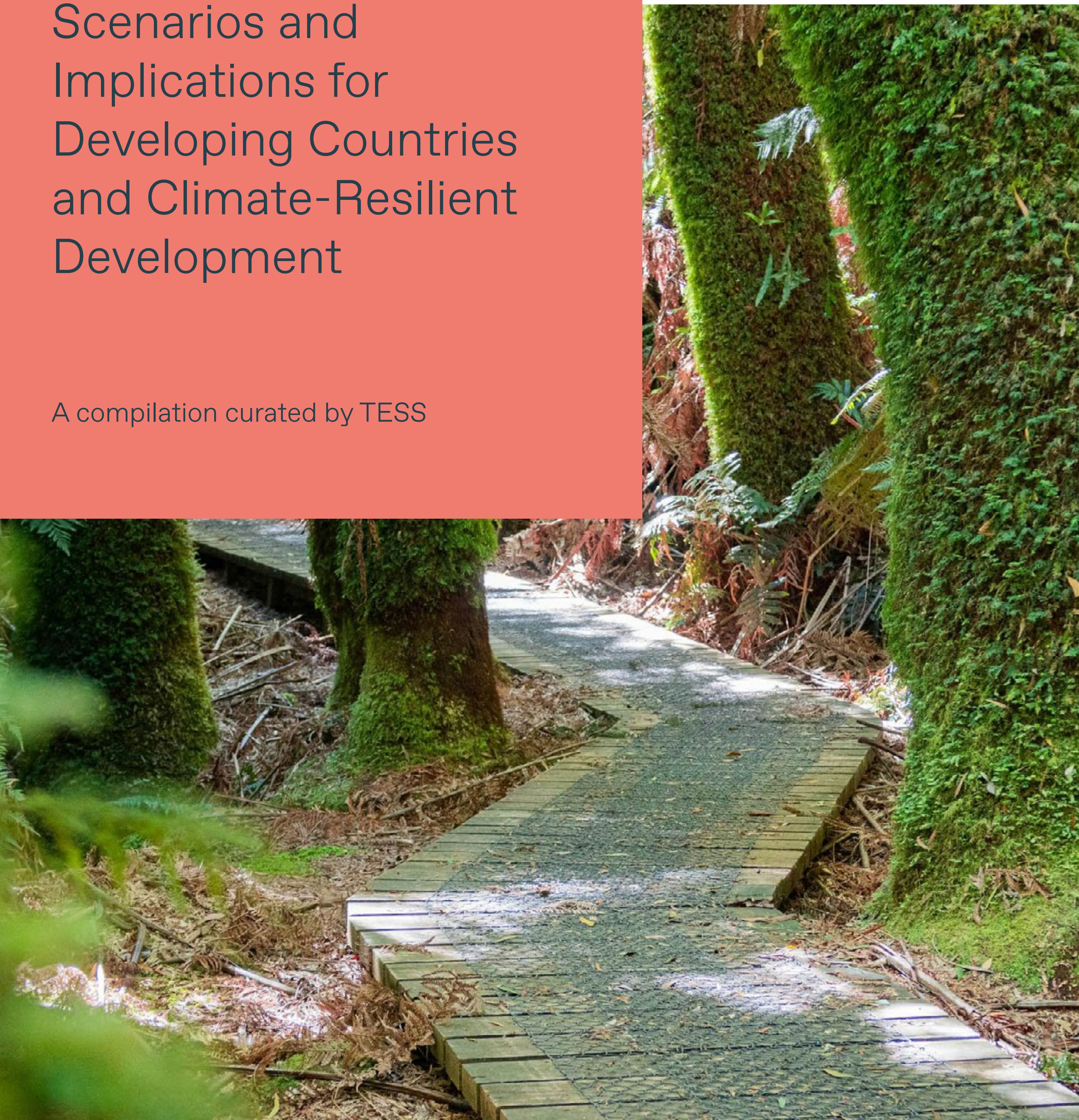
Sectoral Briefing Notes September 2025

TESS Forum on Trade, Environment, & the SDGs

Trade, Climate, and Net Zero Pathways: Scenarios and Implications for Developing Countries and Climate-Resilient Development

A compilation curated by TESS



TESS Forum on Trade, Environment, & the SDGs

About TESS

The Forum on Trade, Environment, & the SDGs (TESS) works to support a global trading system that effectively addresses global environmental crises and advances the sustainable development goals. To foster inclusive international cooperation and action on trade and sustainability, our activities seek to catalyse inclusive, evidence-based, and solutions-oriented dialogue and policymaking, connect the dots between policy communities, provide thought leadership on priorities and policy options, and inspire governments and stakeholders to take meaningful action. TESS is housed at the Geneva Graduate Institute.

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Trade, Climate, and Net Zero Pathways: Scenarios and Implications for Developing Countries and Climate-Resilient Development

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OVERVIEW

From October 2024 to September 2025, TESS commissioned and published a series of briefing notes on *Trade, climate and net zero pathways: Implications for developing countries and climate-resilient development.* These sectoral briefing notes are compiled in this publication.

The series was designed and curated by TESS to provide an overview of current and anticipated transformations in production and trade in key sectors on the road to net zero in the context of the unfolding climate crisis and the international community's climate action agenda. Specifically, the series discusses potential scenarios for these sectors and implications for developing countries and climate-resilient development.

A wider objective of the series is to contribute to a better understanding of emerging trade and trade-related policy trends and dynamics and their implications within the various sectors, with a focus on supporting developing countries in identifying and advancing their interests and priorities in international discussions on climate, trade, and sustainable development.

The sectors covered in the series are agriculture, carbon markets, critical minerals, digital transformation, energy transition, fisheries, heavy industries, shipping, and textiles and garments. Each contribution has been authored by experts in these respective fields.

The briefing notes all loosely follow a similar structure. After a general introduction on the interlinkages between trade, climate change, and sustainable development in a particular sector, the papers explore climate action and impact scenarios in the sector on the road to net zero and then the evolving trade and trade-related trends, policies, and dynamics that will influence the sector in response to the climate crisis. This is followed by an analysis of the trade-related opportunities and challenges for developing countries in the sector in the transition to net zero. The papers conclude with a set of sectoral options or priorities for international cooperation and policy engagement in support of climate-resilient development.

With this compilation, we aim to strengthen the global response to climate change by ensuring that developing countries can successfully navigate the transition to a sustainable, low-carbon, and climate-resilient future, and that international cooperation around trade and trade-related policies, guided by the priorities and needs of developing countries, contributes to this response.

AGRICULTURE

Christophe Bellmann

1. Introduction

Land-based agriculture provides the bulk of world food supply and represents a critical source of feedstock, fuel, and livelihoods. Yet, the sector is failing to deliver food and nutrition security for all and its sustainability is increasingly threatened. Rising temperatures, changing precipitation patterns, and greater frequency of extreme weather events as a result of climate change are already affecting production, disrupting food supply chains, and displacing communities, particularly in developing countries. By 2050, climate change is expected to put millions of people at risk of hunger, malnutrition, and poverty. At the same time, agriculture contributes both directly and indirectly to environmental degradation, including soil and water pollution and biodiversity loss. Between 2000 and 2018, the Food and Agriculture Organization of the United Nations (FAO) estimates that agricultural expansion drove 88% of global deforestation, with cropland expansion and livestock grazing respectively responsible for 50% and 38% (FAO, 2022). Food systems, including on-farm activities, land-use change, and pre- and post-production, contributed more than a third of the global greenhouse gas (GHG) emissions in 2022, placing the sector as both a contributor to global warming and a critical sector for adaptation (FAO, n.d.).

In the coming years, one of the greatest challenges facing the agricultural sector will consist in feeding and providing adequate nutritious food to a growing population while reducing GHG emissions, adapting to climate change, and fostering a fair transition to climate-resilient agriculture systems. With roughly 80% of the world population living in net food-importing countries or relying on imports to meet at least some of its nutrition needs, international trade and trade policies will play a critical role in this equation. Trade is also likely to play a key adaptation role to offset imbalances between supply and demand resulting from climate-induced production shortfalls. More generally, trade and trade-related policies will be essential to strengthening developing countries' mitigation efforts as well as their ability to cope with, and recover from, climate change.

This briefing note looks at the future implications of the climate crisis for agriculture, trade, and sustainable development and highlights some of the key implications for developing countries. It reviews existing agricultural market projections in light of the likely impact of climate change on agricultural production, prices, and food insecurity. It also provides an overview of the GHG emissions associated with the sector and their projected evolution over time. Based on these considerations, it highlights key trade and trade policy implications for developing countries and suggests options for international cooperation to align trade policies with climate objectives to ensure a fair transition reflecting broader, long-standing development priorities.

2. Global Production and Trade Outlook

Global trade in food products has grown significantly over the last 30 years to reach over $2 trillion annually, driven by rising demand for red meat, dairy, and poultry products in developing countries, and by increases in non-food uses of cereals, mostly for biofuels. Since the beginning of the century, the growth in developing countries' agricultural exports and imports has outpaced that of more advanced economies (UNCTAD, n.d.). Today, developing countries account for over 40% of total world agricultural trade. With demand growing faster than domestic supply in these countries, import penetration—i.e. the share of imports in global consumption—has also been growing significantly, particularly for products such as wheat, maize, rice, soybeans, vegetable oil or meat (IFPRI, 2022).

Over the next decade, demand in emerging economies will continue to drive global market development. According to the OECD-FAO Agricultural Outlook 2024–2033, total consumption is projected to reach 20.6 million terra calories in 2033 (OECD & FAO, 2024). Nearly 94% of this increase should occur in middle- and low-income countries driven by growing and wealthier urban populations, with South and Southeast Asia expected to account for about 40%. Diets in middle-income developing countries are expected to shift towards higher-value foods, including more fruits and vegetables, processed foods, and animal-source foods. By contrast, income constraints in low-income countries are likely to slow the transition to more nutrient- and protein-rich diets based on animal products and fruits and vegetables, leading to a continuing heavy reliance on staples (OECD & FAO, 2024).

Projections show that Latin America and the Caribbean, North America, Europe, and Central Asia will reinforce their positions as major net exporters of agricultural commodities. Net imports by Asia and Africa will continue to expand as rising demand outpaces growth in production (OECD & FAO, 2024). While volumes of commodities traded globally are expected to grow further between net exporting and net importing regions, the traded share of production will remain stable with approximately 23% of all calories crossing borders before being consumed. However, as illustrated in Table 1, this average hides significant variations across commodities.

Table 1. Exports of Selected Commodities as a Percentage of Production (2011–2033)

	2011-13	2021-23	2033
Roots and tubers	5.4	7.4	7.3
Rice	7.8	9.4	8.2
Poultry	12	11.4	10.5
Maize	11.7	15	15.5
Beef	15.5	18.3	17.9
Wheat	21.7	24.6	25.3
Sugar	36.4	35.9	42.6
Cotton	41.6	37.2	35.3
Vegetable oils	34.3	37.5	38
Soybeans	38.4	43.6	41.7

Source: Author's elaboration based on OECD and FAO (2024).

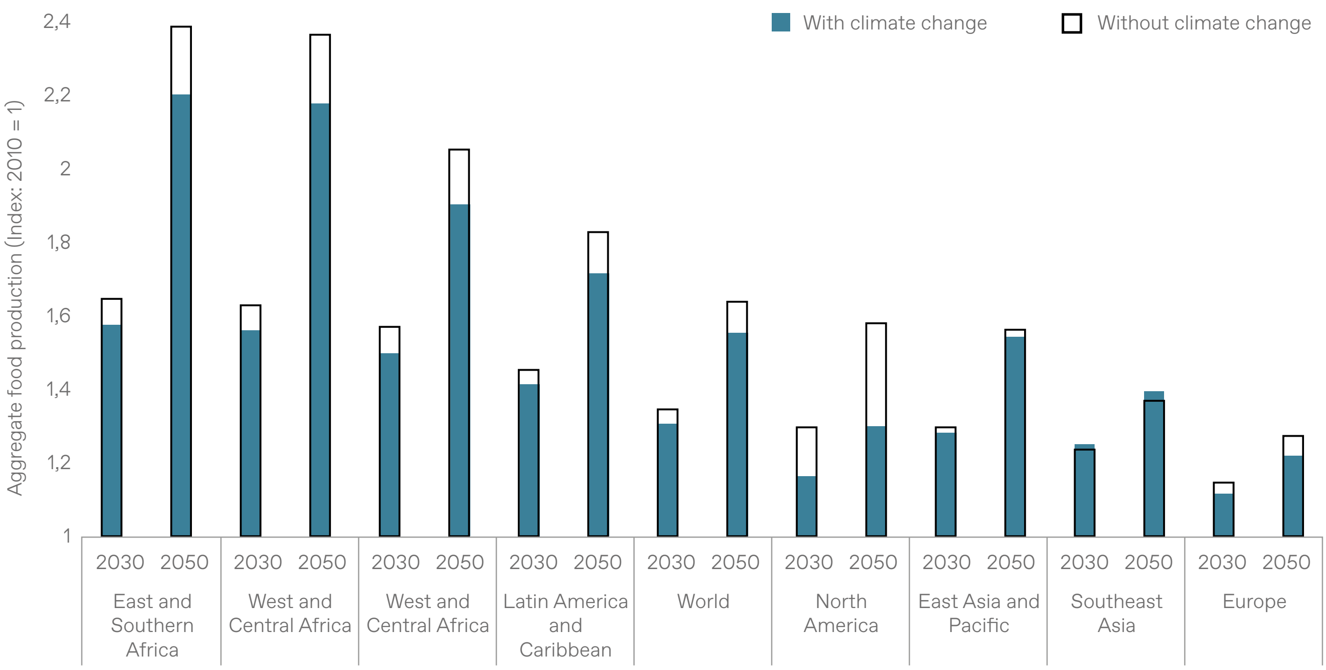
In this context, a challenge relates to the relatively lower level of internationalization of certain key staple foods such as roots and tubers, rice, and maize. The fact that most of this staple food is used domestically results in fairly thin international markets, with a large number of importing countries depending on a small number of exporters to meet their domestic needs. This can expose net food-importing countries and least developed countries (LDCs) to food insecurity risks, making them particularly vulnerable to external shocks as illustrated by the food and energy price crises associated with the Covid-19 pandemic, the conflict in Ukraine, or recent trade disruptions in the Red Sea and the Panama Canal. These interdependencies highlight the importance of well-functioning markets and the need for collective action to ensure sustainable and resilient food systems allowing access to safe and nutritious food, while supporting income generation across agricultural industries.

3. Impact of Climate Change on Agricultural Production and Trade

The physical impacts of climate change—such as increasing temperatures, changing precipitation patterns, and greater frequency of extreme weather events like droughts, floods, extreme heat, and cyclones—are already affecting production, disrupting food supply chains, and displacing communities. Over the coming decades, these impacts will continue to alter crop yields and productivity, reducing the effectiveness of synthetic inputs and accelerating the damage caused by crop pests and soil erosion (The Nature Conservancy, 2024). Declining yields and fertility loss could in turn lead to increased clearing of land for food production, causing the loss of wildlife habitat and biodiversity, while also necessitating increased application of fertilizers and pesticides to maintain productivity, with knock-on effects for surrounding ecosystems. Such impacts tend to hurt developing countries the most, particularly small island developing states and LDCs.

While the scope and magnitude of these effects depend on different climatic and agro-ecological conditions, most models predict that regions in the high latitudes may see increases in production but anticipate major disruptions in lower latitudes, particularly in Africa and South Asia. Figure 1 shows regional food projections by the International Food Policy Research Institute's (IFPRI) IMPACT model for 2030 and 2050 under a scenario that includes the impacts of climate change and a "baseline" scenario that assumes no climate change.[1]

Figure 1. Aggregate Food Production Projections for 2030 and 2050



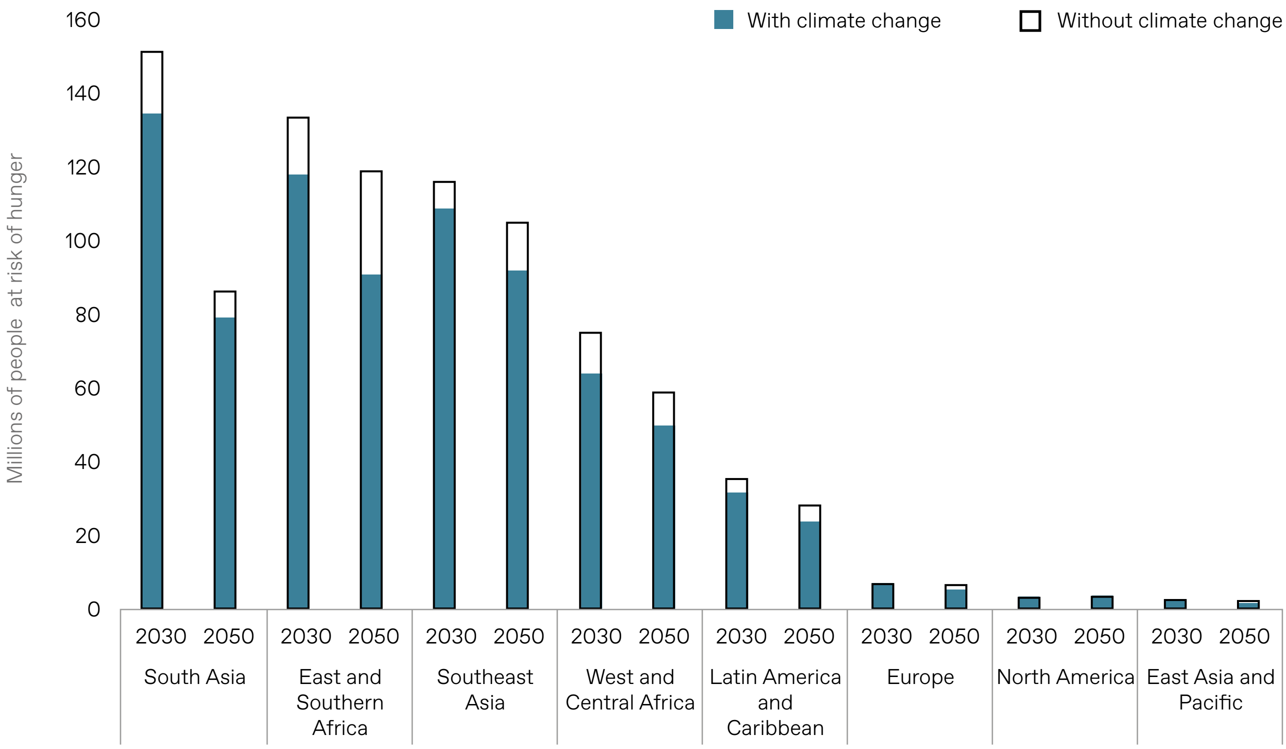
Source: IFPRI (2022).

Overall, IFPRI anticipates a 60% growth in global food production over 2010 levels by 2050 but estimates that food production will be 8 percentage points less than would be the case without climate change, with particularly strong differences in Africa, South Asia, and North America. World prices show increasing trends for most commodity groups. Prices of cereals, fruits and vegetables, and other crops are each projected to

1. IFPRI's IMPACT framework is an integrated system of models that links information from climate models, crop simulation models, and water models with a core global, partial equilibrium, multimarket model focused on the agricultural sector. The economic model simulates national and global markets of agricultural production, demand, and trade associated with 62 agricultural commodities across 158 countries (IFPRI, n.d.).

increase by over 20% by 2050 compared to 2020 levels. Oils and sugars are projected to be 7% higher, with animal product prices beginning to decline after a peak in 2035. Roots and tubers have the highest projected price increase of 37% above 2020 prices (Rosegrant et al., 2024). Small-scale farmers—who produce more than 70% of the food consumed by people in Asia and sub-Saharan Africa—will be the most vulnerable to climate change and the resulting volatility of commodity prices. Overall, IFPRI projects that nearly 500 million people will remain at risk of hunger by 2050 (see Figure 2). Globally, about 70 million more people will be at risk of hunger because of climate change, including more than 28 million in East and Southern Africa. Thus, beyond its direct impacts on agricultural production, climate change will create cascading effects on livelihoods and sustainability through interconnections among economic, environmental, social, and political spheres (IFPRI, 2022).

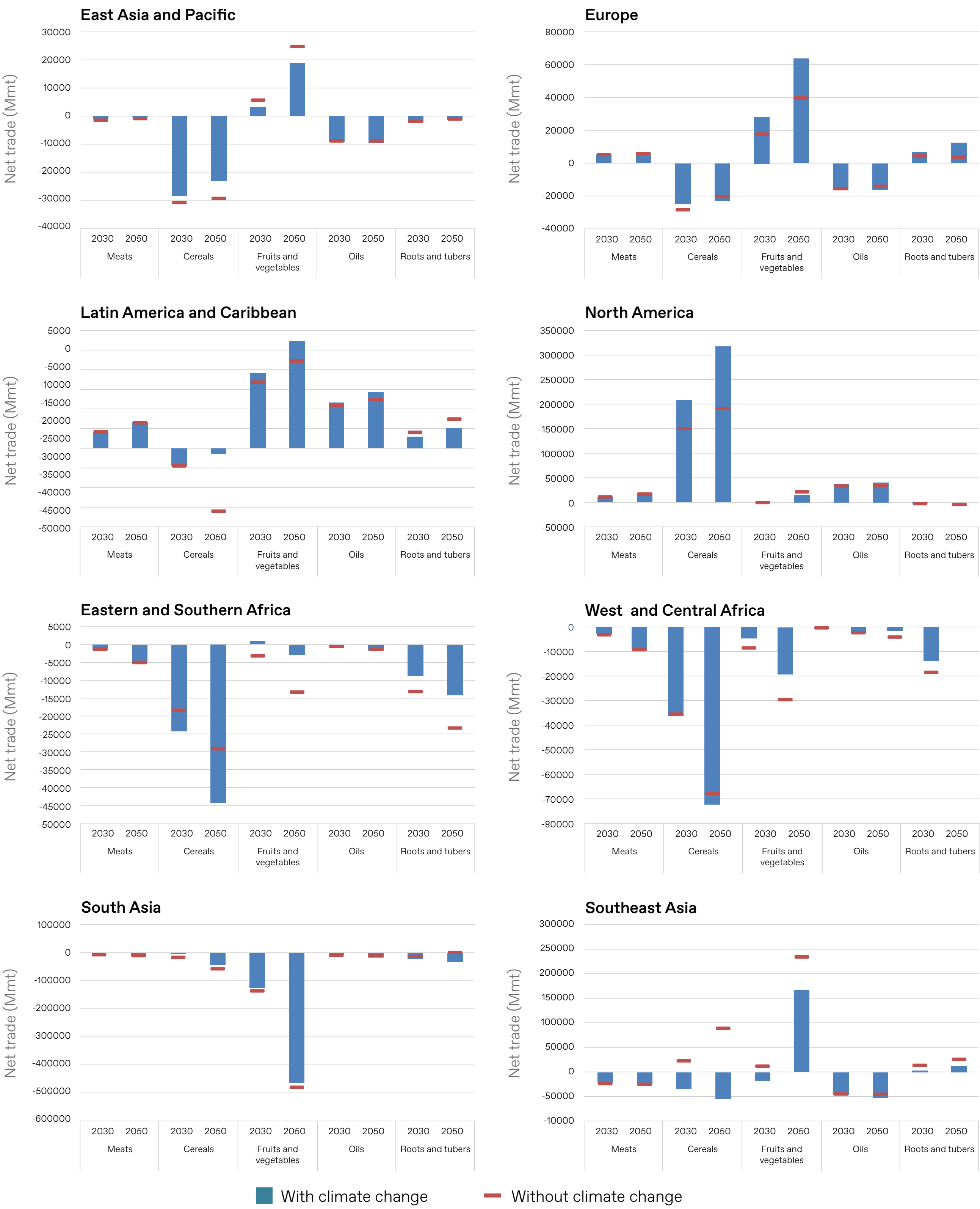
Figure 2. Estimates of Number of People at Risk of Hunger for 2030 and 2050



Source: IFPRI (2022).

Climate induced changes in production and prices will in turn affect the geography and composition of global agricultural trade flows. While the impacts are likely to be region and product specific, climate shocks will tend to limit the ability of affected countries to export food to generate income and employment while forcing them to rely more heavily on imports to meet domestic food and nutrition needs. To illustrate this point, Figure 3 shows differences in net trade projections for various regions and food products by 2030 and 2050 when comparing scenarios with and without climate change. As the effects of climate change alter yields and productivity, well-functioning international agricultural commodity markets will remain critical to address imbalances between supply and demand and also mitigate the impacts of localized shocks such as crop failures or extreme weather events.

Figure 3. Net Agriculture Trade Projections for 2030 and 2050 By Region



Note: Net trade is shown in million metric tonnes (Mmt). It includes negative and positive numbers indicating that a region is a net importer or exporter of food. Projections for 2030 and 2050 assume changes in population and income as reflected in the Intergovernmental Panel on Climate Change (IPCC) shared socioeconomic pathway 2. Climate change impacts are simulated using the IPCC's representative concentration pathway 8.5 and the HadGEM general circulation model (IPCC, 2023).

