highlights why domestic hydrogen-DRI alone is unlikely to scale without complementary access to lower-cost green iron sourced from abroad.

The **UK** faces an even sharper version of this challenge. Primary steel production is concentrated in just one side, Scunthorpe, which is being nationalised precisely for its strategic relevance (DBT 2026b). Moreover, the country has among the highest industrial electricity prices in Europe (DESNZ 2026).

Current decarbonisation plans have focussed on transitioning blast-furnace assets toward electric arc furnaces and improving scrap utilisation, rather than large-scale domestic hydrogen-DRI.

While EAF conversion reduces emissions relative to BF-BOF routes, it increases reliance on scrap and imported iron units for high-quality steel grades. The UK case underscores the limits of nationally bounded strategies in resource-constrained systems. Without access to low-cost green iron from external producers, UK steelmakers will not be able to produce certain types of steel products that are specifically demanded in some key manufacturing industries. This reinforces the case for international green-iron partnerships that allow ironmaking to occur where it is competitive, while retaining steelmaking, finishing and downstream manufacturing domestically. The UK Steel Strategy recognises "new green trading partnerships" as a resilient solution to achieve low carbon steelmaking over time (DBT 2026a).

3.3 THE SOLUTION

3.3.1 Decoupling ironmaking and steelmaking through green iron corridors to reduce the costs of the transition

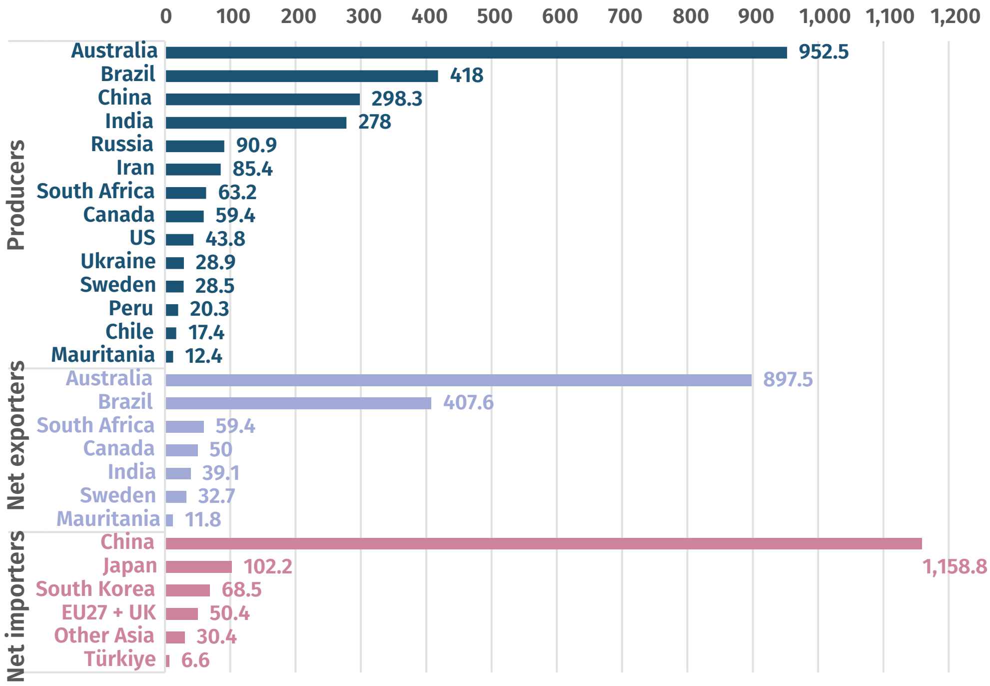
The DRI process offers the possibility of decoupling ironmaking from steelmaking activities, outsourcing part of the ironmaking process in resource- and energy-rich countries, while establishing trade corridors for green iron. This could facilitate the cost-competitive transition of the steel sector in advanced economies facing higher energy costs. With access to cheaper imported green iron, advanced economies could lower the overall production cost of green steel by up to 15 per cent compared to domestic renewable H_2-DRI production (Agora Industry 2025), thereby enhancing the competitiveness of their leading steelmaking players.

This potential model of international specialisation in the global steel industry could also bring benefits to iron ore-exporting nations, as they can further specialise in higher value-added transformation activities. At the same time, outsourcing ironmaking capacity would not lead to a significant loss of employment in advanced economies or compromise their steelmaking capabilities (Agora Industry 2025).

Given that iron ore is already highly traded globally (see figure 3.1) – with a few producing countries such as Australia, Brazil, South Africa and Canada accounting for most exports to steelmaking nations – there is significant potential for the emergence of an international market for green iron. To make it suitable for international shipping and storage, reduced iron in sponge form can be compressed into hot briquetted iron (HBI) (Midrex Technologies 2020). Unlike green H_2, HBI can be supplied directly to steelmaking plants without the need for additional infrastructure, as it is a bulk material compatible with existing iron ore logistics systems.