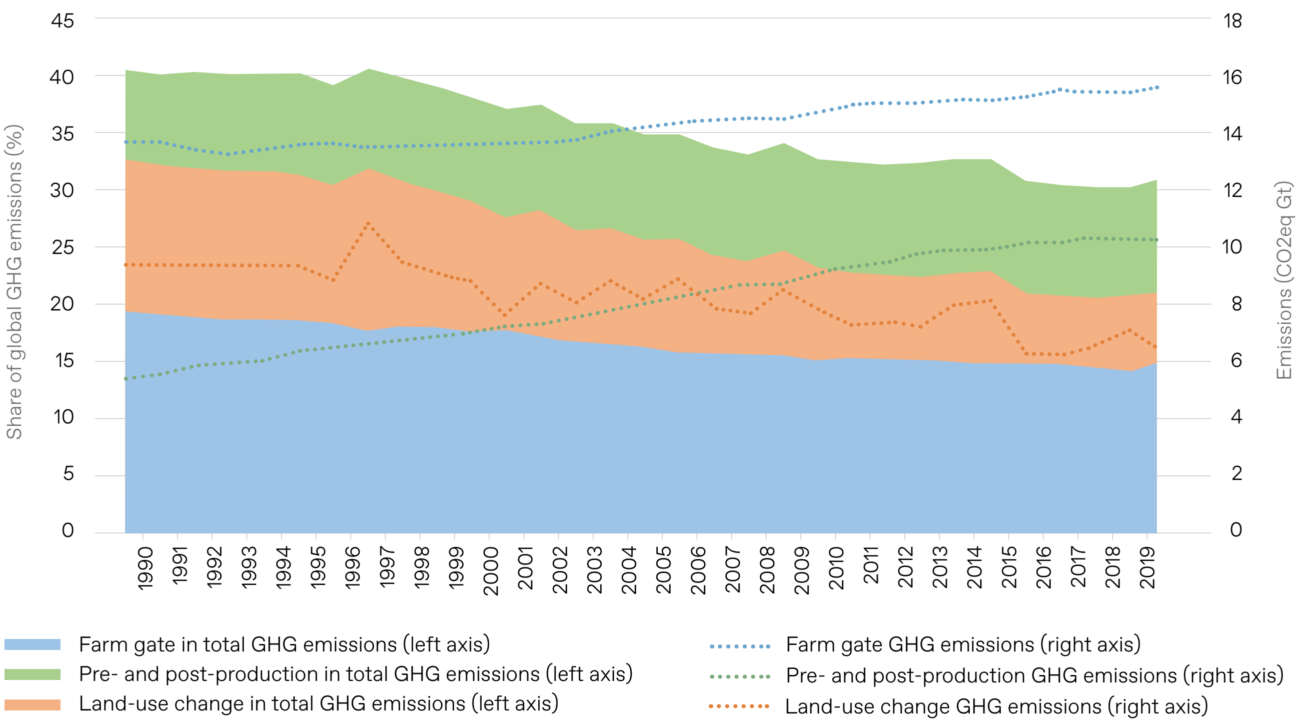
Source: IFPRI (2022).

4. Greenhouse Gas Emissions From the Agricultural Sector

The agricultural sector is not only affected by climate change, it is also a major source of global GHG emissions from different gases, usually expressed as their carbon dioxide equivalents (CO2eq). These include emissions of carbon dioxide (CO2), emanating for example from forest conversion, methane (CH4), coming mostly from ruminant livestock and rice production, and nitrous oxide (N2O), predominantly associated with fertilizer use. According to FAO (n.d.) data, on-farm emissions were 7.8 gigatonnes (Gt) CO2eq in 2022 (14.3% of global anthropogenic emissions) while agricultural land-use change accounted for another 3 Gt CO2eq (5.6% of global emissions). Finally, during the same year, pre- and post-production emissions generated by food manufacturing, retail, household consumption, and food disposal represented 5.3 Gt CO2eq, bringing the total share of emissions from the entire agri-food system to 29.7% of global GHG emissions.

Figure 4 shows the evolution of these emissions since 1990 both in absolute terms (right axis) and as a share of global emissions (left axis). Overall, the share of on-farm and land-use change emissions has consistently declined from more than 32% in 1990 to around 20% in 2022. This was mainly driven by a decline in absolute terms of land-use change emissions from 4.6 to 3 Gt CO2eq. While on-farm emissions experienced a slight increase from 6.8 to 7.8 Gt CO2eq, steady declines in emission intensity resulting from increases in crop and livestock production efficiency explain the declining share of on-farm emissions over the last three decades, even as production continued to increase. By contrast, emissions associated with pre- and post-production stages saw a constant increase both in absolute and relative terms, rising from 7.7% of global emissions in 1990 to nearly 10% in 2022.

Figure 4. Evolution of GHG Emissions From the Agri-Food Systems (1990–2022)



Source: Author's elaboration based on FAO (n.d.).

A further breakdown of GHG emissions from the agri-food system highlights the relative importance of different production and process activities (see Figure 5). In 2022, the most important contributors to global agricultural emissions were CO2 emissions from net forest conversion (2.9 Gt CO2eq) and CH4 emissions from ruminant livestock (2.9 Gt CO2eq). These two activities represent 53.6% of on-farm and land-use change emissions and more than a third of all emissions from the agri-food sector. Other important activities in terms of GHG emissions in 2022 were CO2 emissions from agri-food waste disposal and household consumption, CH4 emissions from livestock manure, and on-farm energy use and the draining of organic soils.

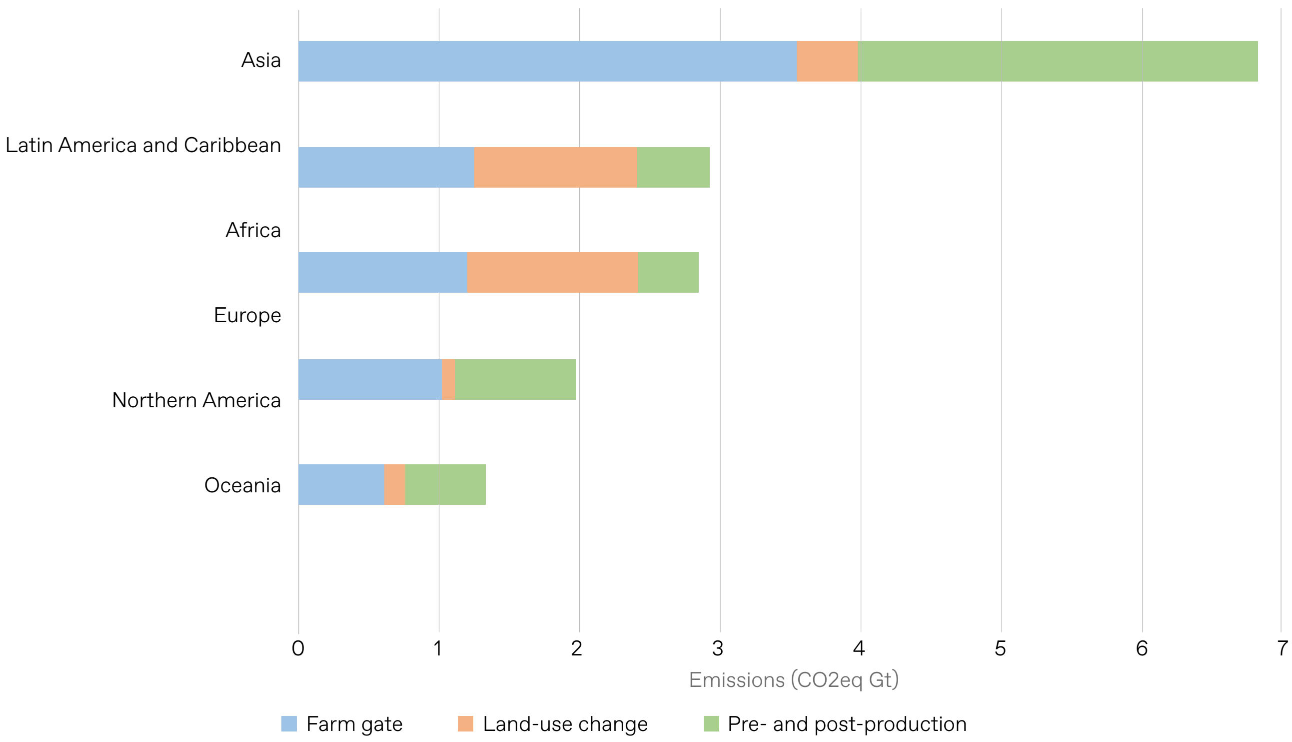
Figure 5. Composition of GHG Emissions From the Agri-Food Systems (2022)

Source: Author's elaboration based on FAO (n.d.).

However, these highly aggregated data and indicators hide significant variations in GHG emissions across different regions, production methods, or agro-ecological conditions. Figure 6 shows, for example, that emissions from land-use change in 2022 accounted for a much larger proportion of total emissions in Africa and Latin America and the Caribbean compared to Asia, Europe, or Northern America, while pre- and post-production emissions were proportionally much smaller. Similarly, aggregate figures hide significant differences in emission intensities—i.e. CO2eq emissions by kilo of production—across agricultural systems (e.g. rain fed or irrigated) or farm management (e.g. traditional, mixed, or modern agriculture). Improvements in production technologies, for example, largely contribute to reducing GHG emission intensities by more effectively targeting fertilizers, pesticides, or energy and water use. Higher yields in turn lead to lower GHG emissions per unit of product. Figure 7 illustrates this reality by comparing average on-farm emission intensities of cattle and rice production across different regions and categories of countries such as LDCs, small island developing states, or low-income food deficit countries.

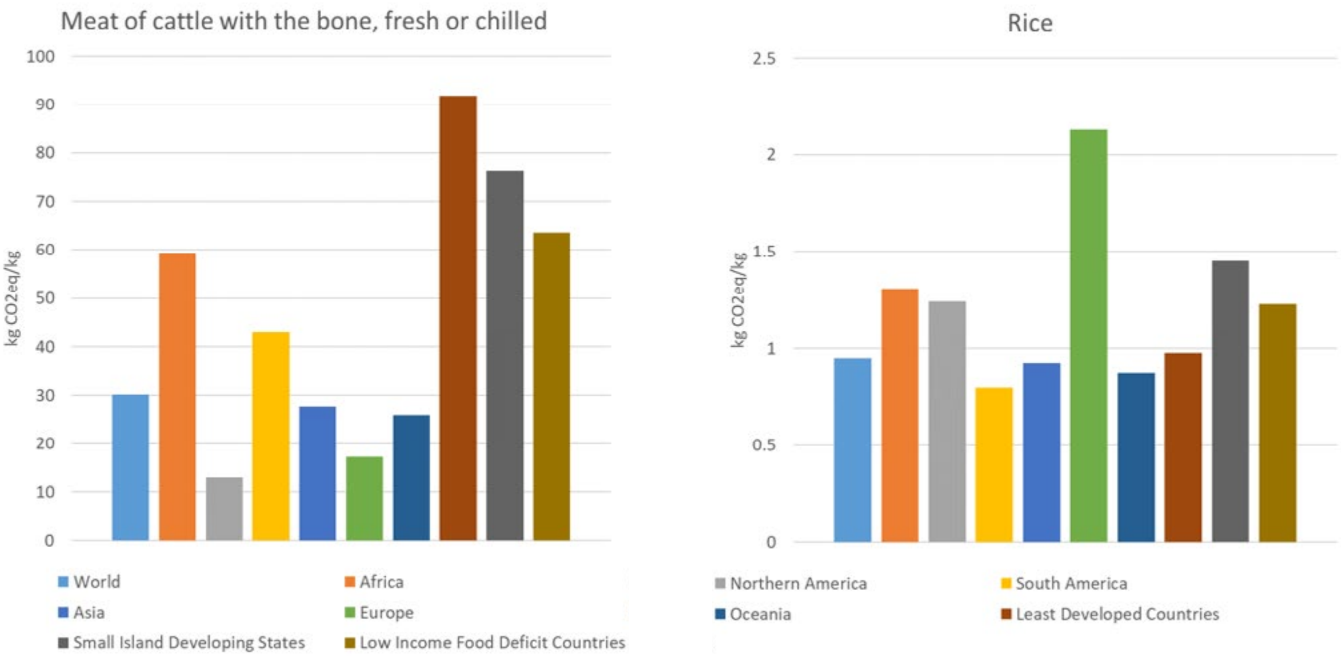
Over the coming decade, the carbon intensity of agricultural production is projected to fall as direct agricultural GHG emissions grow more slowly than agricultural production. Growth in crop production is projected to be driven primarily by productivity increases on existing land, rather than an expansion of the cultivated area. Similarly, a significant proportion of the growth in livestock and fish production is also expected to result from productivity improvements, although herd expansions will also contribute to production growth (OECD & FAO, 2024). In spite of this relative decoupling, growing agricultural production will nonetheless lead to a 5% absolute increase in direct GHG emissions from agriculture and significant productivity gaps are projected to persist, challenging farm incomes and food security and increasing countries’ dependence on food imports.

Figure 6. GHG Emissions From the Agri-Food Systems By Region (2022)



Source: Author’s elaboration based on FAO (n.d.)

Figure 7. Farm Gate GHG Emission Intensity By Region (2022)



Source: Author's elaboration based on FAO (n.d.)

5. Trade Policy Implications

Governments have a wide range of trade-related policy tools at their disposal to build resilience, adapt to the impacts of climate change, or reduce GHG emissions from the agricultural sector. These include border measures (e.g. tariffs, licenses, quantitative restrictions on imports or exports), regulatory measures (e.g. standards, labelling schemes, regulations, conformity assessment procedures, government procurement), and economic incentives (e.g. internal taxes, fees and charges, subsidies, intellectual property rights) designed either to encourage climate-friendly agricultural production and trade or discourage unsustainable practices (Bellmann, 2022).

Faced with the pressing need to act on mitigation, governments are already implementing or considering a variety of trade-related climate measures and policies aimed at reducing GHG emissions from the agricultural sector. A review of World Trade Organization (WTO) notifications of trade measures implemented for climate change reasons in the agricultural sector shows that nearly 250 measures have been implemented by WTO members between 2009 and 2022, mostly in the form of subsidies but also technical regulations and standards (WTO, n.d.). In recent years, tensions have focused on measures targeting more specifically imports as illustrated by the controversy around the European Union's deforestation regulation or proposals for mirror clauses. While existing or planned border carbon adjustment mechanisms in the European Union, United Kingdom, or Australia do not currently cover agricultural products besides fertilizers, this may change in the future as the scope of such schemes evolves and concerns about carbon leakage grow. Finally, a number of private sector initiatives and international organizations are working to improve the sustainability of global supply chains, for example, through voluntary standards and traceability and transparency requirements.

While these environmental efforts can present a range of opportunities for business, including in developing countries, there are growing concerns that the fragmented nature of trade-related climate measures and the cost of complying with a myriad of new requirements risk marginalizing further developing countries. The need for approaches that are fair, and that reflect broader, long-standing development priorities and concerns, is especially high in countries facing significant difficulties in meeting new climate-related requirements, lacking the fiscal space and resources to support large-scale economic transformation and affordable access to relevant technologies or climate financing aligned with the Paris Agreement goals.

Meanwhile, as developing countries respond to these new requirements affecting their exports, they simultaneously need to adapt their productive sector to the disastrous effects of climate change, help producers and communities adapt to the new conditions brought on by climate change, and build a more climate-resilient agricultural sector. In practice, this calls for significant investment in the sector to increase productivity across the supply chain, including through new technologies, crop varieties, inputs, and agricultural equipment and smart agricultural practices adapted to a changing climate, and also through enhanced processing and marketing facilities or production diversification. It also implies building regional and domestic supply chains and associated infrastructure (e.g. roads, storage capacity, distribution networks, and markets) as well as reducing time delays in transportation and transit formalities, including the simplification and harmonization of cross-border regulations. On the demand side, for many developing countries, particularly low-income food-deficit countries, securing continued availability and access to affordable food in the face of external shocks and increased price volatility will be equally important. This should happen both through imports and the provision of food assistance, ideally through cash transfers to avoid trade distortions or through local or regional food procurement in case of in-kind food assistance.

Trade-related mitigation and adaptation measures can be implemented nationally on an autonomous basis, including through nationally determined contributions (UNCTAD, 2023). These measures can range from payments for environmental purposes or mandatory environmental requirements to removing tariff and non-tariff measures on environmentally preferable products. To the extent that they are designed as good faith environmental policies and do not discriminate arbitrarily between countries where the same conditions prevail, they will most probably not violate existing WTO rules. The effectiveness of these measures will increase significantly, however, if they are pursued collectively and applied consistently among a range of countries.

6. The Case for International Cooperation on Trade-Related Climate Measures

The imperative to act both on mitigation and adaptation in agriculture has been widely recognized at the international level. At the 2022 United Nations Climate Change Conference (COP27) in Egypt, the parties adopted the "Sharm el-Sheikh joint work on implementation of climate action on agriculture and food security." This four-year joint work includes implementation of the outcomes of the "Koronivia joint work on agriculture" and previous activities addressing issues related to agriculture. With a slightly stronger emphasis on trade, the Leaders' Declaration on Forests and Land signed by 141 countries at COP26 in Glasgow in 2021 pledged to facilitate trade and development policies that do not drive deforestation or land degradation. Under the Forests, Agriculture and Commodity Trade (FACT) Dialogue, 28 countries—including key global exporters and importers of agricultural commodities—are already cooperating on trade in forest and agricultural commodities. Similarly, ongoing work at the OECD, UN Environment Programme (UNEP), and the FAO is increasingly focusing on the sustainability dimension of the sector.

Acknowledging this reality, several countries have emphasized the need to address collectively the sustainability dimension of agriculture in the WTO. Discussions have already started in different regular WTO bodies and committees, including the Committee on Trade and Environment as well as ongoing negotiations in the Special Session of the Committee on Agriculture. The environmental dimension of agricultural subsidies has also been addressed under the member-led Trade and Environmental Sustainability Structured Discussion (TESSD), launched in November 2020. More recently, members agreed to initiate a structured dialogue on sustainable agriculture based on a proposal by Brazil, starting with a dedicated retreat in early 2025. As growing international tensions and increased fragmentation threaten progress to address the climate crisis and development prospects, there is an urgent need for a comprehensive multilateral agenda for cooperation on trade and climate. Such an agenda could be structured around the following objectives.

Managing and Reducing Trade

While harmonizing existing trade-related climate measures at the global level is likely to remain elusive, international cooperation can contribute to reducing fragmentation and differences in approaches in the design and implementation of those measures. This would include ensuring that environmental regulations, due diligence requirements, standards, or agriculture-related labelling schemes are applied in a way that ensures interoperability across countries, minimizes trade frictions, and takes into account broader sustainable development imperatives. In particular, there is scope for defining international guidance reflecting a shared understanding of good practices that should inform the design and implementation of trade-related climate measures to ensure they achieve their legitimate objectives while minimizing trade frictions and also take into account equity and development concerns. In the short term, these efforts could significantly contribute to reducing trade tensions and avoiding conflicts in a pre-emptive manner.

Reforming Environmentally Harmful Agricultural Subsidies

Government subsidies to agriculture are a critical topic for attention given their influence on international production and consumption patterns and their impacts on the environment. Out of the almost $540 billion spent annually on global support to producers, the FAO, UNDP, and UNEP (2021) estimate that two-thirds can be considered price distorting and harmful to the environment. A significant part of agricultural support relies on policy instruments such as output or input subsidies that are environmentally harmful and generate increased GHG emissions (Ash & Cox, 2022). The Kunming-Montreal Global Biodiversity Framework, adopted at the 2022 United Nations Biodiversity Conference, calls for action to address subsidies harmful to biodiversity, in a “proportionate, just, fair, effective and equitable way.” While eliminating trade and production distorting agricultural subsidies is highly unlikely, and if not offset by less distortionary forms of support could have a negative impact on nutrition, repurposing agricultural support towards development and adoption of climate-smart agricultural practices would help contribute to global climate goals of sustainability, resilience, and emissions reduction.[2]

2. If the reduction of trade and production distorting agricultural subsidies is not offset by less distortionary forms of support, this could have a negative impact on nutrition (Laborde et al., 2021).

Facilitating Access, Diffusion, and Uptake of Climate-Related Goods, Services, and Technologies

Co operation on tariffs, non-tariff measures, and support measures, including trade and investment facilitation measures, can play a critical role in fostering the access, diffusion, and uptake of climate-related goods, services, and technologies. These may be related to adaptation and resilience while increasing productivity, including new crop varieties that can better withstand climate shocks and improve yields, or water management and conservation technologies such as drip irrigation and solar power pumps. They may also be related to climate mitigation such as improved cold chain technologies powered by solar energy. Similarly, continued technological progress in the energy and transport sectors can reduce fossil fuel use and emissions across food systems, including in processing, transport, cold storage, and waste recycling where emissions are currently increasing. Beyond a traditional market access discussion for which there is limited appetite, such cooperation could be built around public-private partnerships involving a range of measures such as government procurement, regulatory cooperation, investment facilitation, and also technical assistance, financing, and technology cooperation.

Disciplining Export Restrictions and Prohibitions

Most developing countries rely at least partially on imports to ensure their food security and are therefore vulnerable to the impact of external shocks and excessive price volatility. As seen during the price spikes of 2007–08 and 2010–11 and more recently during the Covid-19 pandemic, countries sometimes try to buffer the impact of global price shocks by restricting exports to avoid shortages and limit price increases on the domestic market. However, such export restrictions exacerbate price volatility by limiting world supply, which then encourages other exporting countries to follow suit with their own restrictions (Anderson et al., 2014). With production volatility likely to increase because of climate change, countries will be more likely to impose export restrictions. In practice, however, unlike the rules applicable to imports, WTO disciplines on export restrictions are very limited. In the coming years this will constitute an area where further rules may be required to avoid supply chain disruptions and limit excessive price volatility threatening access to affordable food in developing countries.

Cooperation on Maintaining Global Food Security Stocks

Maintaining large physical food stocks in excess of modest levels strictly for emergency use is beyond the financial capacity of most developing countries. Having an adequate level of physical stocks may however not be necessary for each individual country as long as global stocks are at adequate levels and can be released in times of critical shortages or high and volatile prices. This can take the form of food aid but also imports below the market price. In this area, it will be critical to ensure that WTO disciplines on export competition do not prevent such practice because they would constitute an export subsidy. In cases of food shortages or high and excessively volatile prices it may therefore be important to clarify existing disciplines—and, if needed, envisage appropriate flexibilities—under the WTO's Nairobi decision to eliminate agricultural export subsidies or ongoing discussions on public stockholding to allow for exports from acquired stocks to be sold below the market price when requested by some developing countries for domestic consumption. Alternatively, international organizations such as the World Food Programme could be employed to oversee the logistics of transferring supplies to countries in need, while the Agricultural Market Information System (AMIS) at the FAO could maintain up-to-date information on global food security stocks in the context of its ongoing monitoring of overall food stocks globally.

International Food Assistance and Food Import Financing Facilities

For several low-income food-deficit countries, food assistance remains a critical tool to meet their food and nutrition needs. Over time there have been important improvements in the international food aid system in terms of assessing more precisely the specific needs of recipient countries and responding to them with more flexibility. However, as surplus stocks in donor countries have declined, the levels of food aid have gone down considerably. While this has coincided with an increasing share of food assistance being provided in cash, which allows donors to respond much more effectively to emergency needs, the combined effect of declining volumes of food aid and growing emergency situations worldwide have resulted in food aid being increasingly limited to emergency operations. Recently, there have been discussions to revive the FAO idea of a Food Import Financing Facility from which low-income food-deficit counties could borrow short-term loans in the event of soaring food import bills. A multilateral instrument of this type would significantly help secure affordable food imports. Similarly, creating a credit guarantee facility, ideally within regional development banks, could help provide the necessary guarantees for the public sector in financially restrained poor countries to enter into futures and options contracts for the importation of basic foodstuffs.

7. Conclusion

Several elements of the agenda for international trade cooperation outlined in the previous section can be pursued in existing multilateral fora and processes such as the WTO, including in the context of member-led initiatives on sustainable agriculture, but also in relevant UN agencies such as the United Nations Framework Convention on Climate Change (UNFCCC), UNCTAD, FAO, or specialized agencies such as the World Food Programme. Similarly, organizations focused on economic cooperation such as the OECD or regional economic commissions provide a relevant venue to ensure transparency, consistency, and alignment in the design and implementation of trade-related climate measures. At the political level, cooperation on trade can be prompted in the context of initiatives such as the coalition of trade ministers on climate. At the sectoral level, there is also a role for issue-specific initiatives through public-private partnerships involving a broader set of stakeholders beyond traditional cooperative arrangements focused primarily on governments and international organizations.

Regardless of where such discussion takes place, there is an urgent need for an open and inclusive dialogue on trade cooperation. Importantly, these discussions should take a comprehensive approach integrating not only concerns around environmental aspects but also critical public policy objectives around equity and sustainable development considerations.

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CARBON MARKETS

Scott Vaughan

1. Introduction

Carbon markets are expanding. According to the United Nations Framework Convention on Climate Change (UNFCCC, n.d.), over 100 countries have included carbon markets as a climate mitigation tool within their first set of nationally determined contributions (NDCs). Currently, 75 carbon pricing systems are in use worldwide, comprised of 50 national or jurisdiction-wide systems, and another 39 sub-federal systems, some of which overlap with national systems. One indicator of the growing impact of carbon pricing systems is the revenue generated by these systems. According to the World Bank's State and Trends of Carbon Pricing 2024, total revenues derived from one form of carbon markets, known as mandatory or government-led markets, for the first time exceeded $100 billion in 2023, reaching $104 billion (World Bank, 2024a).

This briefing note examines three dimensions of carbon markets. Section one examines three types of carbon markets: (i) mandatory or compliance-based carbon markets, (ii) voluntary carbon markets, and (iii) emerging multilateral-based carbon markets under the Paris Climate Agreement Article 6. Section two then examines some trade-related issues, notably competitive effects of carbon markets. Section three discusses recent steps and issues facing developing countries.

2. Carbon Markets: Overview and Recent Trends

Compliance-Based Carbon Markets

Compliance-based carbon markets fall into two general categories. The first category involves the use of carbon taxes, in which a price, charge of levy, is set for each tonne of CO_2 equivalent (CO_2e) emitted by a firm or household covered under the tax. By putting a price on emissions, entities subject to the tax are incentivized to reduce their tax burden, starting by switching from more carbon-intensive fuel sources such as large, gas-guzzling automobiles to more efficient hybrid vehicles, or from internal combustion engines to electric automobiles, or in the case of non-transport activities, from conventional heating and cooling to rooftop solar panels and heat pumps (Parry 2019).