FIGURE 3.1: A FEW COUNTRIES, PARTICULARLY AUSTRALIA AND BRAZIL, ACCOUNT FOR MOST OF THE GLOBAL NET EXPORTS OF IRON ORE

Major producing, net exporting and net importing countries of iron ore (million tonnes (Mt))



Source: IPPR elaboration on Worldsteel (2025a), year 2023

TABLE 3.1: GLOBAL PRODUCTION AND TRADE OF IRON, IRON-DERIVATES AND STEEL PRODUCTS IN 2024

Product	Production	Trade (Exports)	% of trade relative to production
Iron ore	2,522 Mt	1,712 Mt	67.9%
Pig iron	1,293.5 Mt	10.5 Mt	0.8%
DRI	140.8 Mt	13.3 Mt	9.4%
Finished and semi-finished steel	1,764.8 Mt	449.2 Mt	25.5%

Source: IPPR analysis on Worldsteel (2025a) and Midrex Technologies (2025)

3.3.2 Conditions for outsourcing ironmaking and establishing trade channels

Despite its potential, a global market for green iron has yet to be established and will require targeted policy efforts. In fact, even trade in fossil fuel-based DRI remains limited: international shipments account for less than 10 per cent of total global production (see table 3.1), with most output consumed domestically by major producers such as India and Iran.

Moreover, before any trade of green iron can take place, productive capacity needs to be established. Green iron production could be scaled up competitively only in countries where a set of conditions and policies are in place.

1. **Availability of the right type of iron ore.** To be economically competitive, DRI plants require a particular type of iron ore with a minimum iron content of 67 per cent and a lower concentration of impurities from other minerals such as silica, phosphorus and alumina (RMI 2024). This type of mineral is called DR-grade and accounts for around 5 per cent of total iron ore. Through the DRI process, DR-grade iron ore can be turned into iron pellets for immediate steelmaking use in EAFs. Lower-grade iron ore can also be used to make reduced iron pellets, but their use in EAFs is possible only through a purification process in electric smelting furnaces (ESF). This procedure is still being experimented with and would add extra costs to the integrated cycle of steel production.
2. **Abundance of cheap and clean energy generation, possibly baseload.** Typical DRI plants need substantial and constant amounts of power in the form of natural gas or hydrogen. Countries with the right sun and wind conditions could generate abundant clean electricity that can be transformed into green H_2 at low costs, therefore generation and extra investments in stationary storage are critical features.
3. **Capacity and skills in ironmaking.** Expanding ironmaking production in countries with existing capacity and skills would be easier and faster, especially given the challenges of adopting the DRI technology, currently provided by just three companies worldwide (Midrex Technologies 2025). The US-based MIDREX, the Italian-Argentinian consortium Danieli-Tenova and the Iranian MME control respectively 80.1, 16.4 and 3.4 per cent of the global market share for DRI plant engineering.
4. **Low cost of financing.** The capital expenditure associated with investments in electrolysing capacity and DRI plants is substantial. Some countries, even when possessing the right natural conditions listed above, could find financing costs prohibitive. This hurdle can be overcome with policy actions, including international cooperation providing facilitated access to cheaper financing sources.

Table 3.2 outlines a list of potential candidates for establishing green iron corridors, assessing their potential against the four main conditions listed above.

3.4 POLICY RECOMMENDATIONS

A policy approach to steel decarbonisation needs to align domestic policies with international collaboration, across steelmaking nations and with potential green ironmaking countries. By first creating domestic demand for green steel and then establishing competitive domestic steelmaking capacity through EAFs (backed by renewable electricity), the UK and EU countries will be able to establish country partnerships – green iron corridors – with third country producer partners.

3.4.1 Establishing international 'Green Iron Corridors' to enable decoupling of ironmaking and steelmaking

Locating ironmaking in energy and resource-rich countries while retaining steelmaking domestically is a critical cost reduction strategy for green steel. This could be done through the following.

- Negotiating binding partnerships with countries with iron ore reserves, abundant renewables and low-cost finance (such as Brazil, Canada, Sweden, Australia, South Africa) to co-develop hydrogen-DRI and HBI production, coupled with export capacity.
- Creating joint governance structures for shared infrastructure (renewables, electrolysers, ports).
- Securing long-term steelmaker offtake agreements to underwrite investment.

TABLE 3.2: POTENTIAL PARTNER COUNTRIES FOR GREEN IRON CORRIDORS

Country	Iron ore availability	Renewable power capacity	Ironmaking capabilities and capacity	Cost of financing
Brazil	World's 2nd largest net exporter of iron ore and has the world's largest DR-grade reserves.	High share of renewables in its electricity generation mix (55.6% baseload hydropower), with the potential for installation of further capacity in solar and wind.	World's 9th largest steelmaker and the 6th largest producer of pig iron.	Among the highest in the world, with interest rates on 10-Y government bonds close to 14%.
Canada	World's largest exporter of iron ore.	High share of renewables in its electricity generation mix (55.3% baseload hydropower), with the potential for installation of further capacity in solar and wind.	World's 16th largest steelmaker and the 14th largest producer of pig iron.	Among the lowest in the world, with interest rates on 10-Y government bonds close to 3%.
Sweden	World's 6th largest exporter of iron ore.	High share of renewables in its electricity generation mix (37.7% baseload hydropower and 23.6% wind), with the potential for installation of further capacity in wind.	World's 34th largest steelmaker and the 25th largest producer of pig iron.	Among the lowest in the world, with interest rates on 10-Y government bonds close to 2.5%.
Australia	World's largest net exporter of iron ore, although of lower grade, therefore needing additional processing in ESFs before DRI pellets can be used in EAFs.	Moderate share of renewables in its electricity generation mix (4.8%baseload hydropower, 11.7% wind and 17.8% solar), with the potential for installation of further capacity in solar.	World's 29th largest steelmaker and the 23rd largest producer of pig iron.	Among the lowest in the world, with interest rates on 10-Y government bonds around 4.1%.
South Africa	World's 3rd largest net exporter of iron ore and has significant DR-grade reserves.	Low share of renewables in its electricity generation mix (almost zero baseload hydropower, 4.5% wind and 8.2% solar) but has the potential for installation of further capacity in solar and wind.	World's 28th largest steelmaker and the 24th largest producer of pig iron.	High, with interest rates on 10-Y government bonds close to 9%.
India	World's 5th largest net exporter of iron ore but, with domestic consumption expected to increase, foreign availability might reduce.	Low share of renewables in its electricity generation mix (7.6% baseload hydropower, 4% wind and 6.5% solar), but it holds significant potential for expanding solar and wind capacity, as shown by the exponential increase in renewable installations in recent years.	World's 2nd largest steelmaker and producer of pig iron.	Moderately high, with interest rates on 10-Y government bonds around 6.5%.
Mauritania	World's 7th largest net exporter of iron ore, but with a low overall production.	Low share of renewables in its electricity generation mix (12.8% baseload hydropower, 6.1% wind and 8.5% solar) but has potential for installation of further capacity in solar.	Virtually no existing steelmaking and ironmaking capacity.	Moderately high, with the central bank main interest rate at 6%.

Source: Authors' elaboration.
Green=high potential; Yellow=medium potential; Red=low potential.

- Ensuring technology transfer and technical support on DRI plant engineering and production process in countries lacking capabilities but with existing ironmaking capacity.
- Mobilising public financing entities to co-finance DRI plant construction abroad, lowering cost of capital for early producers.

These corridors will need to be underpinned by demand generation and measures to increase the competitiveness of domestic steelmaking capacity through EAFs.

3.4.2 Enabling domestic industrial policies for decarbonising the steelmaking phase of steel production

Concentrating policy efforts on decarbonising the steelmaking phase of production, while outsourcing ironmaking through international partnerships should require the following.

- Supporting capital expenditure in new EAF plants and renewable energy capacity through grants or preferential financing.
- Accelerating the decarbonisation of the power grid with additional renewable installation capacity and establishing competitive long-term contracts through Power Purchase Agreements (PPAs) with power generators.

3.4.3 Regional cooperation on establishing lead green steel markets with public procurement and binding product standards

Voluntary demand is insufficient. Green steel requires mandated demand signals across major consuming sectors. This can be done by the following means.

- Implementing embodied carbon limits for steel used in automotive, construction, defence and clean-energy supply chains, phased in from 2028.
- Using public procurement (such as rail, grid infrastructure, offshore wind) to offer price premiums or scoring advantages for certified near-zero steel.
- Aligning UK product standards with the EU's Ecodesign and Sustainable Products Framework to shape domestic demand for green steel, complemented by CBAM alignment to address carbon leakage at the border.

4.
CONCLUSION

Clean technologies – particularly in hard to abate industrial sectors – are not scaling at the expected rate. This paper examines why, and what sort of policy action can accelerate progress.

Our answer is partner to scale: establish clean technology partnerships between countries with strong production potential, and countries with a growing demand for low carbon products. Such partnerships simultaneously create and backstop demand, while enabling investment and generating supply. Only action on both sides of the relationship at the same time can overcome the binding constraints which are holding back the development of these sectors.

In this way, clean technology partnerships accelerate decarbonisation, but they also have wider benefits. In consumer nations, partnerships can strengthen energy security and supply-chain resilience and in producer nations they can support industrial development and value creation. In doing so, they underpin both sides' economic competitiveness and support national security. And, over time, they can also support deeper diplomatic engagement, strengthening relationships between the parties based on shared economic and strategic interests.

This agenda is sometimes spoken about as abstract, high-level ambition but it is not. There are already experiments underway in clean tech partnership (eg in green ammonia in Namibia) which show that progress is possible. Clean tech partnerships are implementable. This paper has laid out a set of practical, technology-specific policy recommendations which show policymakers some of the steps that they could take to build more and deeper partnerships. It is time to take these steps, and to reap the dividends.

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