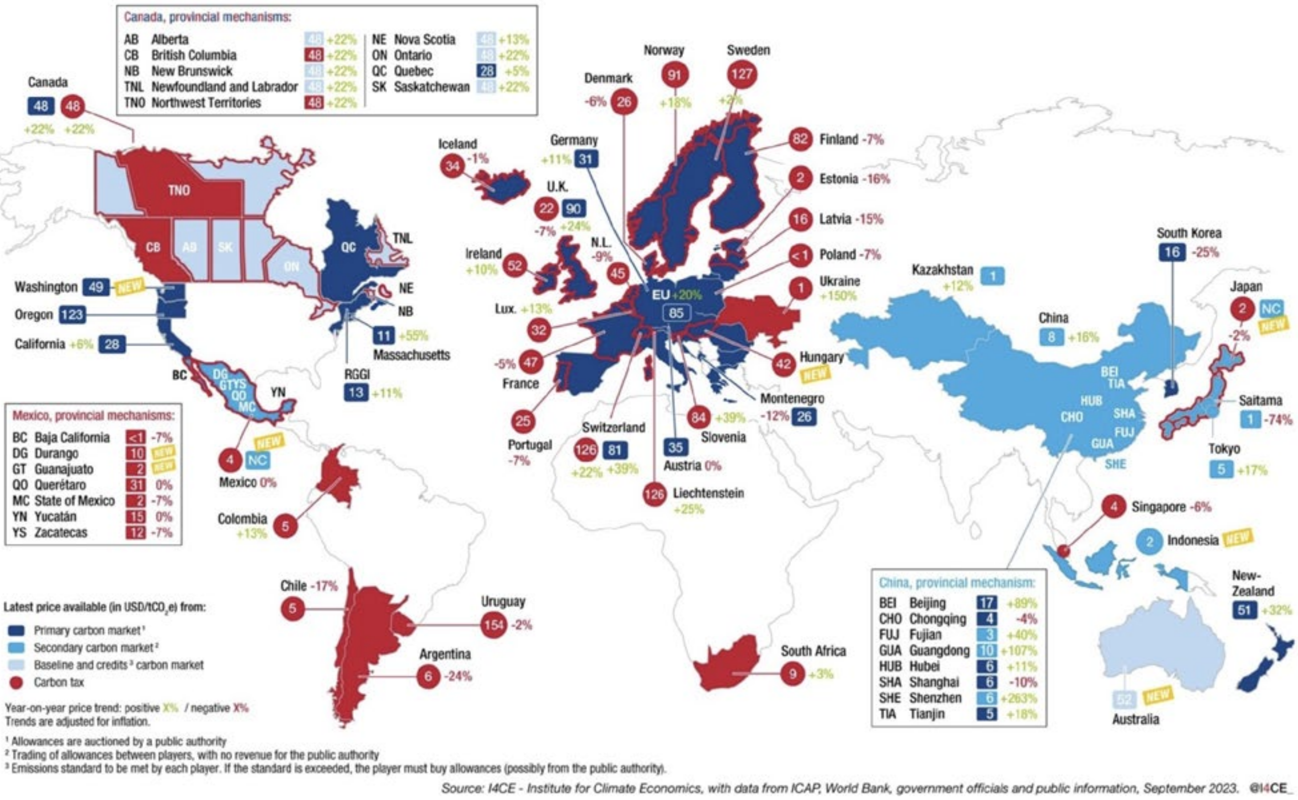
The second category involves emissions trading systems (ETSs). A prominent example of an ETS is known as a cap-and-trade system, in which the government sets a total quantitative limit on emissions for a regulated sector. Each covered entity is allocated emission allowances (also known as emission permits). More efficient firms can sell their excess allowances to less efficient firms through a trading system.

There are variations of emissions trading systems, often to respond to competitiveness concerns from industrial sectors that face international competition. The free allocation of allowance permits is one way to dampen competitiveness concerns, for example, when a firm's allowance rights is calculated based on the average historical emissions of the wider sector. Other options to address competitiveness concerns include the use of emissions-intensity targets as opposed to an emissions cap, and the use output-based carbon pricing systems which function in similar ways to performance standards widely used to control air pollution.

These two categories of carbon markets—carbon taxes and emissions trading systems—have different design features, with relative strengths in each. In general, carbon taxes provide greater certainty with regards to market price levels, since like other tax rates are set by government, but provide less certainty with regards the quantity of greenhouse gas emissions that will be reduced or avoided due to the tax. For example, the Canadian[3] and Irish carbon tax systems are based on an annual schedule of carbon price increases to 2030: Canada's carbon price—

3. Canada's carbon market comprises of three different elements. An escalating tax applied to different types of fuels including gasoline, aviation gasoline, heavy fuel oil and other fuels used for heating, electricity or transport (Government of Canada, n.d.); a separate system for industrial emissions, in which an Output Based Pricing System covers heavy industrial sectors like steel, mining and chemicals; and the use of an ETS system in Quebec, which is determined to be comparable or equivalent to the federal approach.

Figure 1. Map of Carbon Pricing Systems (2023)



Source: I4CE – Institute for Climate Economics, with data from ICAP, World Bank, government officials, and public information, September 2023. ©I4CE

currently at CAD$80/tCO2e—will reach $170/tCO2e in 2030. Similarly, Ireland's carbon price is scheduled to rise by €7/tCO2e each year until 2029, and €6.50/tCO2e in 2030, by which time it will reach €100/tCO2e. These tax schedules reduce uncertainty, thereby helping companies plan their capital investments in less carbon-intensive methods.

By contrast, emissions trading systems provide greater certainty with regards the total quantity of emissions that will be avoided or reduced, but less certainty regarding the price of emissions. For example, the allowance price of the European Union's Emissions Trading System (EU ETS)—the world's largest measured by revenue—the price of emission allowances has swung from nearly €100/tonne in early 2023 to around €70/tonne in the first quarter of 2024.

Like all other emissions trading systems, including sub-federal ETSs,[4] the European Commission which administers the EU ETS has deployed different tools to reduce price volatility, including setting floor prices, or reducing the supply of permits by retiring a proportion of total allowances to prevent the collapse of prices. For example, in 2021, the EU launched its Market Stability Reserve, of which the centrepiece was the backloading of as many as 900 million allowance credits in order to correct a surplus of credits attributed to a price drop (European Commission, n.d.).

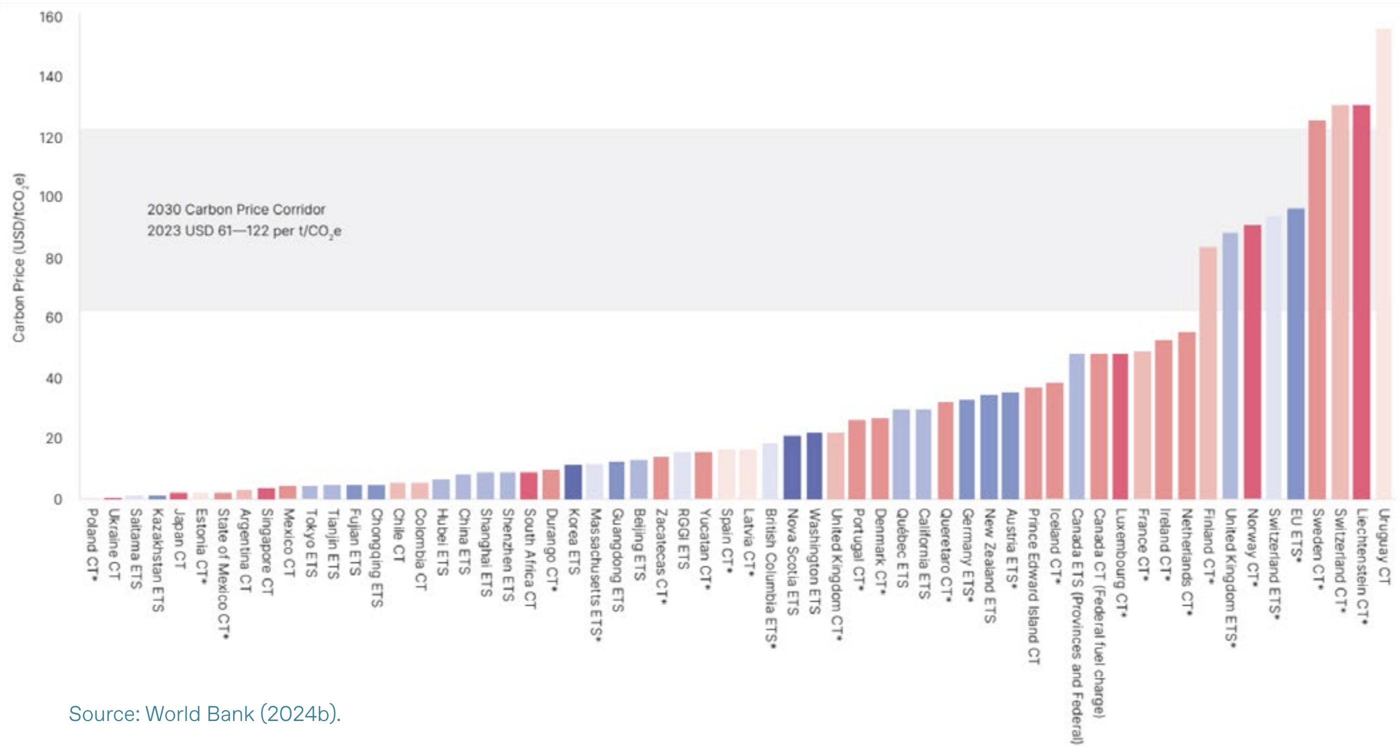
4. In addition to national systems, there are a growing number of sub-federal carbon markets. Precursors to China's current national carbon market comprises eight sub-state emissions trading systems in Beijing, Shanghai, Shenzhen, and elsewhere. The Western Climate Initiative (WCI) comprises an international ETS between California, Quebec, and other sub-federal jurisdictions, while the Regional Greenhouse Gas Initiative (RGGI) comprises a cap-and-trade system for CO2 involving 11 states in the United States, including New York state.

Price levels or stringency: A final word regarding compliance-based carbon markets concerns their price levels. Figure 2 shows the wide range of carbon prices. With few exceptions, current prices are too low to meet the Paris Climate Agreement. The OECD (n.d.) estimates that 58% of the approximately 40 billion tonnes of greenhouse gas emissions covered by market measures were unpriced (by contrast, 7% of measures were priced above €60/tCO2e).

Other estimates for 2023 show 70% of all market-based measures were priced at $20tCO2/e, well below the climate change costs (I4CE, 2023). So what should price levels be to meet Paris? The 2017 report of the High Level Commission on Carbon Prices, also known as the Stern-Stiglitz report, recommended a carbon price of $50–$100/tCo2e (Carbon Pricing leadership Coalition, 2017), while the International Monetary Fund has recommended carbon market pricing levels reaching $75/tCo2e by 2030 (Parry, 2021).

In general, carbon prices tend to be higher in developed countries compared to developing countries. There are however exceptions. For example, the world's highest carbon price is Uruguay's, at roughly $154 tonne, while the world's lowest price is in Baja, Mexico, at one penny a tonne.

Figure 2. Prices and Coverage Across ETSs and Carbon Taxes



Source: World Bank (2024b).

Voluntary Carbon Markets

In contrast to the compliance systems noted above, voluntary carbon markets are private transactions, largely outside of government-regulated markets. While voluntary carbon offsets have existed for well over a decade, they grew sharply in the lead up to and following the Paris Climate Agreement, as hundreds of companies pledged to become net zero or carbon neutral.

The main tools used in these voluntary markets involve the use of carbon offsets based on forests. Science, including through multiple reports of the Intergovernmental Panel on Climate Change (IPCC), confirm that forests (and other ecosystems like peatlands) have the potential to provide up to one-third of cost-effective climate mitigation solutions to reach the Paris Climate Agreement goals. Accordingly, the premise of carbon offsets involves matching or offsetting CO_2 emitted by a firm with projects such as afforestation and conservation. A rough, rule-of-thumb calculation is that it can take as many as 45 trees to offset one tonne of CO_2. According to the Oxford State of Carbon Dioxide Removal report, the vast majority of activities related to removing CO_2 are natural land-based processes led by forestry, afforestation, reforestation, and related projects (Smith et al., 2024).[5] Since tropical forests are the greatest source of carbon sequestration—that is, the rate at which carbon is absorbed by trees—most carbon offset projects are located in tropical developing countries.

Most market forecasts from 2015 (when the Paris Climate Agreement was signed) until late 2022 anticipated the steady growth of voluntary markets. The report of the Taskforce on Scaling Voluntary Carbon Markets (2021) captured the optimism of the time. Chaired by former Bank of England Governor Mark Carney, the report forecast a global carbon offset market set to exceed $50 billion by 2030. Actual investments in 2021 increased by 60% by market value, reaching $748 million in new transactions for a cumulative market value of $6 billion by early 2022.

One of the perceived strengths of voluntary markets was their reliance on private standards as opposed to regulations. Four private, third-party certifiers—Verra, Climate Action Reserve, the American Carbon Registry, and the Gold Standards—determine the standards for private carbon offset markets in similar fashion as the Forest Stewardship Council (FSC) and other bodies set sustainable forestry standards. In addition to these four bodies, which use differing definitions and weighting criteria, there are dozens of private bodies working on net zero projections and standards, including the Sustainability Accounting Standards Board (SASB), Climate Disclosure Standards Board (CDSB), CDP (formerly Carbon Disclosure Project), International Integrated Reporting Council (IIRC), Global Reporting Initiative (GRI), Science-Based Targets Initiative (SBTi), Impact Measurement Project, and Capitals Coalition as well as international third-party certifiers. Under these, there are thousands of companies worldwide offering consulting and other support services associated with calculating and verifying carbon credits.

Practical challenges with this proliferation of private standards have included materially different criteria, definitions, and weightings, leading to standards that were not comparable or interoperable. Rather than moving towards standards convergence, private voluntary markets were dubbed the "wild west" for their lack of clarity (The Guardian, 2023). These concerns were crystalized in early 2023, when The Guardian (2023) newspaper released the results of an investigation that concluded that more than 90% of carbon offset credits issued by the world's largest carbon credit certifier (Verra), comprised almost entirely of carbon offset projects located in tropical forests, were "worthless." Other reviews and assessments reached similar conclusions.[6]

Suddenly, the term "greenwashing"—a term long-used to describe unsubstantiated or exaggerated company claims about the environmental attributes of their products and services[7]—became widely synonymous with voluntary carbon markets. Other assessments pointed to similar gaps between voluntary carbon

5. A tiny proportion, less than 0.1%, comes from novel or engineered carbon dioxide removal activities such as direct air capture systems, which withdraw CO_2 from the atmosphere, or carbon capture, utilization, and storage.
6. Such concerns were hardly new. Reviews of the integrity of carbon offset credits issued through the Kyoto Protocol's Clean Development Mechanism (CDM) similarly uncovered exactly the same kind and degree of problems, with one review finding that 80% of all CDM credits overstated their climate mitigation effects, or were unfounded altogether.
7. The European Commission conducts regular reviews of sweeps of company green claims. The most recent found Paris that 59% of green claims reviewed lacked substantiation (European Commission, 2021).

markets claims and the actual performance of carbon offset projects. A report of the United Nations' High-Level Expert Group on the Net Zero Emissions Commitments of Non-State Entities (2022) established by the Secretary-General recommended steps to "prevent dishonest climate accounting and other actions designed to circumvent the need for deep decarbonization."

In 2023, the Voluntary Carbon Market Integrity Initiative (VCMI) released its Claims Code of Practice (VCMI, 2024). Subsequent work by VCMI and other bodies have tried to restore market confidence by listing higher-level principles as well as detailed procedures. At the 2023 United Nations Climate Change Conference (COP28), various private sector initiatives have taken steps to restore market confidence in voluntary markets—including the creation of a new senior advisory group by Verra (2023).

Despite these and other steps, the private sector has stepped away from voluntary carbon markets for fear that they will be associated with greenwashing. Since 2023, investments have dropped by over 60%, while the price of carbon offset credits shrank by more than 70% to $3.50/tCO2e. An August 2024 independent scientific assessment conducted by SBTi flatly concluded that carbon offsets are "ineffective," adding that their use could delay wider climate mitigation actions and pose legal and other risks to companies using them (Beyond Fossil Fuels, 2024).

The future of voluntary markets is therefore highly uncertain. One recent step has seen greater government oversight of these private markets, in the same way government financial bodies supervise financial markets. At COP28, the environment ministers of Austria, Belgium, Finland, France, Germany, the Netherlands, and Spain released a statement recommending specific steps to bolster the integrity and transparency of voluntary carbon markets (Government of the Netherlands, 2023). In May 2024, the Biden White House issued principles for voluntary carbon markets, including guidance to determine additionality (White House, 2024). Also in May 2024, under the 2022 Canadian Greenhouse Gas Offset Credit System Regulations, Canada issued a new protocol covering carbon offsets derived from privately-held forests (Government of Canada, 2024). In September 2024, the US Commodities Futures Trading Commission (CFTC) introduced new guidelines aimed at more closely aligning voluntary carbon markets assurance standards with other market standards (CFTC, 2024).

The European Commission (2024b) is likely to take the most comprehensive regulatory approach. The Corporate Sustainability Due Diligence Directive sets the stage by bluntly noting that "voluntary action does not appear to have resulted in large scale improvement." A new Carbon Removals Certification Framework proposes a new verification system for all EU-based carbon credit claims (European Commission, 2024a).

Paris Article 6

A third category of carbon pricing is anchored in Article 6 of the Paris Climate Agreement. In 2015, governments agreed on the broad principles intended to enable international cooperation for climate mitigation. It took another six years of negotiations for a first set of rules to be settled, although negotiations continue to decide on critical questions such as methods covering avoided greenhouse gas emissions, that is, the technical methods such as baselines used to calculate whether an additional climate mitigation method leads to avoided or lower-than-usual emissions.

Article 6 is successor to the Kyoto Protocol, with one overarching difference: while the Kyoto Protocol set carbon emission reduction targets for developed countries only, the Paris Climate Agreement covers all countries. The Kyoto Protocol's Joint Implementation provision allowing cooperation between governments is succeeded roughly by Article 6.2, while the Clean Development Mechanism (CDM) has transformed into Article 6.4.[8] Of the two, the CDM was the main international platform for international carbon markets.

The three Article 6 pillars: Article 6 comprises three relatively distinct mechanisms:

- A decentralized, direct government-to-government agreement under Article 6.2 to cover bilateral carbon market cooperative agreements.
- A centralized mechanism by which governments and others propose international carbon markets that in turn are subject to the guidance and approval of the UN Article 6.4 Supervisory Body under Article 6.4.
- A third mechanism under Article 6.8 intended to facilitate non-market international carbon cooperation, including technology transfer, ecosystem services, and others.

These are briefly described below.

To date, there have been a small handful of Article 6.2 deals, all involving Switzerland as the buyer of carbon credits—known as Internationally Transferred Mitigation Outcomes (ITMOs)—with Ghana, Thailand, and Vanuatu as sellers. These early deals have covered agriculture, avoided methane emission from waste, cookstoves, and electric buses.

Article 6.2 is poised to grow. Roughly 140 pre-feasibility project agreements involving bilateral government cooperation agreements have been signed to date (Figure 3).[9] Most involve bilateral agreements between an OECD country (Japan is heavily engaged) and emerging economy governments on potential joint projects.

Article 6.4 continues to elaborate the principles, standards and procedures by which its Supervisory Body (SB) will review and approve carbon market deals.

The objective of Article 6.4 rule-making is to build high-integrity carbon markets and to avoid the pitfalls that have hampered the reputation of voluntary markets. Progress has been made on several issues, including accounting standards regarding how a buyer and seller can record carbon market transactions and the creation of a central electronic project registry to track all deals. As of June 2024, working groups at the 2024 Bonn UNFCCC annual meetings continued to clarify a number of technical rules related to project baselines—that is, the reference point against which forecast avoided emissions can be calculated—additionality, leakage, permanence, and the all-important rules for avoided emissions.

Work is also proceeding in creating a new sustainable development procedure, so that all Article 6.4 projects will be evaluated not only within the narrow context of carbon emissions avoided or reduced, but also in relation to how projects align with the UN Sustainable Development Goals. In May 2024, parties also adopted a new Appeals and Grievances Procedure to empower communities and vulnerable groups affected by Article 6.4 projects with legal recourse mechanisms (UNFCCC, 2024).

The third pillar of Article 6 is the least examined. Several developing countries, including Brazil, led negotiations in Paris to include non-market cooperation. Among the provisions included in Article 6.8 are references to technology transfer, climate adaptation, finance, and capacity building. Subsequent work by the UNFCCC subsidiary body identified additional cooperative areas such as payment for ecosystem services and leveraging Article 6.8 to link carbon credits with sovereign debt in so-called debt-for-climate swaps.

8. According to UNFCCC (2018), since the CDM was launched in 2001, roughly 8,000 CDM projects were implemented, with a combined project value of roughly $300 billion, leading to the avoidance of roughly 2 billion tCO_2e.
9. The United Nations Environment Programme (UNEP) regularly updates Article 6 deals (UNEP-CCC, n.d.).

Table 1. Bilateral Agreements and Projects Between Countries on Article 6 of the Paris Agreement

Buying Country	Region	Sub-region	Host Country	Project
Australia	Oceania	Melanesia	Fiji	-
			Papua New Guinea	-
Japan	Africa	Eastern Africa	Ethiopia	-
			Kenya	2
		Northern Africa	Tunisia	-
		Western Africa	Senegal	-
	Americas	Central America	Costa Rica	2
			Mexico	-
		South America	Chile	3
	Asia	Central Asia	Uzbekistan	-
			Kyrgyzstan	-
			Kazakhstan	-
		Eastern Asia	Mongolia	6
		Southeast Asia	Cambodia	5
			Indonesia	35
			Laos	5
			Myanmar	2
			Philippines	5
			Thailand	24
			Vietnam	18
		Southern Asia	Bangladesh	4
			Maldives	2
			Sri Lanka	-
		Western Asia	Azerbaijan	-
			Georgia	-
			Saudi Arabia	1
			United arab Emirates	-
	Europe	Eastern Europe	Moldova	-
			Ukraine	-
	Oceania	Melanesia	Papua New Guinea	-
		Micronesia	Palau	5
Kuwait	Africa	Eastern Africa	Rwanda	-
Liechtenstein	Africa	Western Africa	Ghana	-
Monaco	Africa	Northern Africa	Tunisia	-
Norway	Africa	Northern Africa	Morocco	-
		Western Africa	Senegal	-
	Asia	Southeast Asia	Indonesia	-
Singapore	Africa	Eastern Africa	Kenya	-
			Rwanda	-
		Northern Africa	Morocco	-
		Western Africa	Ghana	-
			Senegal	-
	Americas	Caribbean	Dominican Republic	-
		Central america	Costa Rica	-
		South America	Chile	-
			Colombia	-
			Perù	-
			Paraguay	-

Table 1. (continued)

Buying Country	Region	Sub-region	Host Country	Project
Singapore	Asia	Eastern Asia	Mongolia	-
		Southeast Asia	Cambodia	-
			Indonesia	-
			Laos	-
			Philippines	-
			Thailand	-
			Vietnam	-
		Southern Asia	Bhutan	-
			Sri Lanka	-
	Oceania	Melanesia	Fiji	-
			Papua New Guinea	-
South Korea	Africa	Middle Africa	Gabon	-
		Western Africa	Ghana	-
	Asia	Central Asia	Uzbekistan	1
			Kazakstan	-
		Eastern Asia	Mongolia	-
		Southeast Asia	Cambodia	-
			Indonesia	-
			Laos	-
			Vietnam	-
Sweden	Africa	Eastern Africa	Zambia	-
		Western Africa	Ghana	-
	americas	Caribbean	Dominican Republic	-
	Asia	Southern Asia	Nepal	-
Switzerland	Africa	Eastern Africa	Kenya	-
			Malawi	1
		Northern Africa	Morocco	2
			Tunisia	-
		Western Africa	Ghana	9
			Senegal	4
	Americas	Caribbean	Dominica	1
		South America	Chile	-
			Peru	2
			Uruguay	-
	Asia	Southeast Asia	Thailand	1
		Western Asia	Georgia	-
	Europe	Eastern Europe	Ukraine	-
		Northern Europe	Sweden	-
			Iceland	-
			Norway	-
	Oceania	Melanesia	Vanuatu	1
United Arab Emirates	Americas	South America	Paraguay	-
Grand Total				**141**

Note: Blank cells mean that UNEP-CCC have no knowledge of any dedicated Article 6 pilot projects between the two countries. Some countries that signed bilateral agreeemnts do not yet publicly provide information on Article 6 pilot activities.

Source: UNEP-CCC (n.d.).

3. Competitiveness and Trade Issues

A long-standing concern of environmental taxes and charges has been their competitiveness effects, especially on industries and sectors that are energy intensive as well as trade exposed. This is especially pertinent with regards compliance carbon markets, in which firms are required to pay a price for carbon pollution.

Different compliance carbon markets have differing sector coverage. For example, China's national carbon market currently applies to approximately 2,200 power sector facilities. That coverage is poised to expand in 2025 and beyond to include other energy-intensive, trade-exposed sectors including aluminium, steel, chemicals, and other heavy industries. The EU ETS covers CO2 emissions from electricity and heat generation, energy-intensive industry sectors, including oil refineries, steel works, and production of iron, aluminium, metals, and others, aviation, and maritime transport as well as some sources of nitrous oxide (N2O) and perfluorocarbons (PFCs). France's carbon tax has varying rates for road transport, industry, buildings, and electricity, the United Kingdom's ETS covers electricity, power, and aviation operators, while Germany's includes the transportation and buildings sectors.

Governments use different design features to reduce direct and indirect competitiveness arising from carbon markets. For example, both China and Canada use output-based pricing systems, which operate in similar fashion to air pollution performance standards intended to reduce emissions as opposed to the output of a firm. The EU has relied on the free allocation of allowance permits as a main tool to address competitiveness concerns, by which the amount of emissions that a firm is allowed is calculated by historical sector-wide baselines and allocated freely to each firm. The EU's shift from a free allocation to auctioning system is one of the main triggers for their use of the Carbon Border Adjustment Mechanism (CBAM). The key rationale provided by the EU's CBAM is the risk of the offshoring of carbon-intensive producers as they seek to avoid the cost of a rising ETS allowance by moving production to jurisdictions with lower or no carbon pricing measures, also known as leakage.

Other instruments are used to address possible indirect effects stemming from carbon markets. Many compliance markets use some form of tax breaks and revenue recycling to smooth the effects on both households and regulated industries. Typically, these include tax exemptions for lower-income households, affected regions, and firms that may be disproportionately affected, such as within the coal sector. Other measures include direct tax rebates, in which firms and households receive a regular payment to cushion the effects of a compliance market. For example, under Canada's carbon tax, roughly 80% of households receive a direct carbon rebate to offset some or all of the costs of the carbon tax.

One of the most prevalent types of revenue recycling involves public financing support for innovative, next generation green technologies. Analysis by I4CE (2023) of 2023 carbon pricing systems found that 58% of total revenues were earmarked in such areas as low-carbon technology development, 32% were directed to general government revenues, and 10% were for direct and indirect transfers. Of note, the European Commission recycles annually a portion of the roughly €55 billion generated annually through its ETS to provide public financing for green technology research and development and deployment at scale. In late 2023, the European Commission awarded €3.45 billion to support 36 low-carbon projects across various sectors including cement, chemicals and others.

Other systems also use green subsidies to accelerate the discovery and deployment of net zero technologies and systems. Since many of these goods and services are in turn exported, various trade policy issues, including the scope of the World Trade Organization (WTO) Agreement on Subsidies and Countervailing Measures, may be further tested in the coming years. Trade cases involving subsidies to green technologies began with the so-called Trump tariffs imposed on solar panels in 2018, and have expanded to include electric vehicles as a major source of trade friction.

Stepping back, discussions regarding the use of taxes have been underway for over three decades. In 1991, when the General Agreement on Tariffs and Trade (GATT) Working Group on Environmental Measures and International Trade was revived, governments examined the possible effects of environmental protection policies like taxes on GATT rules. The first mandate of the WTO Committee on Trade and the Environment (CTE), under Item 3(a), explicitly focused on the intersection between trade policies and rules and environmental taxes and charges. The earliest CTE discussions examined the possible use of border tax adjustment, raising questions of non-product-related process methods and the challenge facing the trade regime's customs codes to differentiate like-products based on their production processes. Discussions have also examined how CBAM aligns with GATT Article II and the use of internal charges. There have been some WTO cases involving both the use of taxes for tobacco products, automobiles, and some agricultural products and for the extra-jurisdictional application of domestic environmental measures.

4. Opportunities and Challenges for Developing Countries

As noted, a growing number of developing country governments have or are on track to introduce compliance carbon markets. Today, Uruguay has the world's highest carbon price, at $154/tCO2e. Indonesia recently launched a national ETS covering the electricity sector, the Mexican states of Durango and Guanajuato recently launched carbon markets, while legislative steps are underway in Brazil. Carbon markets are also in the process of adoption in India, Malaysia, Thailand, the Philippines, Vietnam, and other jurisdictions (World Bank, 2024b).

More countries have indicated through their existing NDCs that they plan, at some point in the future, to introduce carbon markets as part of their wider climate mitigation tools. The updated package of NDCs, to be formally submitted at COP29 in November 2024, contain more ambitious climate mitigation targets involving a large number of developing countries (World Resources Institute, 2024), including Colombia, Peru, Chile, Brazil, Paraguay, Uruguay, Mexico and Costa Rica in Latin America, Kenya, South Africa, Ethiopia, Senegal, Nigeria, and others in Africa, and Indonesia, Malaysia, Thailand, Sri Lanka, and others in Asia. Following COP29, more developing countries are likely to include within their updated NDCs more specific details with regards the intended use of carbon markets.

At the same time, this is a precarious period for many developing countries to introduce new fiscal measures in general, and climate taxes or ETS systems in particular. For many countries, the structural effects of COVID, inflation, and higher interest rates has seen the significant outflow of foreign capital coupled with higher sovereign debt servicing, which has jumped from $99 billion annually before COVID to more than $136 billion in 2023. A special task force recently concluded that development finance is a "disaster" (G20 Independent Experts Group, 2024)

The prospects for voluntary carbon markets as a new source of external finance for developing countries is at best unclear. In June 2024, governments of ten African countries—Burkina Faso, Cape Verde, Ivory Coast, Gambia, Guinea-Bissau, Guinea, Liberia, Mali, Senegal and Togo—signed a letter supporting carbon offsets and discounting "misguided activists" for their criticism of carbon offset markets that have been buffered by greenwashing charges (The EastAfrican, 2024). They argue that carbon offset markets represent the single best means of attracting private climate finance to developing countries. However, the report of SBTi (2024), noted above, is significant in calling into the efficiency of carbon offset markets. Other reports, including an investigative report by the Washington Post (2024) also published in July 2024, have examined the dubious practices of private carbon market investors and brokers, noting that few actual benefits remain in developing countries while climate benefits are at best uncertain.

One alternative to these voluntary markets involves Article 6. Assuming the ongoing UN negotiations can resolve uncertainties involving the reliability, durability, and equity of international transactions, Article 6.4 in particular could be an important new source of international cooperation and transactions-based financing for developing countries.[10] As the successor to the UN Kyoto Protocol's CDM, the aim of ongoing Article 6.4 negotiations is to learn both from past CDM practices as well as the current challenges facing voluntary carbon markets.

5. Conclusions

A key conclusion from the UN global stocktake adopted at COP28 is the gap between current and proposed actions to meet the Paris Climate Agreement goals and the widening climate change crisis (UNFCCC, 2023). Meeting the 2050 carbon neutrality goals will require greater ambition at scale, involving a mix of regulations, subsidies, and market-based measures likely to include the widening use of carbon markets. As domestic carbon markets continue to expand, they are especially exposed to political economy opposition in several countries. While international carbon markets hold promise, especially to tap additional and private sector funding to developing countries, considerable work is needed to address market integrity and quality assurance concerns. As both areas of carbon markets advance, questions involving trade policy will also continue to evolve.

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10. Article 6 differs from the new round of international climate financing targets to succeed the Paris target of an additional $100 billion per year to developing countries, being held under the New Collective Qualified Goal discussions going into COP29.

CRITICAL MINERALS

Peter Wooders and Simon Lobach

1. Critical Minerals and Mining in the Context of Climate Change

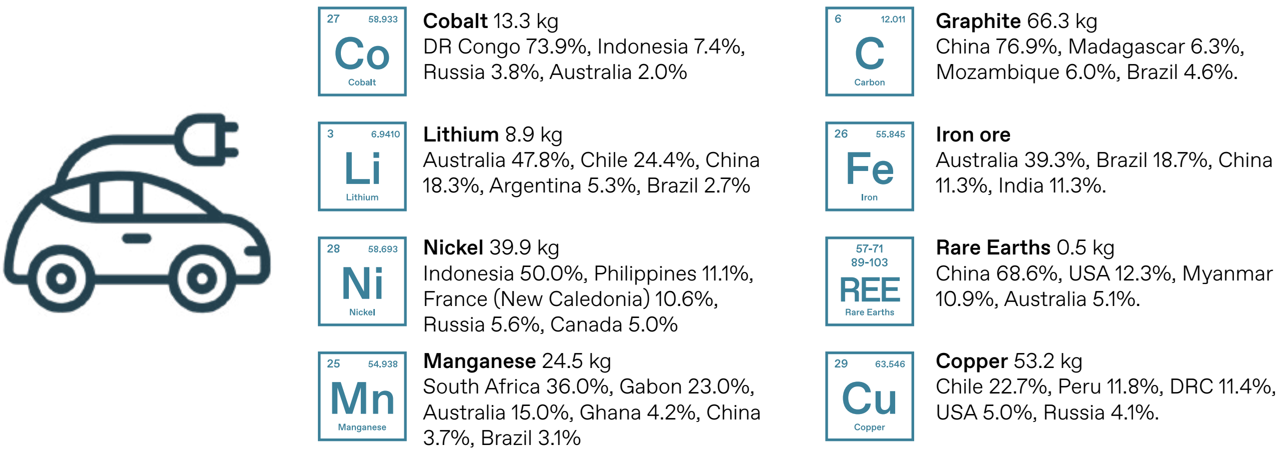
The energy transition is having an enormous impact on the demand for critical minerals. Mineral demand is expected to double, or even quadruple, by 2040, depending on the stringency of climate action adopted (IEA, n.d.-a).[11]

Half of the increase in critical mineral demand is projected to come from the electrification of personal vehicles (see Figure 1) and the production of batteries (for use in electric vehicles, electricity grid storage, and other purposes). At the 2023 United Nations Climate Change Conference, over 130 parties pledged to triple their renewable power capacity by 2030 (COP28 UAE, 2023)—which automatically translates into higher demand for critical minerals. Other energy transition activities that will lead to significant hikes in mineral demand include power generation (especially offshore wind but also solar), electric cabling, and hydrogen production.

Simultaneously, there is little sign that mineral demand from sectors not related to the energy transition will go down. Critical minerals are essential to semiconductors and defence industries, for example, and the extraction of minerals required for the energy transition is thus expected to occur in addition to existing mineral demand.

Additionally, as the ores with the highest metallic content are the first to have been mined and exhausted, mining companies are forced to move to increasingly low-grade ores, which further increases the total ore volume that our economies require (Rötzer & Schmidt, 2018).

Figure 1. Minerals and Metals Required for the Production of Electric Vehicles and Their Source



Note: The figure indicates the minerals and metals for electric vehicles by weight (in kg) and leading producing countries (in percent of production). For graphite, only natural (mined) graphite is included in this percentage, even though electric vehicles may also contain synthetic graphite. For iron, the iron content in raw ore has been used for calculating the percentages. For copper, raw unprocessed ore has been used

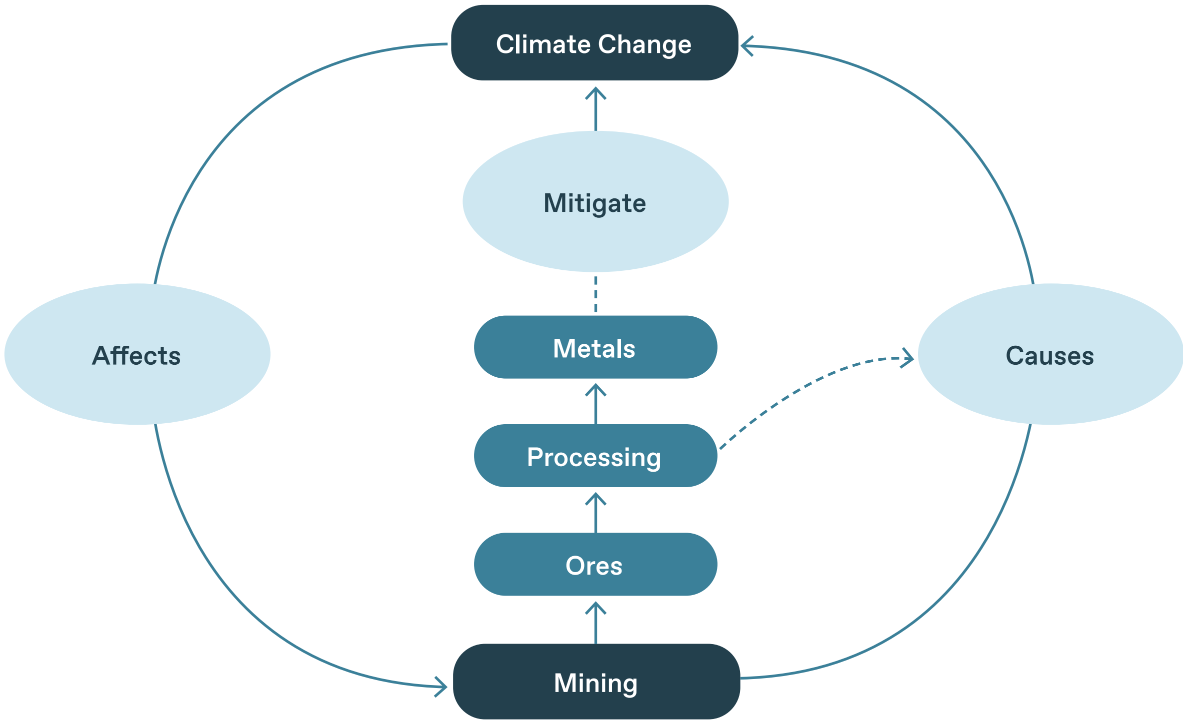
Source: Compiled from Hendriwardani and Ramdoo (2022) (metals used in EV production); USGS (2024) (cobalt, lithium, nickel, manganese, natural graphite, iron ore, and copper); and USGS (n.d.-a) (rare earths).

11. Section 2 of this paper discusses critical minerals in detail, including how they are defined and where they are mined and processed.

Interlinkages Between Critical Minerals and Climate Change

The positioning of the mining sector in environmental debates is two-sided. The mining industry is actively associating itself with a “green” image, given the importance of critical minerals for the energy transition (Archer & Calvão, 2024). At the same time, mining itself has important environmental impacts. The expansion of mining worldwide leads to the generation of mining waste, greater energy use, and increased greenhouse gas (GHG) emissions. Figure 2, schematically illustrates the interlinkages between mining and processing of critical minerals and climate change.

Figure 2. Interlinkages Between Mining and Processing of Critical Minerals and Climate Change



Source: Authors’ elaboration.

While most of the emissions resulting from the mining sector are caused by iron and steel production, the role of critical minerals in GHG emissions is significant. In recent years, the production of critical minerals has represented approximately 4% of total global emissions, mainly attributable to aluminium production (2.8%—calculated on the basis of International Aluminium Association (n.d.)), followed by nickel (0.3%) (CarbonChain, 2024), and copper (International Copper Association, 2022). A large share of these emissions derives from the processing of mined ores (Lehne, 2024).

Additionally, coal is used to process some critical minerals, including significant shares of copper and aluminium output; and the use of coal for these purposes is rising. Due to these and other factors, GHG emissions from critical mineral production for the energy transition are rising consistently (Fahimi Bandpey et al., 2024).

Mitigating the Climate Impact of the Mining Sector

International commitments for the mining sector to contribute to mitigation, adaptation, and loss and damage with regards to climate change have been made at the multilateral level (among states) and at the sector level (industry standards).

In order to meet climate agreements and national net zero pledges, governments have created a range of mechanisms for mining companies to phase out their GHG emissions. These include rules and regulations, fiscal measures, subsidies, and investments in research and technology. Several countries have outlined these policy choices in their nationally determined contributions (Schaap & Karamira, 2024).

Reducing GHG emissions from critical mineral production should be obtained through changes in production processes and efficiency gains (including through circularity and recycling), while the use of critical minerals for products unrelated to the energy transition should be reduced to the extent possible. Colombia, for example, in its National Mining Policy ("A new vision of mining in Colombia"), highlights the objective of considerably expanding its mining activities to meet demand for critical minerals, but in a way that lowers the carbon intensity of its mining sector as a whole (Government of Colombia, 2023).

The industry is also adopting voluntary standards, and several mining companies are experimenting with technologies to ultimately eliminate GHG emissions from their operations, including through: on-site renewable energy generation and storage (including through pumped hydro); electrification of mining equipment and processing; process optimization (including through digital technologies); using hydrogen; carbon capture and storage; and replacing diesel-power crushing and grinding with hydrometallurgy and biomining and relying on living organisms to retrieve metals from deposits (Ahmad et al., 2024; Kaksonen & Petersen, 2023).

Not all mining companies are moving at the same pace, however, with some companies operating internationally having made voluntary commitments to achieve net zero by 2050 while others have not. As a result, a divide is starting to appear within the sector. Organizations like the International Council on Metals and Mining (ICMM) require their members to strive to net-zero by 2050 (ICMM, 2021).[12] Additionally, price premiums exist for low-carbon aluminium (Argus Media, 2024), and the London Metal Exchange is exploring the possibility of implementing a similar premium for nickel (LME, 2024). This divide may become more pronounced as a result of trade measures specifically directed at carbon-intensive goods, such as the European Union's (EU) Carbon Border Adjustment Mechanism (CBAM), which specifically targets aluminium as one of its focus sectors.

Adaptation of the Mining Sector to Climate Change

The mining industry also needs to implement measures to adapt to climate change (Bellois, 2022b). Mining-related adaptation challenges can be divided into three broad categories:

1. *Climate-related direct threats to mining operations.* Examples include: mines at risk from flooding during extreme weather events (BHP, 2019), mines in coastal regions prone to sea level rise, and mines in permafrost regions where global warming may cause soils to become unstable. Extreme weather events and sea level rise may also endanger transportation facilities used for trade in minerals, such as ports or railways for example.

12. The ICMM is a collaborative group of leading mining and metals companies created to strengthen the industry's contribution to sustainable development.

2. *Risks to local communities caused by a combination of mining and climate change*. This can occur, for example, when extreme weather events cause failure in tailing dams, which can endanger human lives and ecosystems in across a vast area (as happened in the Mariana (2015) and Brumadinho (2019) disasters in Brazil).

3. *Water scarcity caused by a combination of mining and climate change*. Climate change may reduce water availability in a given area. If mining operations are also contributing to water stress in this area, this can lead to water disputes between local communities and mining operations, for example in evaporation-based lithium production (Lakshman, 2024).

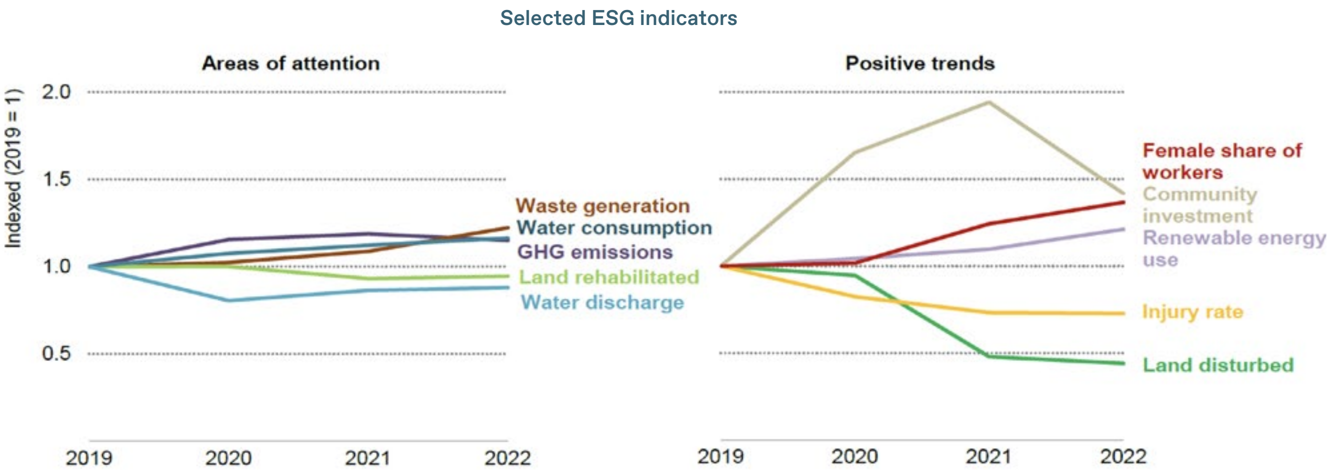
Mining is currently mentioned in only a small share of the national adaptation plans submitted to the United Nations Framework Convention on Climate Change, often together with oil and gas activities. The National Adaptation Planning Global Network has reviewed 59 national adaptation plans and found that only 8 of them (13.5%) include "Mining and/or oil and gas" as a priority sector for climate change adaptation (NAP Trends Platform, n.d.).

Developing countries may have less resources available to ensure that their mining ambitions are climate-resilient, while high levels of dependence on a limited number of minerals may decrease their ability to adapt. Conversely, successful expansion of economic activities linked to critical minerals can allow for increased investments in climate adaptation and mitigation and help address social and other environmental challenges.

Broader Environmental and Social Impacts of the Mining Sector

Sustainability reporting by companies with a strong presence in critical minerals supply chains paints a mixed picture with regards to environmental, social, and governance (ESG) performance. Based on self-provided sustainability reports by some of the main mining companies, Figure 3 illustrates the evolution of mining's ESG impacts between 2019–2022. There are several environmental issues where companies (on average) are not improving their performance, including around water, land rehabilitation, and GHG emissions.

Figure 3. Self-Reported Evolution of Social and Environmental Impacts of Mining (2019-2022)



Notes: Aggregated data for 25 major companies that have a strong presence in critical minerals supply chain. Considers reported data for all operations. Indicators are calculated per tonne of mineral produced—except for injury rate, water recycling, and female share of workers—which reflect the weighted average of production.

Source: IEA (2024).

Sustainability standards help provide a framework for the assessment of performance. However, the large number of competing standards in the mining sector creates complexity, and in recent years there has been a growing chorus of calls for greater harmonization or convergence of ESG standards and sustainability initiatives. In this context, the ICMM, The Copper Mark, the Mining Association of Canada, and the World Gold Council announced in November 2023 that they will seek to consolidate their individual standards into one global responsible mining standard with a multistakeholder oversight system (ICMM, 2023). This collaboration aims to simplify the landscape of standards and sustainability initiatives and drive performance improvements at scale.

Box 1. Summary of the Mining Sector's Net Zero Challenges

1. To significantly increase metal output, especially for the green transition
2. To do so from ores that are increasingly low-grade
3. To do so without causing any GHG emissions by 2050
4. To adapt its operations to reduce climate change vulnerabilities

2. What Are Critical Minerals and Where Are They Produced?

Which Minerals are Critical?

There is no generally accepted definition or list of "critical minerals." The term is often used interchangeably with "critical raw materials," "strategic minerals," and "energy transitions minerals," even though these terms may designate very different things depending on the context in which they are used (Hendriwardani & Ramdoo, 2022). Examples of national and regional definitions include:

- The Chinese government uses an undisclosed list of materials that it considers critical under its 14th Five Year Plan (2021–2026). It can be observed, however, that China's trade policies give special consideration to certain minerals (Andersson, 2024).
- The United States (US) regards as "critical minerals" those minerals that are "essential to the economic or national security of the United States" (USGS, n.d.-b).
- Similarly, for the EU, "critical raw materials" have "economic importance, high risk of supply disruption [...] and [a] lack of affordable substitutes." The EU also distinguishes a subset of critical raw materials that it considers "strategic" based on their expected supply growth and complex production pathway.
- India, in 2025, adopted a National Critical Mineral Mission. This framework, encompassing all stages of the value chain, aims to secure the supply of critical minerals resources vital to green technologies (Prime Minister of India, 2025).

Criticality is thus country- and context-specific and depends on factors such as mineral endowment (including whether the country is a producer or consumer), strategic importance, supply risks, and volatility

(Hendriwardani & Ramdoo, 2022). International organizations like the International Energy Agency (IEA) and the World Bank tend to emphasize the link between critical minerals and the energy transition more explicitly (IEA, n.d.-b; World Bank, n.d.).

Box 2. Definition of Critical Minerals and Minerals Generally Recognized as Critical

This briefing note adopts the definition used by Hendriwardani & Ramdoo (2022), according to which critical minerals can be defined as: "the raw materials—minerals and metals—that are necessary for renewable energy, clean technology, and our transition to a more sustainable, low-carbon future."

Cobalt, copper, lithium, nickel, and graphite are generally recognized to be critical minerals. They are important inputs into renewable energy technologies, batteries, and electric vehicles. In addition, generally included are the 17 "rare earth" elements: a fixed set of metals with similar properties, which are found concentrated in certain locations and used in a variety of clean energy technologies (Alves Dias et al., 2020). Other elements (such as aluminium and manganese) are also often included due to their use in green technologies.[13]

Where are Critical Minerals Mined and Processed?

Large-scale mining occurs in a range of countries, but the location of mines does not necessarily correspond to their ownership. Companies from the Global North play a predominant role in mining worldwide, while China is increasing its influence. For example, Indonesia is the largest processor of nickel, but many of the plants are owned or controlled by Chinese interests (C4DS, 2025).

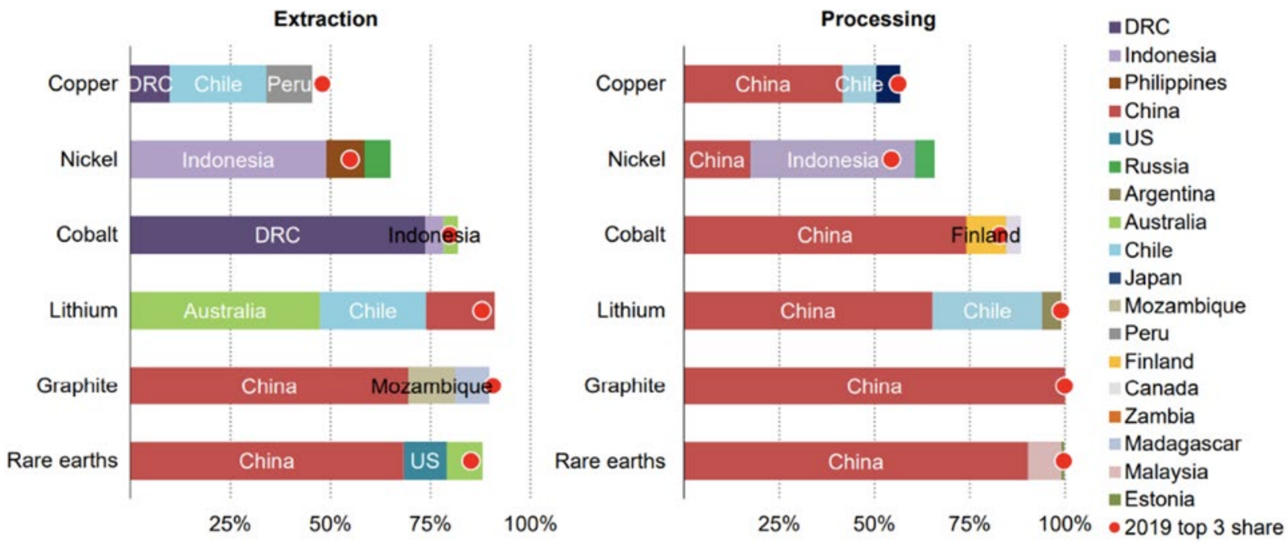
Moreover, even if mining activity takes place in a variety of countries, mineral processing capacity is often far more concentrated. As illustrated in Figure 4, China dominates global processing of many critical minerals, currently refining a large majority of graphite, rare earths, cobalt, and lithium.

As noted in section 1, demand for critical minerals is projected to rise, with some seeing significant hikes in production. Lithium production, for example, is projected to increase sevenfold, from 0.2–1.4 million tonnes per year between 2025–2040, primarily for use in batteries. Cobalt production, after having doubled over recent years to meet demand for batteries, is expected to continue to grow at an annual rate of over 5% (Jenns, 2025). Copper, aluminium, nickel, and graphite production are projected to double by 2040 for uses related to green energy generation, batteries, and electricity cables (IEA, 2024a).

Where mining and processing will be located to serve this demand is not fixed. Kulik et al. (2025) estimate that 20% of the critical minerals needed in 2035 have yet to be found. At a regional level, the IEA (2024a) projects that the "benefits of market expansion are shared across different regions, especially for mining. Latin America captures the largest amount of market value for mined output with around USD 120 billion by 2030. Indonesia sees the fastest growth, doubling its market value by 2030 due to its burgeoning nickel

13. This sectoral briefing note is part of a series, which includes analysis of the energy transition and heavy industries sectors. There are some overlaps—for example Lehne (2024) on heavy industries includes aluminium—and the briefing note should be read in conjunction with these papers.

Figure 4. Share of Extraction and Processing of Material Production by Country (2022)



Notes: DRC = Democratic Republic of the Congo. Graphite extraction is for natural flake graphite. Graphite processing is for spherical graphite for battery grade.

Source: IEA (2023).

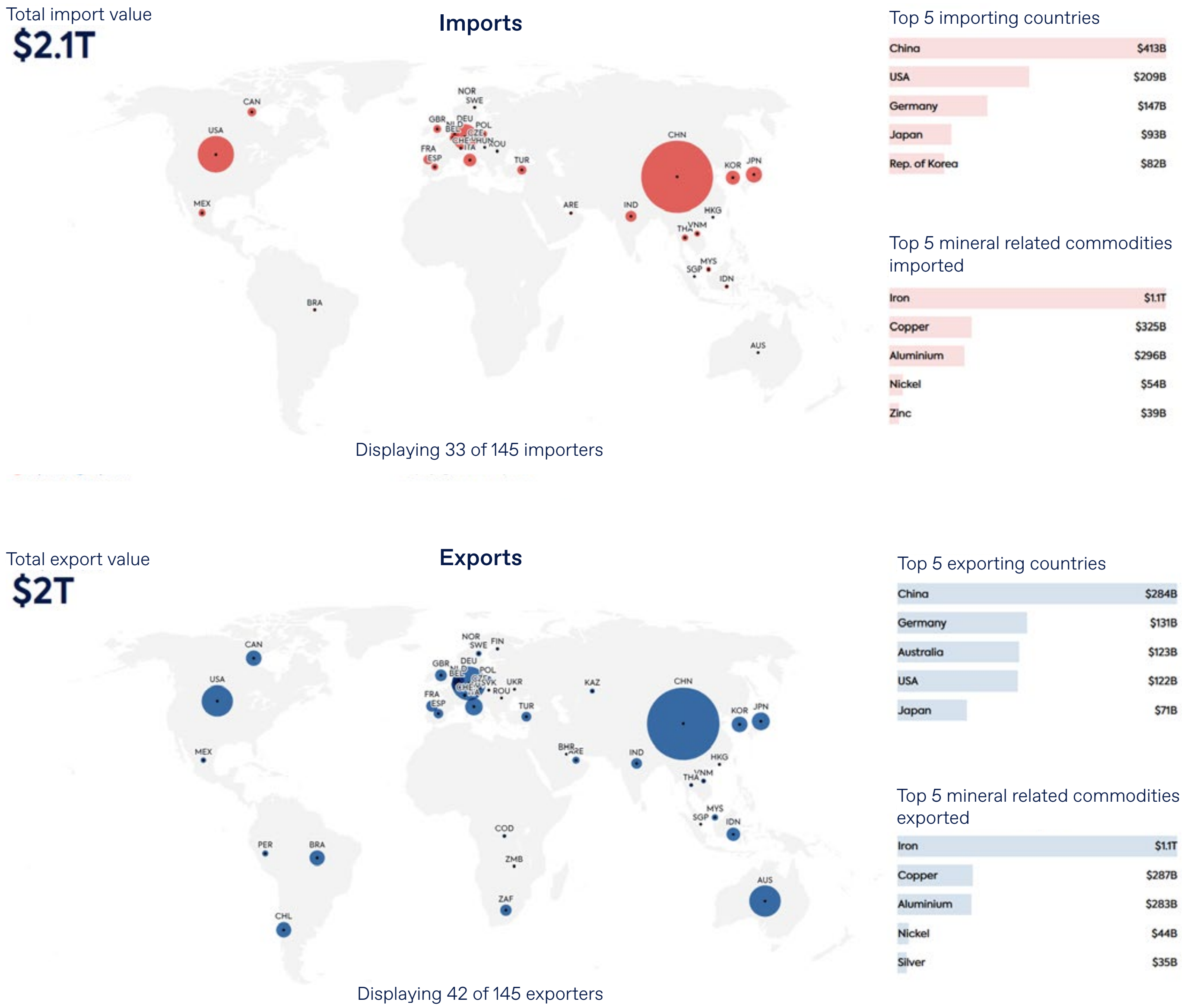
production. Africa witnesses a 65% increase in market value by 2030." Investments of around $800 billion will be required "to get on track for a 1.5 °C scenario to 2040." The IEA further projects little change in processing share by location in the period to 2040, despite current government concerns over the need to diversify critical minerals supply chains.

3. Overview of International Trade in Critical Minerals

Trade in critical minerals is highly globalized and growing quickly. The World Trade Organization (WTO) estimates that annual trade in energy-related critical minerals has increased from $53 billion to $378 billion between 2002–2022; an average annual growth rate of 10% (Snoussi-Mimouni & Avérous, 2024). In 2022, China accounted for 33% of global total in unprocessed critical minerals, followed by the EU at 16% and Japan and the US both at 11%. Figures 5 and 6 show the total import and export values of all minerals (including critical minerals) in 2022, indicating the main import and export destinations and the top mineral imports and exports that year.

Ores are heavy and bulky and therefore rely on bulk transport solutions: large ships, rail, and large road vehicles. Bulk transport prices have seen high levels of volatility in recent years (UNCTAD, 2024). There are also increasing efforts to decarbonize transport in the transition towards net zero. For example, members of the International Maritime Organization reached an agreement in April 2025 focused on "setting mandatory fuel standards and introducing an industry-wide carbon pricing mechanism" (Mishra, 2025).

Figure 5. Global Mineral Imports and Exports (2022)



Source: Critical Minerals Monitor (n.d.).

Future trends in critical minerals trade will depend on many factors, including the degree of international cooperation and environmental ambition. Kulik et al. (2025) note that 30% of critical mineral flows could be disrupted by geopolitical realignments, which, in turn, will depend on the ability of countries to build up domestic, regional, or "friend-shored" supply chains.

Import and Export Tariffs and Restrictions on Critical Minerals

Import tariffs and restrictions on critical mineral imports tend to be low. Snoussi-Mimouni and Avérous (2024) note that the most-favoured-nation tariffs applied to imports of critical minerals in 2022 were around 4% while bound tariffs were on average 26%, "indicating significant room for manoeuvre for WTO members to increase their applied tariffs should they need to do so."

There are few examples of significant tariffs or quantitative restrictions on critical minerals imports—the EU's CBAM levied against embodied carbon emissions is an outlier and currently only applies to aluminium within the set of critical minerals. Import tariffs on batteries—which to a large extent are embedded critical minerals—are generally low but some developing countries levy tariffs in the range of 10–20% on imports from China and other producers. Rather, countries have put in place a range of incentives to encourage domestic mining and processing. For example, under former US President Biden, the Inflation Reduction Act and the Infrastructure Investment and Jobs Act granted a range of financial and other incentives to encourage local mining and production of critical minerals, including for semiconductors and defence.[14] The EU is also operationalizing its supply chain diversification strategy, including through the identification of "strategic projects" similarly aimed to "secure and diversify access to raw materials" (European Commission, 2025).

Tariffs and restrictions on critical mineral exports are often much higher than on imports. Much of the current concern around critical minerals is on the ability of import-dependent countries to obtain them reliably and at acceptable prices. In contrast to imports, there are many instances of export tariffs or quantitative restrictions being employed, mainly for economic or geopolitical reasons. The OECD (n.d.) maintains a database on export restrictions of critical raw materials, which "shows a five-fold increase in the export restrictions of CRMs [critical raw materials] since the OECD began collecting data in 2009, with 10% of global trade in CRMs now facing at least one export restriction measure." Export tariffs are the most common measure employed, but there are also examples of quantitative restrictions (e.g. bans, quotas, licencing restrictions), some of which have been implemented in retaliation for other trade policies (Lederman & Barattieri, 2024).[15]

OECD (n.d.) note that "while export taxes and licensing requirements remain the most common restrictive measure for critical raw materials, recent years have seen a sharp increase in quantitative restrictions such as export prohibitions and quotas. Since 2019, export bans have become increasingly prominent, reflecting more assertive policies and efforts to retain value domestically." In 2025, restrictions on exports of rare earth elements from China have received considerable global attention (CSIS, 2025).

International Partnerships and Agreements to Secure Access to Critical Minerals

As countries around the world seek to secure access to critical minerals, many have developed strategies for that purpose and are using trade agreements, foreign investment, and a range of other mechanisms (IEA, n.d.-b). Examples include:

- Chinese institutions and companies have invested significantly in foreign mining and processing, including through the Belt and Road Initiative (Chatham House, n.d.).
- The EU passed its Critical Raw Materials Act in 2023, aiming "to ensure secure and sustainable supply of critical raw materials for Europe's industry and significantly lower the EU's dependency on imports from single country suppliers" (European Commission, n.d.). The bloc has also announced: (i) the first Clean Trade and Investment Partnerships (CTIP), a "mini-trade deal" with South Africa focused on "investment, the

14. At the time of writing (July 2025) both of these initiatives faced an uncertain future as the Trump administration had ordered federal authorities to freeze the disbursement of related funds (Guarna & Turner, 2025; Archer, 2025).
15. Some of these measures have led to legal challenges at the WTO.

clean energy transition, skills and technology, and on developing strategic industries along the entire supply chain" (European Parliament Think Tank, 2025); (ii) a Partnership on Sustainable Raw Materials Value Chains and Renewable Hydrogen with Namibia (European Commission, 2022) and a strategic partnership on raw materials with the Democratic Republic of Congo (European Commission, 2024) ; and (iii) 47 "strategic projects to secure and diversify access to raw materials in the EU" within and outside the EU's territory designed to "boost domestic strategic raw material capacities" (European Commission, 2025). The EU also continues to incorporate sustainability chapters, including provisions on critical minerals, in its trade agreements with partners.

- The US is looking to conclude trade deals to consolidate supply chains for critical minerals feeding industries including defense (Boudreau, 2025). The US has recently signed a memorandum of understanding with the Democratic Republic of the Congo and Zambia for the development of value chains for battery-grade materials and is looking to deepen its cooperation on minerals supply with other African countries through its Minerals Security Partnership Forum (Tucker, 2025).

Groups of countries with common interests have also formed partnerships and cooperation agreements. Beuter et al. (2025) identify almost one hundred bilateral agreements in Africa alone, noting their diversity; with some emphasizing direct state cooperation and others simply seeking to foster an enabling environment for example. A number of these agreements cover social and environmental standards while others do not. An example of note is the cooperation agreement between the Democratic Republic of the Congo and Zambia, which, in the context of rising demand from the battery sector, is based on adding value to the vast cobalt and copper reserves that the countries respectively hold (UNECA, 2022). The Lithium Triangle is another illustration where Argentina, Bolivia, and Chile are cooperating in a variety of ways to realize greater value from their resources.

Table 1 lists a selection of key multi-country partnerships and agreements. These are often reached between developed and emerging economies looking to gain preferential access to the minerals produced in resource-rich developing countries, sometimes with provisions on financial and other resources to increase production.

Table 1. Selection of Critical Minerals Partnerships and Agreements

Partnership or Agreement	Description/Objective*
Australia-Japan-India-US (Quad) critical minerals initiative	Collaboration between the four partners to bolster supply chains for critical minerals and reduce reliance on single countries (e.g. China)
China's Belt and Road Initiative	Mining, processing, and infrastructure investments in a range of countries
EU Critical Raw Materials Act & Global Gateway	EU developing projects and access with a range of partners**
India's Critical Mineral Alliances	Secure access to minerals from countries other than China
Latin America's Lithium Triangle (Argentina, Bolivia, and Chile)	Regional processing in lithium mining and (downstream) battery manufacturing
Minerals Security Partnerships	US, EU, and a range of developed countries aim to develop projects in developing countries through this forum
US-Canada Joint Action Plan on Critical Minerals	Strengthen supply chains between the US and Canada (e.g. to support electric vehicle production)
US-Japan Critical Minerals Agreement	Secure access to critical minerals for both countries

* Beuter et al. (2025) note that "lack of transparency means that the specific provisions of agreements are often difficult to ascertain."

** In its Critical Raw Materials Act, the EU stipulates that no more than 65% of any key raw material should come from a single country (Lee, 2023).

Source: Authors' elaboration based on IEA (n.d.-b).

4. Critical Minerals and Climate-Resilient Development: Key Considerations for Developing Countries

Developing countries' critical minerals strategies can include increasing any or all of extraction, processing, and downstream activities using processed minerals (e.g. the production of batteries or battery components). Imports of critical minerals can create opportunities to expand economic activities, as can circularity and recycling. Greater production can lead to higher exports and/or lower imports. Finally, there are opportunities for countries to increase the provision of services they offer to the mining and critical minerals sectors—this has been an important part of the strategies followed by a number of countries, including Chile's national lithium strategy (Government of Chile, n.d.).

Assessing Whether Increased Critical Mineral Production Will Lead to Climate-Resilient Development

Developing countries need to critically assess whether in their specific circumstances greater engagement in critical minerals production will support climate-resilient development.[16] Benefits and costs should be assessed across economic, social, and environmental dimensions, informed by a range of possible future scenarios and risk assessments. Table 2 provides an list of questions, grouped into five main categories, which can help guide such an assessment. Accounting for Price and Price Volatility

Table 2. Guiding Questions to Assess Whether Critical Minerals Strategies Will Support Climate-Resilient Development

Economic Case	▪ What are the financial, trade, and geopolitical conditions and considerations around the investment? ▪ How much risk will the country take? ▪ How volatile are product markets? ▪ What incentives could competitors offer? ▪ Are there substitutes which could erode market value?* ▪ Are there downstream opportunities, for example manufacturing of batteries or their components? ▪ How would extraction affect the macroeconomy, for example exchange rates and credit ratings?
Technology and Infrastructure	▪ Does the country possess the necessary technology and infrastructure? ▪ If not, with whom should it partner to get these? ▪ What are the terms and conditions of technology transfer? ▪ Does the implementation of necessary supporting infrastructure (e.g. harbours, roads, electricity generation and grids) require the country to borrow money? If so, under what conditions?
Employment	▪ How many jobs will be created? ▪ Are locals or expats being employed? ▪ What are the points in the project timeline when employment is higher and lower?
Fairness	▪ Does the country receive a fair price for the minerals that it is allowing to be extracted? ▪ How is the revenue being reinvested into the economy? ▪ Who benefits the most from this revenue? Who does not benefit? ▪ Who sees an increase/decrease in their living standards? ▪ What kind of regulatory regimes are needed to make sure that mining-based development is inclusive?
Local Environmental and Health Impacts	▪ Will the project exacerbate local climate impacts? ▪ Does the project take place on land used by local communities, including Indigenous and/or tribal groups? ▪ If so, how will they be affected/compensated? ▪ Are there any other environmental impacts, such as emissions or depositions of toxic substances, flood or earthquake risks related to mineral extraction, or environmental impacts of energy generation (e.g. hydro reservoirs)? ▪ Are there potential human health impacts that need to be considered?

* For example, LFP (lithium iron phosphate) batteries now account for around 40% of the market. They do not need the nickel, manganese, or cobalt required in the competing NMC (lithium nickel manganese cobalt oxides) chemistry. This diversifies the options for battery makers but constitutes a risk for countries that have invested in mining of nickel, manganese, or cobalt.

Source: Authors' elaboration.

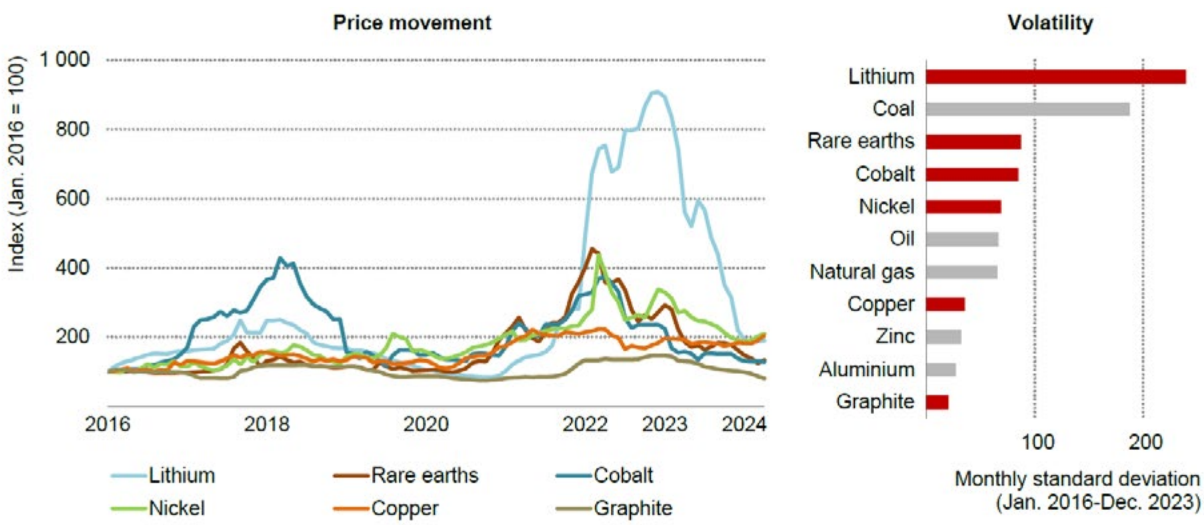
16. The Intergovernmental Panel on Climate Change, in their 6th Assessment Report, define climate-resilient development as "a solutions framework that successfully combines strategies to deal with climate risks (adaptation) with actions to reduce greenhouse gas emissions (mitigation) which result in improvements for nature's and people's well-being – for example by reducing poverty and hunger, improving health and livelihoods, providing more people with clean energy and water and safeguarding ecosystems on land, in lakes and rivers and in the ocean" (IPCC, 2022).

Accounting for Price and Price Volatility

Concerns over the ability of critical minerals supply to meet future demand are often raised. For example, looking to 2035, the IEA (2024a) notes that "[t]here is a significant gap between prospective supply and demand for copper and lithium: Anticipated mine supply from announced projects meets only 70% of copper and 50% of lithium requirements. Balances for nickel and cobalt look tight relative to confirmed projects, but better if prospective projects are included".

However, it should not be assumed that such concerns around future demand and supply of critical minerals will necessarily translate into high prices or profits. The prices obtained for critical minerals may eventually disappoint. The lithium market offers clear recent examples of countries generating lower than expected returns, partially explained by the strong downward trend in battery prices, a sector prone to fierce competition (BMI, n.d.). Moreover, critical mineral prices, notably lithium, have exhibited strong volatility in recent years, more so than for oil and natural gas (Figure 6). Volatility increases uncertainty around investment returns and future prices. Increasing Value Addition

Figure 6. Price Movement and Volatility of Selected Commodities



Notes: Assessment based on the London Metal Exchange (LME) Lithium Carbonate Global Average, LME Nickel Cash, LME Cobalt Cash, LME Copper Grade A Cash prices, China flake graphite (-194 free on board), and neodymium oxide 99.5-99.9% Min China prices.

Source: IEA (2024a).

Increasing Value Addition From Critical Minerals

Although critical minerals are increasingly seen as strategic, standard mining and processing considerations and concerns around greater activity still apply: capital costs are high, markets are volatile and competitive, social and environmental risks are considerable, and new production takes a long time to get online and requires large amounts of capital and know-how (Omonube & Mataba, 2024). Additionally, most developing countries are marginal producers and lack market power (Gaylor et al., 2024).

Table 3 lists the strategies that developing countries can consider to support value addition from critical minerals (see Table 4 for a detailed description of possible trade policy tools and options for international cooperation for each strategy).

Table 3. Strategies to Support Value Addition from Critical Minerals in Developing Countries

Provide incentives for domestic mining, processing, and manufacturing
Promote downstream industries (e.g. metals, batteries, electric vehicles)
Invest in infrastructure (e.g. ports, railways, energy supply)
Strengthen legal and regulatory frameworks (e.g. fiscal regimes, mining codes)
Build human capacity and technology absorption
Promote circularity and recycling
Diversify supply chains and build up strategic reserves
Ensure environmental sustainability and social responsibility

Source: Authors' elaboration.

One strategy governments can pursue is to encourage investment, including from foreign sources. Multinationals and sovereign investors have many options and countries often need to compete and create attractive investment and regulatory environments to access finance and associated expertise. Stable, predictable, and transparent rules are valued by foreign investors, ideally accompanied with participatory processes. Multiple governments providing incentives for critical minerals production can drive down prices, increasing risks for newcomers in the market, especially countries with limited financial resources. As noted, there are many possible scenarios regarding the future trajectory of critical mineral prices, influencing the profitability of different production and trade opportunities—developing country governments must prepare for the full range of possibilities. Efforts among consumers of critical minerals to diversify their supply chains, particularly to reduce their dependence on Chinese minerals, could open opportunities for developing countries to exploit.

Moving downstream of the value chain—into mineral processing, battery production, or associated activities for example—is strategy that is widely proposed.[17] Some of these industries (e.g. batteries and their components) are highly competitive and mature. Any such strategy should carefully assess the extent to which these markets are accessible for developing countries as well as their potential to contribute positively to employment generation and state revenues and negatively to pollution and other externalities. Some minerals have substitutes, including for example minerals used in battery cathodes. If a country decides to invest in producing such minerals, it may need to generate a return relatively quickly or risk seeing demand evaporate because of evolving technology choices.

To support value addition, a range of industrial policies (including subsidies and local content requirements) are being tested around the world. These should be carefully considered using the list of guiding questions to assess whether critical minerals strategies will support climate-resilient development identified in Table 2.[18] In addition, some countries have introduced export bans on unprocessed critical minerals in order to incentivize a domestic processing industry.[19] It is too early to assess the effectiveness of such policies, but an important factor to consider is a country's potential market share in any given mineral—without market power, export restrictions are less likely to achieve their policy objectives.

17. In considering the use of fiscal incentives as an investment promotion tool, "the increased demand for critical minerals, which could result in some producing countries having more bargaining power than previously, could offer an opportunity to remove overly generous, poorly targeted fiscal incentives. Whereas in the past, incentives have largely been used to encourage investment in mineral extraction (the upstream part of the business), this could be a moment for countries to think more about incentivizing processing, or value addition more broadly, through such measures as performance-based incentives to increase processing capacity" (IGF, 2024).
18. Local content requirements in the mining sector generally means requiring that a percentage of processing is done in a country. This can be successful, but only if the country has the industrial capacity, infrastructure, and skills, and a guaranteed market (e.g. backed-up offtake contracts)—otherwise there are many examples where such measures have not achieved their aims (Ramdoo, 2018).
19. This is the case, for example, of Indonesia's nickel policy (IEA, 2024b).

Circularity and recycling can help developing countries comply with external standards and also increase access to critical materials. Battery recycling is becoming a key sector and developing countries should assess their options in this regard and the policies and frameworks—trade and otherwise—needed to support the sector. This may also include the transport and trade of wastes.

Working to high sustainability standards provides another opportunity to enhance value addition. Sustainability standards—many linked to carbon intensity—exert growing influence over critical minerals supply chains, and complying with them will increasingly become a requirement to access markets and, potentially, charge premium prices compared to products that do not meet these standards. However, compliance with such standards can be a challenge for developing countries.[20]

Implementation of a critical minerals strategy needs policy support, including in relation to industry and trade. The development of the critical minerals sector often requires active state involvement, which can come with risks. If policies are "poorly designed and implemented, expanded state participation could result in adverse unintended consequences, including corruption, operational inefficiency, and knock-on impacts on investor confidence" (Omonbude & Mataba, 2024).

5. Options for Trade-Related Policies and International Cooperation to Support Climate-Resilient Development and Value Addition in Critical Minerals

While developing countries have varied experiences in mineral policy, critical minerals are distinctive due to their growing strategic importance and rising demand, which could alter the balance of power and strengthen the negotiating positions of resource-rich countries.

As noted, the appropriate policies to promote value addition are context-specific and depend on factors such as a country's role in the mineral value chain, market conditions, resource scale, infrastructure, investment appeal, and the existence of trade agreements among others. As such, there is no one-size-fits all approach or generic advice on the best mix of policies or measures—both trade and non-trade related—any given country should follow. In addition, countries will seek to pursue varying objectives, including to increase any or all of extraction, processing, downstream industries, critical minerals access, or exports.

Table 4 provides different types of trade and trade-related policy tools developing countries could employ as well as options for trade policy engagement and international cooperation to help achieve three overarching objectives: increase economic activity in the critical minerals sector; increase access to critical minerals; and reduce impacts and support access to export markets.

The strategies to support value addition from critical minerals identified in Table 3 are grouped under these three objectives, and each strategy is associated with a set of trade and trade-related policy tools for consideration and options for international cooperation.

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20. "Demonstrating how mineral development will bring positive social benefits on the ground not only for the elites is a must—not only because it is the right thing to do but because it will strengthen the resilience of resource security" (Lee, 2023).

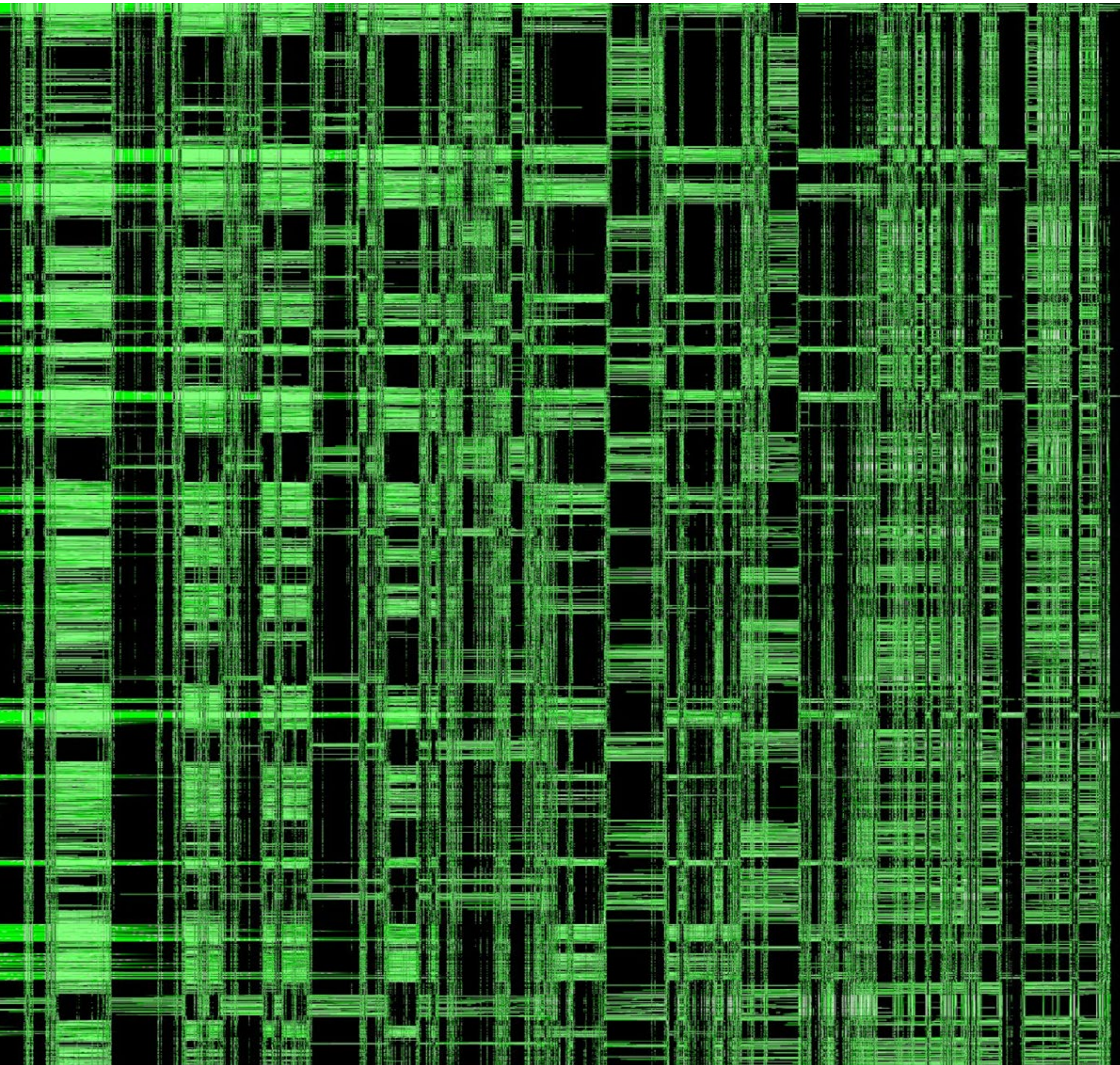
Table 4. Potential Trade Policy Tools and Options for International Cooperation to Support Climate-Resilient Development and Value Addition in Critical Minerals

Objective	Strategy	Potential Trade and Trade-Related Policy Tools	Options for International Cooperation
Increase economic activity in the critical minerals sector	Promote upstream activities in the mining sector, including extraction and related services	Subsidies (including tax breaks and low-interest loans), special economic zones, regulatory measures, public–private partnership (PPP)s, price floors, preferential offtake agreements	▪ Bilateral or regional trade and investment or access agreements (e.g. EU CTIPs), involving, for example, premium prices, offtake agreements, new investments, or technology transfers ▪ Joint investment frameworks with blended finance mechanisms that reduce risk and the cost of capital that would help spearhead and sustain investments in new projects extracting and processing critical minerals
	Promote downstream activities, including domestic transformation and value addition	Industrial policies (e.g. subsidies, local content requirements, export restrictions or taxes, intellectual property rights, standards and regulations), public–private partnerships, public procurement of manufactured goods	▪ Regional integration schemes (e.g. AfCFTA) to foster the development of regional supply chains allowing for transformation and value addition ▪ Bilateral or regional trade and investment or access agreements involving support measures for local transformation and value addition (e.g. joint investment frameworks with blended finance mechanisms or public-private partnerships that reduce risk and the cost of capital for investment in processing critical minerals) ▪ Clarifying international disciplines applicable to subsidies and trade-related investment measures (e.g. on local content requirements), intellectual property rights, and export restrictions and prohibitions and how they should be allowed/applied (with a view to minimizing trade distortions)
	Invest in infrastructure (e.g. ports, railways, energy supply)	Government subsidies and more general expenditure Trade and investment facilitation measures aimed at improving infrastructure for critical mineral trade routes and energy supplies	▪ Regional trade infrastructure initiatives and integration schemes (e.g. the Lobito Corridor between Angola, Democratic Republic of the Congo, and Zambia) to foster modernization of transport and logistics, linking mineral-rich regions to global markets and promoting value chains. ▪ Investment from multilateral development banks, international financial institutions, multinational firms (where investments in infrastructure can be conditional on wider agreements granting access to resources), export credits
	Strengthen legal and regulatory frameworks (e.g. fiscal regimes, mining codes); and build human capacity and technology absorption	Stable, predictable, and transparent trade rules, ideally accompanied by participatory processes Trade focus in R&D, education, and training	▪ Regional trade integration schemes to help upgrade regulatory frameworks and develop consistent and transparent fiscal and regulatory regimes across different jurisdictions ▪ Establish regional R&D centres
Increase access to critical minerals	Promote circularity and recycling	Recycling programmes and infrastructure development, regulations including enhanced producer responsibility, standards, waste transport, trade regulations	▪ Rules negotiations for cross-boundary transfer of key waste streams, notably used batteries, in line with the Basel Convention and the application of its rules ▪ Regional and global approaches can reduce costs and improve security for all
	Diversify supply chains and build up strategic reserves	Regulations, subsidies, investment in further infrastructure, trade agreements, stockpiling	▪ Regional integration schemes to promote diversification and help develop regional value chains.
Reduce impacts and support access to export markets	Ensure environmental sustainability and social responsibility	Regulations and standards to drive progress towards environmental and social sustainability, and make provisions for end-of-life decommissioning of mines and facilities	▪ Promotion of harmonization, equivalence, or mutual recognition of rules of origin and use of international standards in bilateral and regional agreements ▪ Technical assistance and capacity building to support compliance with emerging ESG requirements ▪ Engagement in development and implementation of private and public standards and technology hubs, pools, and partnerships for sustainable mining and processing technologies

Source: Authors' elaboration.

DIGITAL TRANSFORMATION

Yasmin Ismail and Nadira Bayat



1. The "Twin Transition": A Simultaneous Pursuit of Digital and Green Transformations

The digital transformation is reshaping the architecture of economies, societies, and trade systems. It is driven by two interrelated processes: digitization—the conversion of analogue data and processes into a machine-readable format—and digitalization—the use of digital technologies and data as well as interconnection that result in new or changes to existing activities (OECD, 2019). Collectively, the changes produced by different forms of digitization and digitalization on economic and social activities constitute the digital transformation (IMF et al., 2023). This shift is propelled by a wave of "frontier technologies"—including artificial intelligence (AI), generative AI, the Internet of Things (IoT), blockchain, big data, cloud computing, 3D printing, robotics, and drones—that are fundamentally changing how goods and services are produced, exchanged, and delivered (UNCTAD, 2025).

The widespread adoption of digital technologies is reshaping value chains, creating new business models, and accelerating the transition towards digitally enabled economies. At the same time, the urgency of addressing climate change and transitioning to a net-zero economy demands a fundamental transformation of production and consumption across manufacturing, transport, agriculture, and services. This transformation requires cutting greenhouse gas (GHG) emissions, accelerating the production and use of clean and renewable energy, and deploying low-carbon and carbon-free technologies. The "twin transition" captures this dual dynamic, with the green and digital transformations interconnected and unfolding simultaneously. The world is increasingly reliant on digital tools and innovations to accelerate the transition to low-carbon economies and mitigate and adapt to climate change (World Bank, 2023).

While digital technologies are central to climate action, their potential to accelerate progress towards net-zero goals is neither automatic nor assured. Realizing this potential depends on deliberate policy choices, effective governance, and adequate institutional, technical, and financial capacity. The convergence of digital transformation and climate priorities offers new opportunities to advance sustainable development, but it also raises concerns about environmental impacts, equity, and the ability of developing countries to participate meaningfully and capture the benefits of the twin transition.

2. The Digital Transformation, Climate Change, and Trade Nexus

Digital technologies are opening new pathways to cut emissions, improve energy efficiency and resource use, and build resilience to climate impacts. One important pathway is through dematerialization: replacing physical goods and services with low-emission digital alternatives such as virtual meetings, cloud computing, and digital financial services, which reduce the need for travel and paper-based transactions (Calvino, et al., 2025). At the same time, technologies such as cloud computing, AI, the IoT and big data carry environmental costs, including rising energy demand and growing volumes of electronic waste (UNTAD, 2024). Digitalization does not automatically reduce sectoral carbon footprints. Some solutions may lower emissions per unit of activity but drive greater overall consumption, creating rebound effects (World Bank, 2023).

These risks are real, but the gains are also significant: digital technologies can drive process efficiency and resource optimization. This includes through enabling predictive maintenance in manufacturing, optimizing transport networks, and supporting real-time energy management in smart grids (UN DESA, 2018). Digital agriculture is transforming farming by harnessing new technologies, platforms, and analytics to deliver more precise, productive, and sustainable practices. In developing countries, these innovations are making precision agriculture increasingly affordable and accessible for smallholder farmers. Tools such as satellite- and unmanned-aerial-vehicle-based remote sensing, field sensors, and IoT systems allow farmers to monitor crop health, optimize input use, and raise yields, thereby advancing climate-resilient agricultural practices (UNDP, 2021). Digital technologies are also central to disaster preparedness. Digital risk mapping and early warning systems powered by cell broadcast and messaging provide timely alerts that save lives and protect vulnerable communities (ITU, 2023).

In addition, digital technologies contribute to circular economy models by facilitating sharing, repair, and reuse. For example, the rise of IoT-enabled products with self-diagnostic capabilities allows consumers to receive targeted, timely advice on optimal use and maintenance, helping to enhance product lifetime and reduce the need for costly repairs. These systems also make repair instructions more accessible and can connect consumers directly with quality-certified repair services, thereby supporting more sustainable consumption (OECD, 2025).

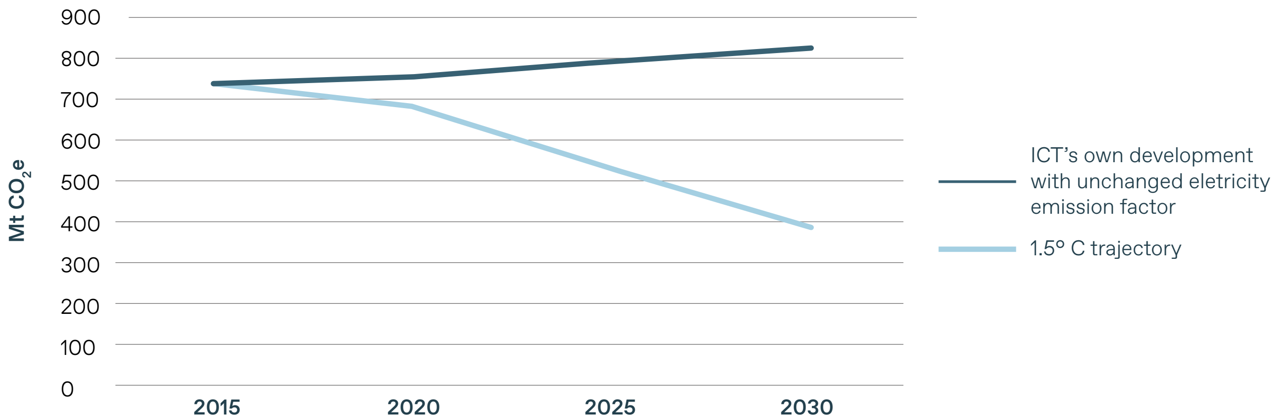
Climate-related digital opportunities are unfolding rapidly, but persistent inequalities and a widening digital divide have far-reaching implications for the ability of developing countries to realize this potential. As of 2024, an estimated 2.6 billion people—around 32% of the world's population—remained offline, with internet penetration in low-income countries at only 27% (ITU, 2024). This exclusion limits access to technologies that are critical for climate adaptation, emissions reduction, and participation in emerging green markets. Moreover, the ability to harness the digital transformation varies widely, with disparities in access to and use of digital infrastructure, tools, and platforms across gender, age, and geography (Chauvet, 2020). Bridging these divides is essential for inclusive and climate-resilient development, enabling developing countries to participate fully in the green transition and advance along net zero pathways. At the same time, expanding connectivity requires significant investment in infrastructure and greater access to devices, which must be carefully managed to avoid escalating energy demand and emissions (ITU & World Bank, 2024).

The environmental costs of digital transformation are increasingly evident. World Bank (2023) research finds that while technology-based solutions advance climate progress they also contribute between 1.4% and 4% of global GHG emissions—comparable to the emissions of the airline industry. To help reach the 1.5°C target of the Paris Agreement, emissions from the digital sector will need to be slashed by at least half by 2030. Rising energy demand compounds this challenge. Data infrastructure—particularly data centres and cloud services—is highly energy- and resource-intensive, with heavy reliance on refrigerants and water for cooling (World Bank, 2023). The International Energy Agency (2024) projects that total electricity consumption by data centres (including cryptocurrency operations) could more than double from 460TWh in 2022 to over 1,000TWh by 2026.

Figure 1 shows two trajectories under different scenarios of the overall carbon footprint of the information and communication technology (ICT) sector—the backbone of the digital transformation involving mobile and fixed networks, data centres, user devices, and cloud or enterprise networks.

In developing countries, rising digital energy demand risks exacerbating grid instability, straining scarce power supplies, and deepening energy access inequalities. Climate change amplifies these risks, exposing digital infrastructure to a growing range of natural hazards, including riverine and coastal flooding, cyclones, landslides, water scarcity, and extreme heat (World Bank, 2023). These shocks can overwhelm cooling systems, damage submarine and terrestrial cables, and disrupt mobile and satellite networks. They can also disrupt digital tools and services dependent on data centres and cloud computing, with cascading impacts across communities, communications, financial services, energy grids, and other critical public infrastructure.

Figure 1. ICT Sector Carbon Footprint Trajectories, With and Without Decarbonization of Electricity by 2030



Notes: $MtCO_2e$ stands for metric tonnes of CO2 equivalent. The green line shows the projected carbon footprint trajectory of the ICT sector with the decarbonization of electricity in alignment with the 1.5 °C objective of the Paris Agreement. The blue line shows the trajectory with unchanged electricity emission factor.

Source: ITU (2020b).

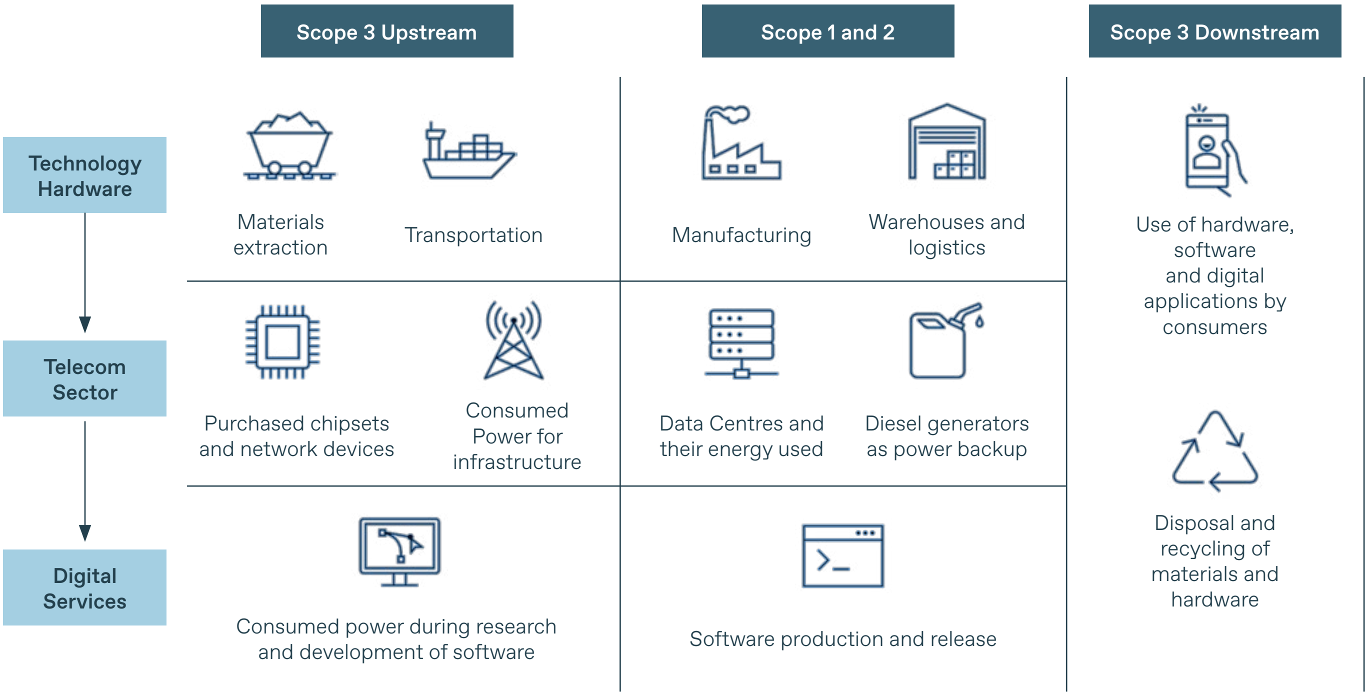
Digital trade or e-commerce—the cross-border exchange of digitally ordered, delivered, or enabled goods and services—is amplifying opportunities and risks at the intersection of digital and green transitions.[21] According to UN Trade and Development (UNCTAD, 2024), e-commerce and digital platforms offer new prospects for sustainability through low-emission delivery, eco-friendly packaging, sustainable returns, and efficient logistics. These models lower market entry barriers for micro, small, and medium-sized enterprises (MSMEs), facilitating participation in global and green value chains and accelerating the uptake of climate-smart technologies. At the same time, the rapid expansion of digital trade and digital services innovations are intensifying environmental pressures. E-commerce activity contributes to packaging waste, emissions from last-mile delivery, increased product returns, and risks fuelling overconsumption. Moreover, the digital backbone powering these electronic transactions is expanding to meet rising demand, while remaining energy-intensive and carbon-reliant, risking to deepen fossil fuel dependency (IEA, 2024; UNCTAD, 2024).

These trends underscore the need to advance digital trade and the economy more generally within a low-carbon framework, ensuring that the digital transformation accelerates the net-zero transition and supports climate-resilient development. Figure 2 illustrates key sources of GHG emissions across the digital economy, from technology hardware and the telecom (or ICT) sector to digital services, structured along three scopes of emissions. Scope 1 and 2 emissions cover direct and indirect energy use from core operations, including consumed power for infrastructure, software production, data centres, and diesel generators for backup power. Scope 3 upstream emissions capture impacts from materials extraction, purchased chipsets, and network devices, consumed power for infrastructure, and transportation or logistics. Scope 3 downstream emissions reflect emissions from consumer use of hardware, software, and digital applications, as well as the disposal and recycling of devices and materials.

The framework in Figure 2 distinguishes between the technology hardware sector, the telecom sector, and digital services. It illustrates how each stage of the digital economy life cycle—from materials extraction and production to use and end-of-life—contributes to the sector's overall carbon footprint.

21. The OECD notes that, while there is no single recognized and accepted definition of digital trade, there is a growing consensus that it encompasses digitally-enabled transactions of trade in goods and services that can either be digitally or physically delivered (López González & Jouanjean, 2017).

Figure 2. Main Sources of GHG Emissions Across the Digital Economy by Sector and Scope



Source: Authors' elaboration based on ITU (2020b), KPMG (2024), Jose (2014), and Microsoft (2021).

3. The Digital Transformation on the Road to Net Zero: A Patchwork of Initiatives

In the multilateral deliberations of the United Nations Framework Convention on Climate Change (UNFCCC), digital technologies are recognized as a means for facilitating and enabling climate action, yet their environmental footprint remains largely unaddressed. The 2015 Paris Agreement emphasized technologies primarily as enablers of climate action through: facilitating the exchange of information, knowledge, and best practices among countries and stakeholders; promoting the development of low carbon energy solutions; enhancing energy efficiency; and supporting adaptation efforts (UNFCCC, 2016; UNCTAD, 2024). Building on this, the 2023 UN Climate Change Conference (COP28) outcome on the first global stocktake under the Paris Agreement specifically referenced "digital transformation" and the accelerated deployment of existing clean technologies and accelerated innovation as essential for achieving the agreement's long-term emission reduction goals (UNFCCC, n.d.; UNCTAD, 2024).

The International Telecommunication Union (ITU), the UN specialized agency for information and communication technologies, has been active in providing analysis and producing non-binding standards and recommendations (ITU-T products) to policymakers and stakeholders addressing the adverse effects of the ICT sector on climate and the environment. Notably, ITU Recommendation L.1470 outlines GHG emissions trajectories for ICT sub-sectors compatible with a 1.5°C scenario, establishing a long-term ambition to halve emissions by 2030 and achieve net zero by 2050. It identifies key levers, including increased energy efficiency, renewable energy sourcing, and circular economy models for devices and networks and proposes examples of supporting actions

(ITU, 2020b). Other ITU-T recommendations cover, among others, requirements on energy efficiency in the ICT sector and the role of AI and the optimization of 5G wireless networks' energy consumption.[22] However, there is limited information available on the level of adoption and implementation of these recommendations across jurisdictions and stakeholders.

Multistakeholder initiatives are increasingly emerging to support emissions reduction in the digital sector. At COP29, a broad coalition of state and non-state actors issued a Declaration on Green Digital Action, expressing concern over the carbon footprint and climate impacts of digital technologies and related tools along their value chains and full life cycle, and highlighting the need for more data and analysis of the sector's emissions (COP29 Azerbaijan, 2024). The declaration recognized that digital divides can impede equitable transitions and set a common objective to mitigate the climate impacts of the digital sector, with national governments and other stakeholders—including international organizations, financial institutions, philanthropies, private sector entities, academia, and civil society organizations—committing to develop policies and collaborate to achieve this goal.

Alongside global and multistakeholder action, governments are introducing measures to promote environmental responsibility in the digital sector. For example, the European Union's (EU) Corporate Sustainability Reporting Directive obliges companies, including those operating digital infrastructure and ICT services, to report sustainability information in line with mandatory European Sustainability Reporting Standards. The directive expands the number of companies covered and the range of information to be disclosed across environmental and social indicators, including climate (European Commission, n.d; Pitre et al., 2023).

The private sector is also taking steps to advance digital net zero pathways. In 2019, the board of the Global System for Mobile Communications Association (GSMA), representing almost half of global mobile connections, set an industry-wide goal for the mobile sector to achieve net zero by 2050 (GSMA, 2024). The GSMA-led Mobile Net Zero Initiative now includes 70 operators that have committed to reducing emissions in line with science-based targets, signalling growing momentum for industry-driven climate action. The GSMA publishes annual reports on progress towards its net zero targets, with the 2025 report finding that there has been progress in addressing scope 1 and 2 emissions (operational emissions), yet the initiative continues to face challenges in tackling scope 3 emissions, which account for 70% of overall mobile industry carbon emissions (GSMA, 2025).[23]

The 2025 report highlights regional disparities, with more progress in scope 1 and 2 emissions reductions between 2019–2023 achieved in developed economies—i.e. Europe (-56%) followed by North America (-44%)—compared to other regions—i.e. Latin America (-36%), Sub-Saharan Africa (-25%), Middle East and North Africa (-13%), Asia Pacific (-5%), and Eurasia (-1%). Greater China reported an increase in operational emissions of 8%. In general, circularity in mobile and network equipment remains a significant challenge for the industry.

At the request of the EU Council, the European Green Digital Coalition was established in 2021. Coalition members (37 companies at the time of writing) together are committing to support the EU's green and digital transformation by investing in the creation and implementation of green digital solutions, collaborating with expert organizations to develop tools and methodologies for assessing the climate impact of digital technologies, and working jointly with stakeholders from other sectors to design recommendations and guidelines that promote a green digital transition (European Green Digital Coalition, n.d.).

Private sector initiatives are also taking place in the area of digital trade. A number of e-commerce platforms have been declaring, individually, their pledges to achieve net zero. Amazon (n.d.), for example, announced in 2019 its target to reach net-zero emissions across its operations by 2040 and investing in carbon-free energy to achieve

22. For other relevant ITU-T recommendations see ITU (n.d).
23. Scope 3 emissions include purchased goods and services, capital goods, fuel and energy-related activities, and product use.

this goal. The Chinese platform Alibaba (2021) has committed to achieving carbon neutrality in its operations and to halving scope 3 emissions by 2030 compared to 2020 levels. The e-commerce platforms Mercado Libre (2024) in Latin America and Jumia (2021) in Africa have also reported measures and progress towards emissions reductions from their operations . However, the accuracy, frequency, and level of detail in sustainability reporting by digital platforms vary considerably, reflecting disparities in data availability and reporting capacity across regions and business size. Reliance on voluntary disclosure frameworks, which differ widely in scope and methodology, makes meaningful comparison across firms and countries difficult. This fragmented landscape increases the risk of selective reporting and greenwashing, weakening the credibility of disclosures. Limited regulatory oversight compounds these challenges, leaving stakeholders uncertain about the reliability and comparability of sustainability information (UNCTAD, 2024).

While the growing number of initiatives, commitments, and declarations across international fora, multistakeholder and industry coalitions, and private sector actors reflect increasing awareness of the need to address the digital sector's climate footprint, these efforts remain fragmented and largely uncoordinated. Divergent methodologies for measuring GHG emissions and differences in reporting capacities across these initiatives, among other factors, further complicate efforts to compare outcomes or track the sector's collective progress. World Bank and ITU (2024) research finds that reliable country-level data collection and analysis of the ICT sector's GHG emissions and energy consumption remain scarce. Assessments of the sector's climate impact remain largely based on aggregate global estimates, constraining the evidence base for informed policymaking on reducing ICT emissions and managing energy demand. In addition, methodologies remain inconsistent, and no harmonized global framework exists to support transparent, comparable reporting.

4. Decarbonization Pathways in the Digital Sector, Impacts on Trade, and Opportunities and Challenges for Developing Countries

The rapid expansion of the digital sector is driving exponential growth in data traffic, creating unprecedented demand for transmission capacity. This demand is being met through advances in network technologies, rising investment in infrastructure, and a corresponding surge in electricity consumption. Data centres—at the core of data storage and processing—are especially energy intensive, relying heavily on electricity, refrigerants, and often large quantities of water for cooling (World Bank, 2023). Given the digital sector's fast-paced innovation cycles and structural complexity, achieving net-zero targets will require integrated pathways that address scope 1, 2, and 3 emissions across value chains. These pathways should embed ambitious mitigation strategies, with priority given to the rapid decarbonization of electricity use through the integration of renewable and other low-carbon sources, complemented by the systematic implementation of energy efficiency measures across operations (KPMG, 2024; ITU, 2020a). Equally important is the promotion of responsible and sustainable sourcing and supply chains, adopting circular economy approaches to extend product life cycles and minimize e-waste, and favouring the deployment of climate-resilient digital infrastructure to sustain the sector's efficiency and decarbonization momentum.[24]

Table 1 synthesizes five priority pathways (levers) to guide decarbonization across the digital sector. It highlights their expected impacts on emissions and trade, and assesses the trade-related opportunities and challenges they present for developing countries.

24. Climate-resilient digital infrastructure refers here both to systems that reduce the sector's carbon footprint—through an expanded use of renewable energy, energy efficiency, and decarbonization pathways—and to infrastructure able to withstand the impacts of climate change.

Table 1. Levers of Decarbonization and Climate Resilience in the Digital Sector: Emission and Trade Impacts and Implications for Developing Countries

Lever	Description	Impact on Emissions	Impact on Trade	Trade-Related Opportunities	Trade-Related Challenges
Green and energy-efficient infrastructure and data centres	Deployment of low-power, climate-optimized data centres and network infrastructure using efficient cooling and increasingly powered by renewable electricity.	**HIGH** Data centres contribute up to 45% of ICT sector emissions.	Shift in data hosting and cloud service production to countries with low-carbon infrastructure and renewable energy production abundance.	Developing countries with renewable energy and established connectivity (e.g. Kenya, Morocco, and South Africa) are well positioned to attract investment in green data centres. Kenya is leveraging its green electricity mix to become East Africa's data-centre hub (Microsoft and G42 are developing a 100 MW geothermal-powered facility, with plans to expand to 1 GW.) The exponential growth of AI is amplifying demand for data processing. African countries with access to renewable energy are well placed to capture this market by hosting AI workloads in low-carbon data centres.	High capital and operational costs, unreliable electricity grids, and limited access to green finance constrain the deployment of energy-efficient infrastructure and data centres. These challenges are compounded by the sector's energy and water demands that strain already weak infrastructure. Regulatory gaps, a lack of targeted incentives, and fragmented policy frameworks further slow the transition to green data centres.
Green and energy-efficient ICT operations and digital trade logistics	Decarbonization of ICT operations and trade logistics through electrification powered by renewable energy, smart routing, and low-emission data transmission networks. Also use of AI for emissions monitoring and energy optimization.	**HIGH** ICT operations rely heavily on electricity.	Increased demand for low-carbon ICT services, digital exports, and e-commerce logistics and transport services.	Countries with solar/wind potential can export clean digital services and low-carbon logistics solutions. Rising demand for low-emission logistics and digitally optimized delivery creates entry points for green entrepreneurship and digital services. Smart logistics, AI-enabled monitoring, and real-time data systems expand opportunities for efficient transport, cleaner trade flows, and competitive participation in sustainable value chains.	Grid unreliability, low renewable penetration, and high capital and operating costs of clean energy technologies limit competitiveness. Carbon-intensive last-mile delivery models and slow uptake of sustainable transport solutions drive higher emissions from e-commerce expansion. Regulatory and institutional gaps, including weak carbon pricing signals, fragmented logistics policies, and lack of incentives, hinder investment in sustainable logistics.

Table 1. (continued)

Lever	Description	Impact on Emissions	Impact on Trade	Trade-Related Opportunities	Trade-Related Challenges
Sustainable and transparent digital supply chains	Integration of AI, blockchain, IoT, and digital measurement, reporting, and verification systems to enhance traceability, responsible sourcing of raw materials, and critical minerals, and compliance with environmental, social, and governance (ESG) standards across digital value chains.	**MEDIUM** Emission reductions come from upstream supply chain improvements and lower risk of environmental harm from mining.	Differentiation based on traceability. Firms with robust ESG practices gain better market access.	Compliance with international ESG and due diligence standards enables developing countries to shift from exporting raw, low-value materials to becoming verified, sustainable suppliers in global electronics and ICT value chains. Projected global demand for critical minerals is expected to rise by up to 500% by 2050, creating new trade opportunities for resource-rich countries to move up value chains through local processing to higher value-added activities. Opportunities include producing intermediate goods such as precursors and batteries, and developing regional value chains for final products like electric vehicles and smartphones.	Digital and institutional capacity gaps limit compliance with complex ESG and traceability rules. Extraction of critical minerals—e.g. cobalt, lithium, and rare earth elements—intensifies ecological pressure and undermines sustainable development. Weak safeguards and unsustainable mining practices heighten risks of biodiversity loss, environmental harm, and community conflict. Continued dependence on unprocessed raw material exports exposes economies to commodity price volatility and missed value addition opportunities. Limited domestic processing capacity prevents many developing countries from capturing greater value from digitalization, leaving them reliant on imports of high-value digital equipment and services.
Digital circular economy and e-waste management	Designing devices for reuse and recyclability, scaling e-waste recycling infrastructure, and formalizing cross-border trade in secondary raw materials.	**HIGH** Formal recycling and circularity reduce demand for virgin materials and energy-intensive production.	Reduced import demand for raw and processed materials. Increased import demand for secondary materials. Emphasis on durability, modularity, and recyclability in product design standards.	Establishing regional hubs for repair, refurbishment, and recycling can generate trade opportunities through the export of recycled materials and components. Rising demand for sustainable packaging, reverse logistics, and modern recycling systems can generate green jobs and expand participation in circular value chains. Scaling refurbishment and recycling industries allows countries to capture more value locally while advancing resource-efficient and low-carbon development pathways.	Informal sector dominance, regulatory gaps, and lack of circular design ecosystems constrain scaling-up. Weak waste management infrastructure and hazardous informal practices expose communities to severe health and environmental risks. Limited formal collection and recovery mechanisms leave most e-waste unmanaged.

Table 1. (continued)

Lever	Description	Impact on Emissions	Impact on Trade	Trade-Related Opportunities	Trade-Related Challenges
Digital circular economy and e-waste management				Circular e-commerce and digital tools for e-waste recovery can create pathways for green jobs, regional recycling hubs, and higher value addition in digital value chains.	
Resilient and climate-compatible digital infrastructure	Adapting infrastructure to withstand climate risks (e.g. floods, heatwaves) and expanding decentralized models (e.g. satellite, mesh, and solar-powered networks.	**LOW** Ensures continuity of low-impact digital services (e.g. e-health, digital finance, smart energy) and reduces reliance on carbon-intensive alternatives like paper systems or in-person logistics at climate hazard times.	Trade continuity during climate shocks. Enhanced cross-border service reliability and resilience.	Rising demand for resilient digital infrastructure generates new opportunities for trade diversification and sustained economic activity, particularly in landlocked and climate-vulnerable countries. Investment in climate-proofed networks and decentralized models can secure service continuity, reduce economic disruptions, and strengthen the resilience of regional trade systems. Green industrialization, underpinned by clean energy and low-carbon manufacturing, enables developing countries to move up digital and green value chains and capture broader economic gains from net-zero transitions.	Adaptation to climate risks is often under-prioritized in national adaptation and ICT strategies, leaving digital infrastructure exposed to floods, heatwaves, and other shocks. Limited access to concessional and blended finance—including climate finance, private–public–philanthropic sources, and debt-for-climate instruments—further constrains investment in climate-proofed infrastructure and decentralized models, exacerbating exposure in climate-vulnerable regions.

Source: Authors' elaboration based on OECD (2022; 2025), Calvino et al. (2025), Energy News Network (2025), UNCTAD (2024), IEA (2024), IMF et al. (2024), World Bank and ITU (2024), McDonald and Ballan (2023), World Bank (2023), and Syamsuri & Pakartipangi (2025).

5. Priorities for Developing Country Policy Engagement and International Cooperation for Digital and Green Transitions

The digital transformation presents developing countries with a strategic opportunity to align trade and trade-related policies with climate action and climate-resilient development. Without deliberate interventions, the digital sector's rapid growth risks reinforcing structural inequalities and generating new environmental pressures. As noted, placing the digital sector on a net zero pathway can be particularly challenging for developing countries. High upfront costs, long investment cycles, weak grids, financing gaps, and limited access to affordable green technologies remain significant barriers to catching up with the digital and green transitions and participating equally in international coordination and policy efforts.

The following priorities identify key areas for policy action, engagement, and international cooperation to support digital and green transitions in developing countries.[25]

25. This section draws on analyses by OECD (2022; 2023; 2025), UNCTAD (2024), World Bank (2023; 2024), WTO (2021), ITU (2020b), IEA (2024), McDonald and Ballan (2023), World Bank and ITU (2024), Calvino et al. (2025), and Muench et al. (2022).

Direct Subsidies, Public Procurement, and Finance Towards Greening Digital Infrastructure

In countries where digital infrastructure is expanding rapidly, directing subsidies, public procurement, and financial support towards renewable-powered ICT infrastructure—including data centres, telecom networks, and cloud services—should form part of a wider package for greening digital development. Targeted financial incentives such as tax credits, accelerated depreciation, grants, or VAT relief can lower affordability barriers and reduce the cost of renewable-powered cloud services, efficient data transmission, and low-emission logistics. These instruments not only reduce emissions but also create jobs in renewables and stimulate investment in sustainable digital infrastructure. Redirecting fossil fuel subsidies can form part of this package, alongside green public procurement to stimulate demand for energy-efficient ICT equipment and remanufactured devices. Blended and concessional finance remain essential to de-risk early-stage projects and attract private capital into resilient, low-carbon connectivity.

Use Carbon Tax to Advance Sustainable Digital Infrastructure and Operations

Well-designed carbon tax frameworks can support environmentally sustainable digital transformation by allocating revenues to renewable integration and efficiency upgrades in ICT infrastructure—including data centres, networks, and cloud services. Domestic carbon tax revenues can be allocated to instruments such as grants, concessional loans, or dedicated green infrastructure funds, with eligibility explicitly contingent on verifiable reductions in emissions and energy use. This approach both incentivizes emissions reductions and ensures accountability in the use of public funds.

Carbon taxes also provide a continuous price signal for innovation and R&D, encouraging investment in energy-efficient digital infrastructure, circular economy solutions, and smart grids. Conditioning fiscal incentives and financing on independently verified emissions reductions and energy savings—through transparent measurement, reporting, and verification systems—reinforces accountability and motivates firms to adopt cleaner technologies to qualify for benefits. Digital tools, including AI-enabled analytics and blockchain-based registries, can further enhance transparency, compliance, and public trust in carbon tax systems. While the application of carbon taxes to digital infrastructure remains limited in developing countries, piloting such approaches could help mobilize domestic revenues, reduce investment risks, and align digital expansion with climate goals.

Provide Investment Incentives and Foster Public–Private Partnerships

For many developing countries, high upfront costs and financing risks remain key constraints to achieving environmentally sustainable digital infrastructure. Targeted investment incentives, such as tax breaks, concessional loans, and streamlined permitting, can help lower barriers to investment and accelerate the deployment of energy-efficient data centres, telecom networks, and digital services. Complementary measures are also needed to strengthen domestic digital ecosystems. Expanding access to venture capital and government-backed financing facilities, including incubation and acceleration programmes, can scale up sustainable digital solutions.

Public–private partnerships can reinforce these efforts by embedding climate performance criteria on emissions, resilience, and circularity, while ensuring that fiscal support is tied to independently verifiable outcomes. Blended finance and green bonds are particularly impactful in higher-risk markets, where they can attract long-term private investment. They help prioritize projects that expand access, create jobs, and strengthen climate resilience in underserved regions. Examples from countries demonstrate how targeted reforms, when aligned with investment incentives, can mobilize private capital for renewable-powered digital infrastructure. In South Africa, for example, energy market liberalization enabled Amazon to power its data centres with renewable energy through one of the country's largest solar farms. Similarly, in Brazil, distributed generation regulation catalysed a shift by telecom operators towards clean energy.

Cooperate On Greening Digital Trade Agreements

Digital trade agreements typically lack environmental provisions or pathways for sustainable digitalization. For developing countries, integrating such provisions should be gradual, voluntary, and non-prescriptive—leveraging pilot initiatives and best-endeavour commitments that reflect national circumstances and preserve policy space. Cooperation can focus on harmonizing measurement, reporting, and verification of ICT emissions and circularity, enabling transparent disclosures across borders. Mutual recognition of green ICT standards can further reduce technical barriers, expand access to circular digital markets, and allow developing economies to benefit without undue burden.

At the same time, it is important to ensure that cooperation does not simply transplant models from advanced economies that may not fit the distinct economic structures, institutional capacities, or national priorities of developing countries. Targeted international support—financial, technical, and institutional—is essential to help developing countries meet global standards, advance circular economy initiatives, and participate effectively in a sustainable digital economy.

Ensure Affordable Access to Green and Circular Technologies and Secure Technology Co-Development or Transfer

Ensuring affordable access to green and circular technologies is essential for developing countries to participate fully in the digital and green transition. Trade policy can help address barriers by lowering tariffs and streamlining customs for renewable energy inputs, efficiency equipment, and ICT repair technologies—reducing costs and encouraging uptake. Open standards and voluntary licensing for climate-smart digital tools can broaden access and allow local providers to adapt solutions to domestic needs. Partnerships with developed economies should be equity-based, supporting domestic value addition through technology transfer, skills development, and knowledge-sharing. Equally important, South–South partnerships can drive technology co-development tailored to regional contexts, while targeted technical assistance can complement these efforts by strengthening skills, infrastructure, and institutional capacity in developing countries. Concessional finance and guarantees remain vital to scale affordable, durable, and repairable ICT products, ensuring that digital transformation is both environmentally sustainable and inclusive.

Upgrade Standards to Meet and Conform With International Practices

Aligning ICT standards with global benchmarks on energy efficiency, eco-design, repairability, and emissions accounting can enhance interoperability and expand market access. This, in turn, facilitates cross-border digital trade, lowers compliance costs, strengthens participation in circular value chains, and supports sustainable investment. To avoid overburdening firms in developing countries, this process should remain gradual and flexible, with transitional pathways that reflect local capacity and cost constraints. Upgrading standards must also be accompanied by robust conformity assessment systems—including accredited laboratories, certification services, and targeted support for MSMEs—to reduce compliance burdens and help firms demonstrate credibility in global markets.

Regional and international cooperation on harmonization and mutual recognition is essential to prevent new trade barriers, lower costs, and ensure that developing economies can fully participate in circular and sustainable digital trade. Developing common standards and classifications for hazardous wastes, non-hazardous wastes, and goods destined for reuse or repair could help to avoid misclassification and facilitate circular trade flows. Compliance with the Basel Convention's 2025 amendments, which require prior informed consent for all e-waste shipments, will be central to ensuring environmentally sound waste management. Capacity development is particularly important to equip governments, regulators, and border agencies to meet these requirements and harmonize technical and environmental standards across borders.

Foster Assistance to Measure and Report Carbon Emissions and Footprint Across Value Chains

Developing robust systems to measure, report, and verify GHG emissions, energy use, and material footprints across digital value chains—data centres, networks, device manufacturing, and cloud services—is essential for greening digital trade. However, in many developing countries compliance with evolving international standards for carbon accounting and environmental measurement is constrained by high costs, weak institutional capacity, and technical skill gaps. Additional challenges stem from uneven levels of development and limited enforcement capacity, as well as the absence of established international standards for emerging technologies.

Targeted capacity development and financial support are therefore essential. Governments, regulators, and firms require digital tools and internationally recognized methodologies for emissions accounting, eco-design, circularity, and conformity assessment. Such measures enhance the credibility, comparability, and cost-effectiveness of reporting. Stronger international cooperation is needed to build local expertise, promote knowledge sharing, and ensure interoperable measurement, reporting, and verification systems across borders, while advancing new standards in areas where gaps remain.

Data-driven decision making must be prioritized. Reliable data on the ICT sector's GHG emissions and energy consumption is essential for governments to set realistic targets, monitor progress, and make informed policy decisions. Strengthening collaboration among ICT, energy, and environmental regulators can optimize joint efforts to address the sector's carbon footprint.

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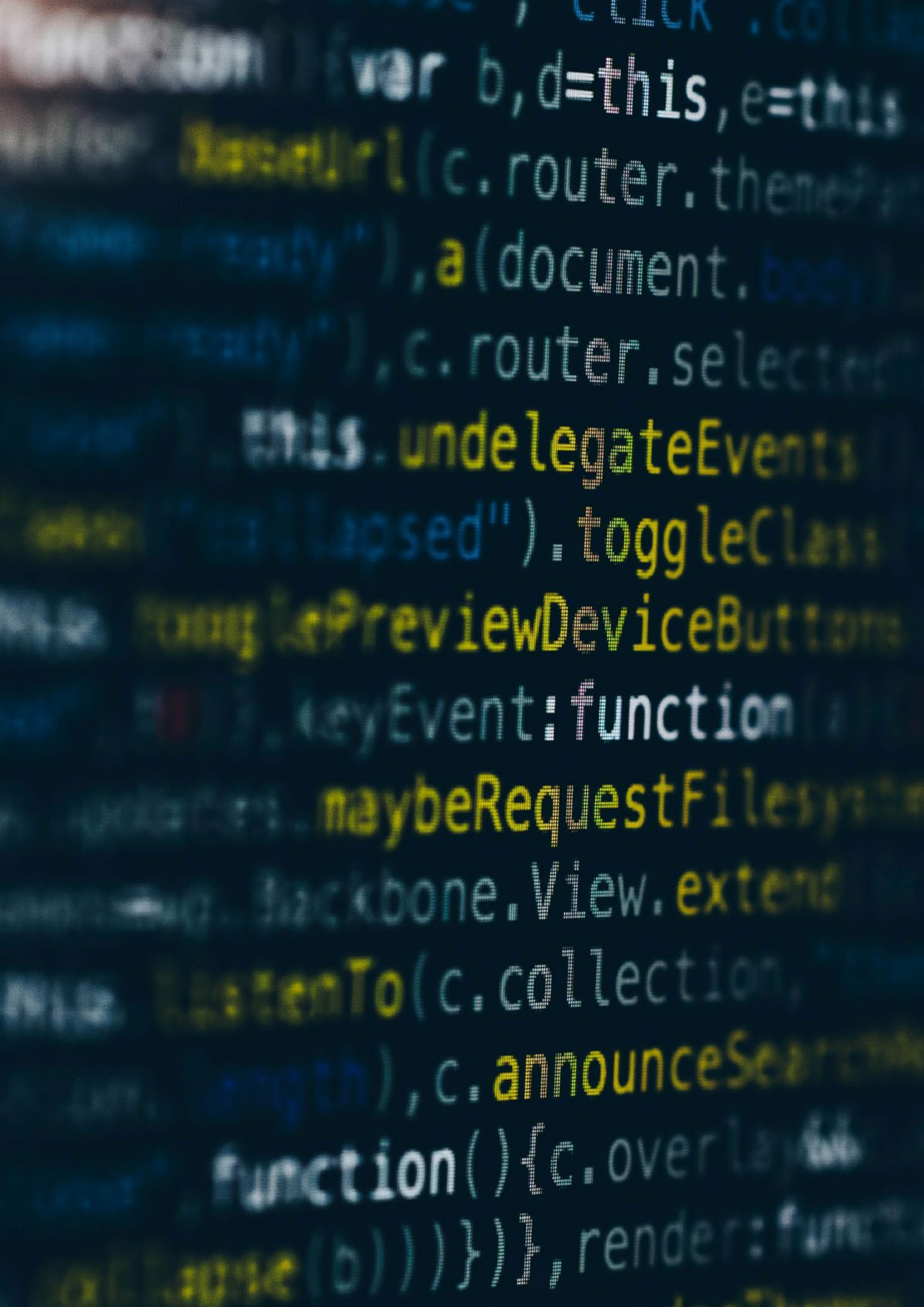
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ENERGY TRANSITION

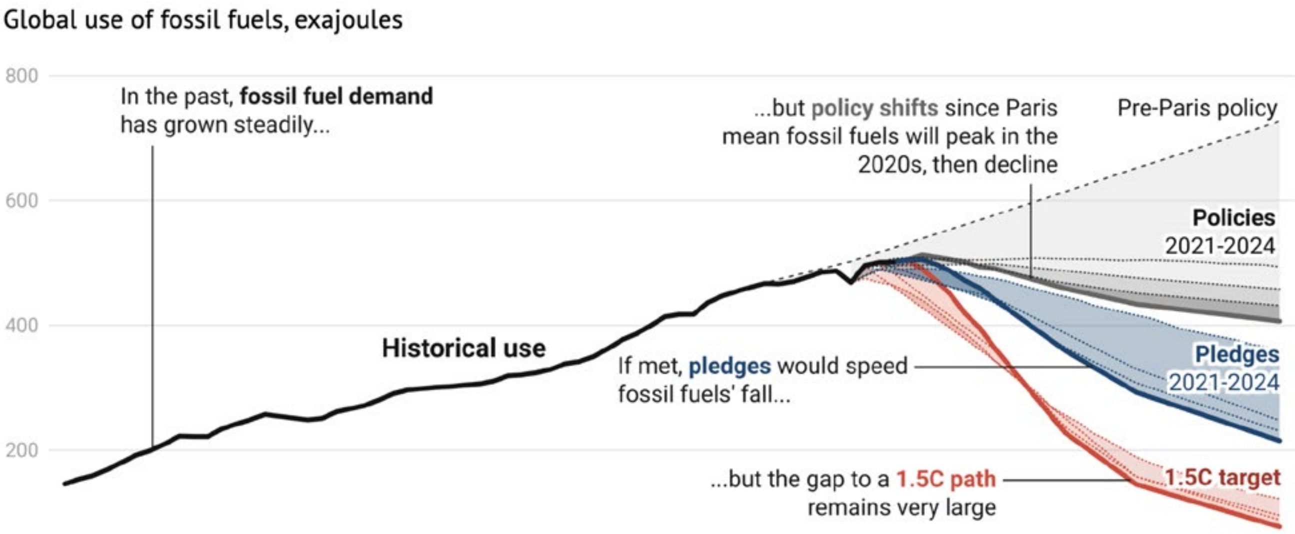
Beth Walker and Ellie Belton

1. Energy Transition and the Trade, Climate, and Sustainable Development Nexus

Preventing climate change requires a radical phase down of the production and use of oil, gas, and coal. Fossil fuels contribute over 90% of global carbon emissions through their extraction, processing, and burning—fuelling warmer temperatures and more frequent extreme weather events globally (Global Carbon Project, n.d.; UNEP, 2023a). Meeting the Paris Agreement goal of limiting global warming to 1.5°C requires the world to halve global greenhouse gas emissions by 2030 and reach net zero emissions by 2050. To achieve this, fossil fuels must drop from 80% to 16% of the global energy supply, according to the International Energy Agency's (IEA) Net Zero Emissions by 2050 Scenario (NZE Scenario).[21]

The energy transition is happening faster than expected, driven by a mixture of economic, energy security, and climate concerns. This is marked by record growth in renewable energy and the electrification of transport and heating sectors. Energy efficiency improvements in key sectors such as artificial intelligence (AI) chips are also rapidly transforming global energy demand. Major economies, such as the European Union (EU) and China, are reducing demand faster than planned.[22] However, current efforts are insufficient to avoid severe climate impacts. Global carbon emissions from the energy sector are still on the rise and the effects are on full display in proliferating heatwaves, forest fires, and floods. Without faster reductions in fossil fuel use, global temperatures are on track to rise by 2.4°C by the end of the century. Governments must implement stronger policies to accelerate the decline in fossil fuel use.

Figure 1. The IEA predicts demand for all fossil fuels will peak by 2030 under current policies—but stronger action is needed to reduce oil and gas use after that



Source: Carbon Brief (2024) using IEA (2024c) data.

26. Around one-third of the remaining fossil fuel demand in the NZE Scenario is fully abated, around half is used as a feedstock or in other non-energy use, and the remainder is offset by direct air capture, negative emissions from bioenergy, or other forms of carbon removal (IEA, 2023b).
27. EU demand for oil and gas is set to fall 80% by 2050, depriving many of their key suppliers with government revenue and foreign exchange (Walker et al., 2024).

This shift will reshape geopolitics and transform global trade and finance flows. International power dynamics will change as fossil fuel exporters lose market and political leverage. The growth in renewable energy supply chains and critical minerals will shift trade flows and countries' competitive advantages in the energy sector. Global trading practices will also transform, given fossil fuels are currently used in 99% of international shipping and form 40% of maritime cargo (by volume) (IEA, n.d.; Barnard, 2023). And trade is likely to become more regionalized, affecting the structure and resilience of international supply chains.

These changes are likely to have a disproportionate impact on emerging markets and developing economies. While advanced economies are rapidly progressing in the clean energy transition, many emerging markets and developing countries still face significant barriers, including high capital costs, project risks, and high levels of debt. Meeting global goals will require the massive scale up of finance and support to developing countries with growing energy demands and countries dependent on fossil fuel rents for their development.

Trade policy has a vital role to play in delivering the energy transition in developing countries. This includes reducing the cost of clean technologies, driving private capital into green industries, and addressing market distortions which hinder decarbonization efforts. International coordination is essential to reduce trade-related tensions and ensure developing country interests are supported. Initiatives such as the EU's Carbon Border Adjustment Mechanism, methane regulations, and the United States (US) Inflation Reduction Act highlight the potential for trade policies to accelerate change—but they will also create new legal challenges and provoke wider tensions if they are not carefully designed and coordinated.

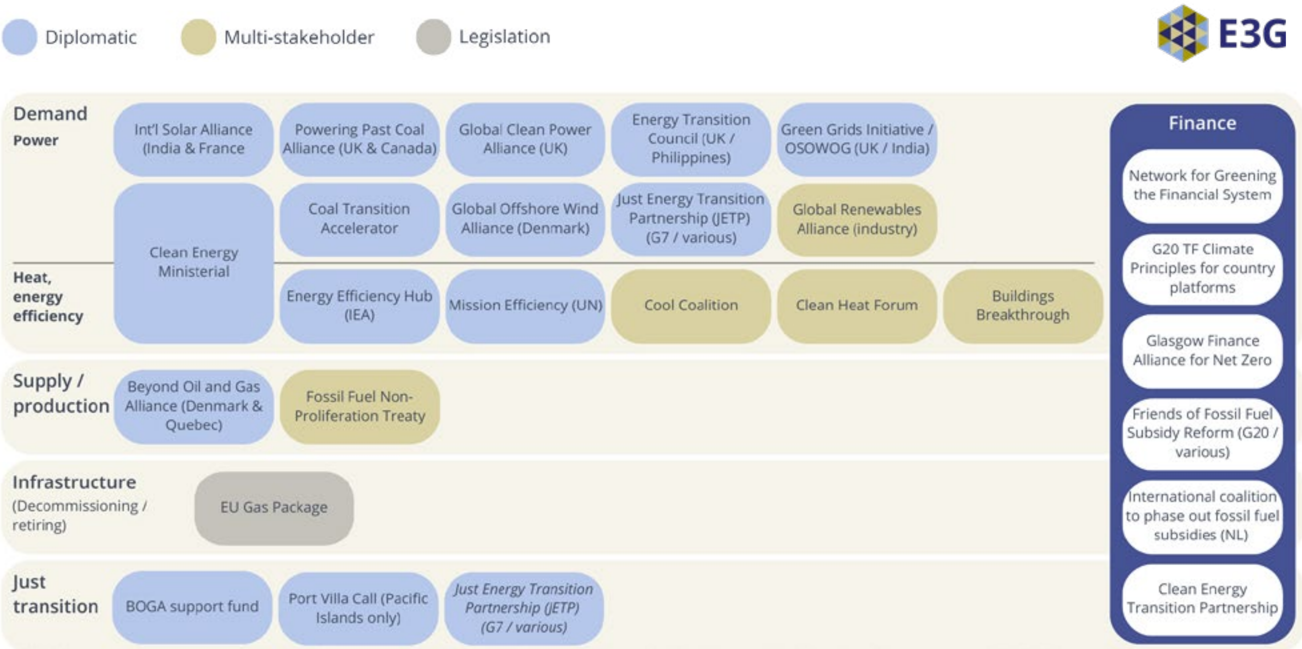
2. Climate Action and Impact Scenarios in the Energy Transition

Global agreements and multilateral action have played a role in driving the transition. For decades, climate policies and international agreements have focused on reducing demand for fossil fuels through energy efficiency and building out renewable energy capacity. The 2023 United Nations Climate Change Conference (COP28) marked a turning point, when almost 200 governments committed to transition away from fossil fuels in energy systems "in an orderly, just and equitable manner" as part of the first Global Stocktake (known as the "UAE Consensus"). This agreement also includes commitments to triple renewables capacity and double energy efficiency by 2030, phase down unabated coal power, and phase out inefficient fossil fuel subsidies. However, challenges remain. Failure to agree how to take these commitments forward at COP29 in 2024 demonstrates the challenges of driving progress amid growing geopolitical tensions.

While diplomatic coalitions, such as the Powering Past Coal Alliance and Energy Transition Council, champion coal phase-out in key geographies, global action on gas and oil demand reduction is yet to emerge. The Danish-led Beyond Oil & Gas Alliance (BOGA) is mobilizing national and subnational champions to lead the phase out of production but is yet to recruit a major producer. The Fossil Fuel Non-Proliferation Treaty Initiative is calling for a binding global treaty to end the use and production of fossil fuels to complement the Paris Agreement.[28] Major producing countries still fail to acknowledge that the transition away from fossil fuels is about reducing production as much as reducing demand.

28. The group spearheaded by Tuvalu and Vanuatu have the support of 14 governments and over 100 sub-government level constituencies and institutions such as the European Parliament and World Health Organization (Fossil Fuel Non-Proliferation Treaty Initiative, n.d.).

Figure 2. Existing diplomatic initiatives to deliver the transition away from fossil fuels



Source: Adapted from Walker and Pastukhova (2024).

The G7 and G20 countries, as the group of the world's largest economies, should take a leadership role on stronger commitments to the wider transition away from fossil fuels, including ending public finance and fossil fuel subsidies.

The G7 have mainly focused on phasing out coal power generation and decarbonizing power systems. In April 2023, the G7 climate, energy, and environment ministers agreed to "accelerate the phase-out of unabated fossil fuels" so as to achieve net zero in energy systems by 2050 at the latest.[29] While countries have made progress on decarbonizing power, delivery risks remain, particularly in reducing reliance on gas. The G20 failed to mention the transition away from fossil fuels at the G20 Leaders' Summit in Brazil in 2024. The job now falls to the G7 Canada Presidency and G20 South Africa presidency to drive progress in 2025.

International public finance for fossil fuels is declining but is still far greater than support for clean energy.[30] Commitments to end new direct public finance support for overseas fossil fuel projects, such as export finance, have successfully cut finance up to two-thirds (by up to $15bn/year).[31] The challenge is now to repeat this with all international and domestic financing for fossil fuels, and ensure the finance goes to scaling up clean power, rather than being displaced into gas expansion as is happening at present. Meanwhile, fossil fuel subsidies remain at record levels, with public support from G20 countries almost doubling between 2019 and 2022 (Laan et al., 2023).

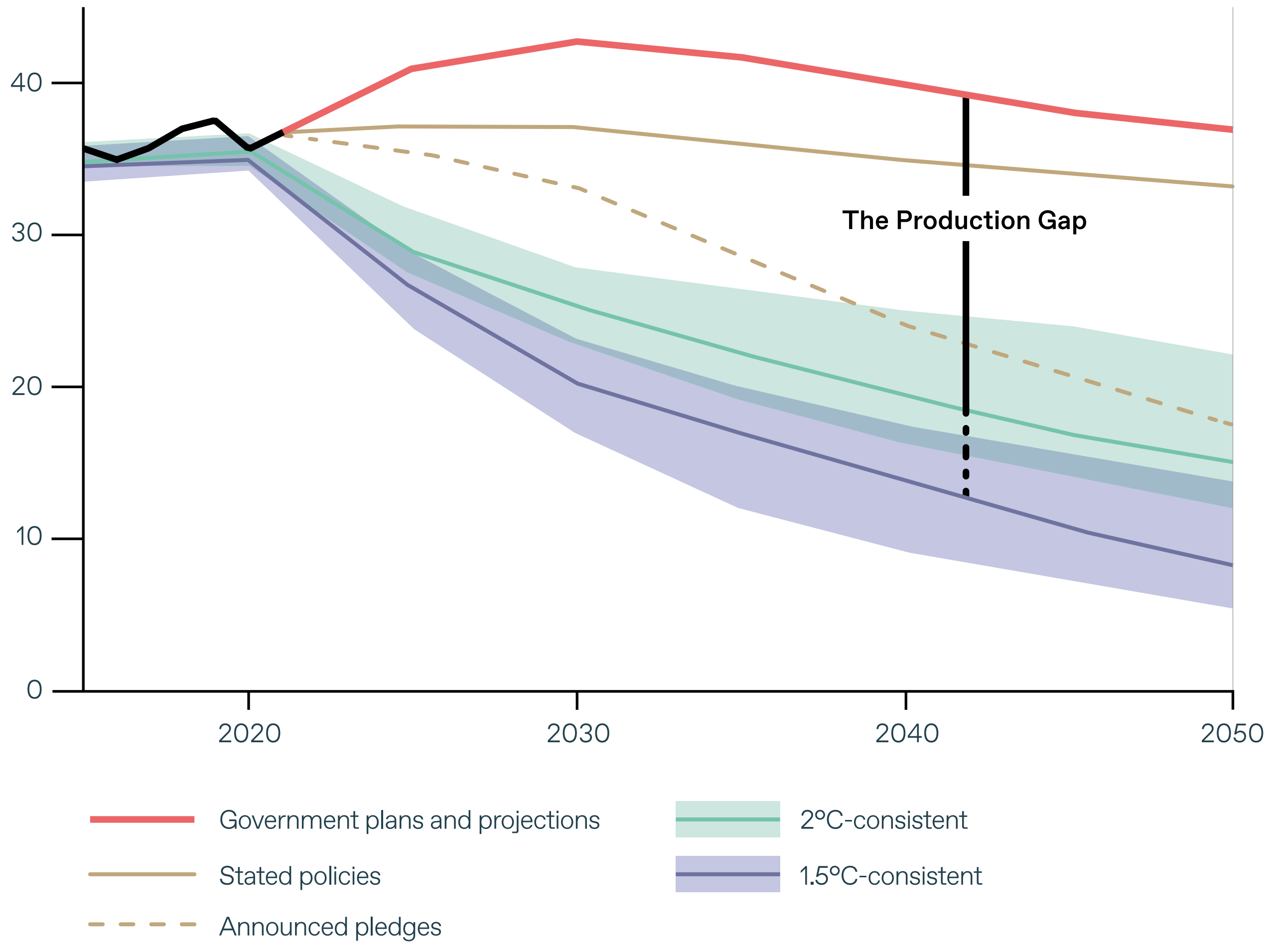
29. In 2024, G7 countries went further to reaffirm COP28 agreements and committed to "operationalizing our contribution to the global transition away from fossil fuels in energy systems, through the development and implementation of domestic plans, policies and actions [...] and call on others, particularly other major economies, to act likewise" (G7, 2024).
30. G20 and multilateral development bank public finance fell from $96 billion in 2013 to $43 billion in 2022 (Public Finance for Energy Database, n.d.).
31. In 2021, 34 countries and five institutions committed to end public international fossil fuel financing including Canada, Germany, Italy, the US, United Kingdom (UK), and France (CETP, n.d.). A similar pledge was then adopted by G7 leaders in 2022 (Harvey, 2022). If countries uphold the set of commitments made as part of the Clean Energy Transition Partnership (CETP) and the G7, fossil fuel finance will fall by a further 71% by the end of 2050 (Oil Change International, 2024).

While the world now invests almost twice as much in clean energy as it does in fossil fuels, emerging market and developing economies outside China account for only around 15% of global clean energy spending. Upstream oil and gas investment is expected to increase by 7% in 2024 to reach $570 billion, following a 9% rise in 2023. This is being led by Middle East and Asian national oil companies (IEA, 2024b). According to the IEA, meeting COP28 energy goals requires a doubling of global clean energy investment by 2030 and a quadrupling in the developing world outside China.

Despite growing momentum, the world is not on track to limit warming to 1.5°C. While demand is set to peak in this decade, fossil fuel production plans far exceed the limits of a net-zero pathway, with countries like the US, Norway, and Gulf states leading oil and gas expansion. To meet global climate goals, governments must urgently scale up actions to phase out production as well as demand.

Figure 3. Governments plan to produce around 110% more fossil fuels in 2030 than the 1.5°C temperature limit allows

Global fossil fuel production, gigatonnes CO2 equivalent per year



Source: UNEP (2023c).

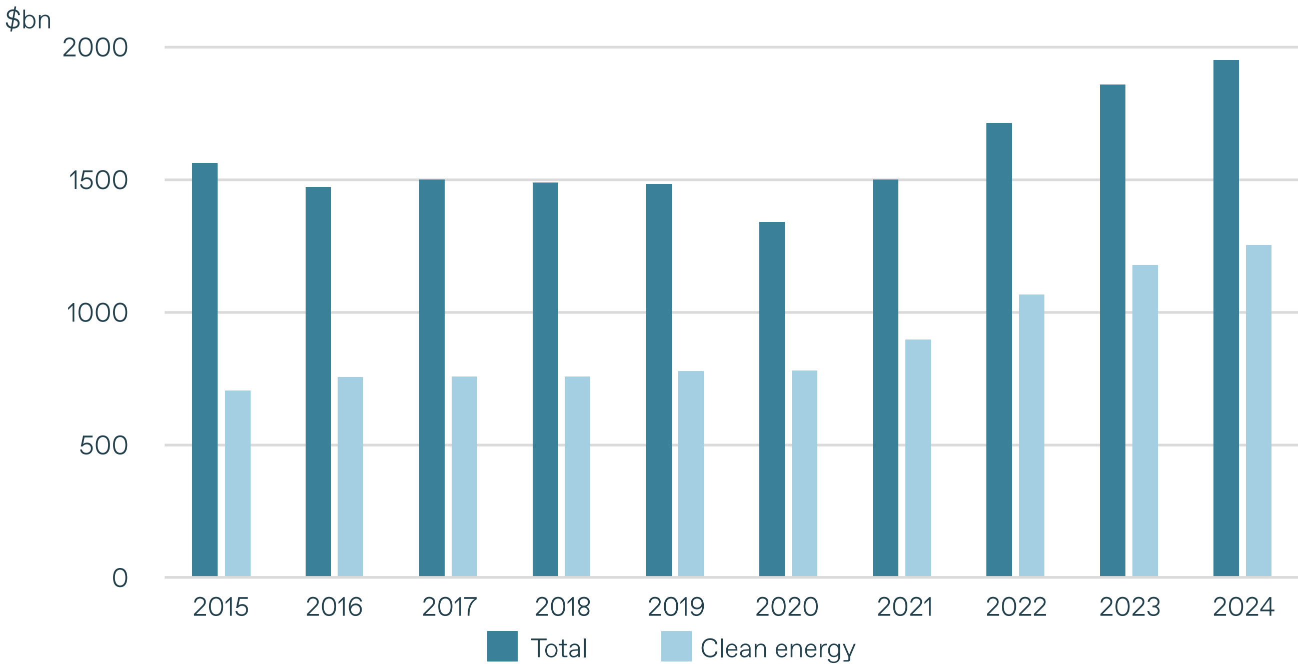
3. Trade Dynamics and Policy Solutions for the Energy Transition

Global trade has a vital role to play in driving action on climate change and transitioning the energy sector, and this is particularly true for heavily traded commodities that will be required to accelerate the global transition away from fossil fuels. As a result, evolving international trade dynamics will be a driving force behind both the pace and direction of the global energy transition over the coming decades. This means that trade policies can and should be used proactively as a tool to drive better outcomes in the energy sector, including for developing countries who face the greatest transition risk.

The Impact of Climate Change and the Energy Transition on Global Trade in Fossil Fuels

The global energy transition is already disrupting international trade patterns. As countries implement policies to transition their economies away from fossil fuel production and towards sources of renewable energy, the comparative advantage of trading partners will shift in response. Mitigation policies focused on reducing greenhouse gas emissions will also directly impact demand for fossil fuels globally, with international commitments to phase out fossil fuels expected to further decrease demand over the coming decades. Under the IEA's NZE Scenario, the share of global energy demand provided by fossil fuel imports could decrease from approximately 25% today to less than 10% in 2050 (IEA, 2024a). This would have significant implications for developing countries, many of which are currently heavily dependent on fossil fuel exports. As the transition accelerates, they will be forced to diversify their economies in order to seek alternative sources of income and will face tough competition from advanced economies who are already taking advantage of the growing renewable energy market globally.

Figure 4. Global investment in clean energy is rapidly growing and constitutes an increasing share of total global energy investment



Source: IEA (2024b).

As global demand for renewable energy continues to grow, countries that are already leading in the production of clean power technologies will benefit. The IEA (2023e) estimates that more than 90% of the increase in clean energy investment since 2021 has taken place in advanced economies and China, and that China will deploy almost four times more renewable energy than the EU (the second largest growth market) in the period from 2023–2028 (IEA, 2023c). This increasing capacity is also restructuring cross-border supply chains, as China continues to dominate the global market by exporting clean energy technologies to its trading partners at low cost. In the first half of 2023, exports of solar panels from China grew by 34% compared to the same period in 2022, with over half of these solar modules exported to Europe (Ember, 2023). This is also true for the production and processing of critical raw materials, which are key inputs used to manufacture renewable energy technologies. China currently accounts for approximately 60% of global production and 85% of global processing capacity of the minerals needed for the energy transition, including lithium, cobalt, and graphite (Logan, 2024). Building local refining and manufacturing capacities in these commodities will be essential for other developing economies to foster industrial growth opportunities and ensure equitable participation in global supply chains as the energy transition accelerates.

While the energy transition can create new trading opportunities for developing economies who are rich in renewable energy potential, many of these countries will struggle to capitalize on those opportunities due to significant investment barriers. Developing and emerging economies currently account for around two-thirds of the world's population but only one-fifth of global clean energy investment, which makes it difficult for those with higher fossil fuel dependencies to transition their economies and take advantage of changing global trade patterns (IEA, 2021). To take Africa as an example, it is estimated that the continent could have reserves of hydro, wind, and solar energy accounting for 13%, 18%, and 30% respectively of the world's total supply (GEIDCO, 2024). But despite having such significant potential for clean energy development, Africa only attracts around 2% of global renewable energy investment (IEA, 2023a). Building local value addition and driving capital investment into developing countries in Africa and around the world will therefore be crucial to help diversify clean energy supply chains and support the resilience of the global trading system going forward.

Evolving Global Trade Trends and Geopolitical Dynamics

The regionalization of global trade flows is also being accelerated by the transition to clean energy. Renewable energy sources are typically locally produced and consumed, which means that the demand for long-distance transportation of energy is likely to decrease over time. For example, approximately 85% of the global production of hydrogen gas is currently consumed on-site, largely due to the cost and logistical difficulty of transporting it over large distances (IRENA, 2022). As the clean energy transition accelerates, the IEA (2024a) estimates that the share of electricity in the global energy mix will increase from 20% in 2023 to over 40% in 2050, of which nearly 80% will be generated by domestic renewable sources like solar, wind, and hydropower. This shift will reduce the demand for fleets of oil tanks and LNG (liquefied natural gas) vessels, and instead require greater investment into energy infrastructure for the transportation of renewables, such as electricity grids that are equipped to handle variable energy supply. It is also likely to encourage countries to build industrial value in domestically or regionally sourced renewable energy sources, further reducing their reliance on international trade in the energy sector. These changes will significantly impact low-income and lower-middle-income countries, the vast majority of which are currently net importers of wind and solar components (Bridle, 2021). These economies often lack the necessary resources to rapidly diversify their export base or develop alternative growth opportunities, meaning that they will also struggle to benefit from new global trade opportunities in higher-value clean technologies.

Rising protectionism globally is likely to increase the cost of the global energy transition and create an unequal playing field for developing economies. For example, in the electric vehicle (EV) industry, the use of industrial subsidies and other non-market practices in China has allowed Chinese EV manufacturers to produce vehicles at a 30–40% cost advantage versus European carmakers (Bailey, 2024). This has led to the EU, US and other G7 economies implementing tariffs of up to 100% on Chinese EVs in order to protect domestic industries from unfair competition (Aylett, 2024). As countries increasingly seek to leverage trade policy for economic security purposes, these additional tariff fees will increase the cost of manufacturing low-carbon technologies and could eventually result in higher prices for consumers. Further tariffs expected under the new US administration could exacerbate this problem, particularly if they are met with retaliatory tariffs from third countries.[32] The green industrial subsidies provided under the US Inflation Reduction Act also demonstrate the impact of protectionist policies in boosting domestic production in developed economies, with US solar module manufacturing capacity quadrupling between 2022–2024 (Wood Mackenzie, 2024). These interventions could not only increase the cost of the global energy transition, but the increased competition will also make it even more difficult for developing economies to transition their economies away from fossil fuels.

This growing tension is already starting to disrupt international cooperation on climate action and the wider energy transition, with developing countries expressing concern across multilateral venues that trade policy measures place an unequal burden on their economies, and therefore on their domestic energy transitions. At COP29, the BASIC group of countries (Brazil, India, China, and South Africa) tabled a proposal to discuss "climate-change related unilateral restrictive trade measures," citing concerns over disproportionate adverse effects on developing countries and increasing the cost of worldwide climate action (UNFCCC, 2024). Better international diplomacy and cooperative action is urgently needed to ensure fairer outcomes in this space, including calls for countries introducing carbon border adjustment mechanisms, such as the EU and UK, to provide increased support for developing countries to implement the required regulation. As the global energy transition accelerates, greater care must be taken to ensure that the production of clean technologies does not become a race to the bottom, and that developing countries receive adequate provisions to adjust and grow their green economies.

Trade Policy Solutions to Drive the Energy Transition

Given the role of trade in the energy transition, trade policy solutions should play an important part in addressing the challenges set out above. The following section evaluates a number of areas in which trade policy is being used to help drive the clean energy transition.

1. Market Access to Boost Clean Energy Competition

Rebalancing tariffs in line with climate ambition can help to make renewable energy solutions more accessible, affordable, and competitive in the global market. This is particularly important for developing countries, where tariff rates are typically much higher (UK Board of Trade, 2021). When assessing an illustrative list of environmental goods, the World Trade Organization (WTO) found that tariffs range from around 1.4% in high-income countries to 7.3% in low-income countries, with non-tariff measures following a similar pattern (WTO, 2022). Reducing these tariffs on renewable energy products could help to make them more affordable and therefore increase their uptake in developing economies, particularly if used alongside other taxation or subsidy policies to make fossil fuel alternatives more expensive in comparison.

Recent efforts to liberalize tariffs on environmental goods at the multilateral level have struggled, with the collapse of WTO negotiations on the Environmental Goods Agreement in 2016 (Benson, 2023). This was partly due to the difficulty in defining what constitutes an environmental good, with trade rules failing to properly distinguish

32. Research from the London School of Economics suggests that initial tariff proposals by President Trump could reduce gross domestic product (GDP) in both the US and China by approximately 0.6% (Saussay, 2024).

between fossil fuel and renewable energy products. However, some progress has been achieved at the plurilateral level, with the recently signed Agreement on Climate Change, Trade and Sustainability (ACCTS) between New Zealand, Costa Rica, Iceland, and Switzerland committing to eliminate tariffs on over 300 environmental goods, including products required in the energy transition, such as wind turbine structures and raw materials used to manufacture solar panels (ACCTS, 2024).

However, trade liberalization alone will not necessarily generate environmental benefit without the accompanying support of other policies targeted at increasing the competitiveness of local economies. This could include introducing measures to reduce investment costs, providing servicing of renewable energy production technologies, and stimulating the creation of new markets both at the national and global level (UNCTAD, 2022). Increasing market access through reducing tariff barriers is therefore just one part of a wider solution.

2. Alignment of Technical Standards

Non-tariff measures such as emissions-based standards and product requirements are becoming an increasingly important factor in the market access conditions for renewable energy products. Between 2000–2017, energy efficiency regulations reduced energy-related emissions by 12% annually, with over 1,180 energy efficiency regulations notified to the WTO by over 70 members since 2009 (WTO, 2023). These notifications include developing countries, such as Indonesia's Minimum Energy Performance Standard for energy-utilizing household products (2021) and the Draft East Africa Standard (2022), which aims to harmonize energy performance requirements for lighting products across East African economies.

However, the divergence of standards across different jurisdictions can create trade barriers for exporters of clean energy products, particularly in developing countries where resources for regulatory compliance are often limited. Analysis by the Organisation for Economic Co-operation and Development (OECD) finds that divergent national standards constitute the main technical restriction for foreign investors in the wind energy sector—for example, South Africa has strict grid connection regulations which diverge from international norms, Brazil faces different environmental rules across different regions, and China requires all producers to meet strict test certifications (OECD, 2015).

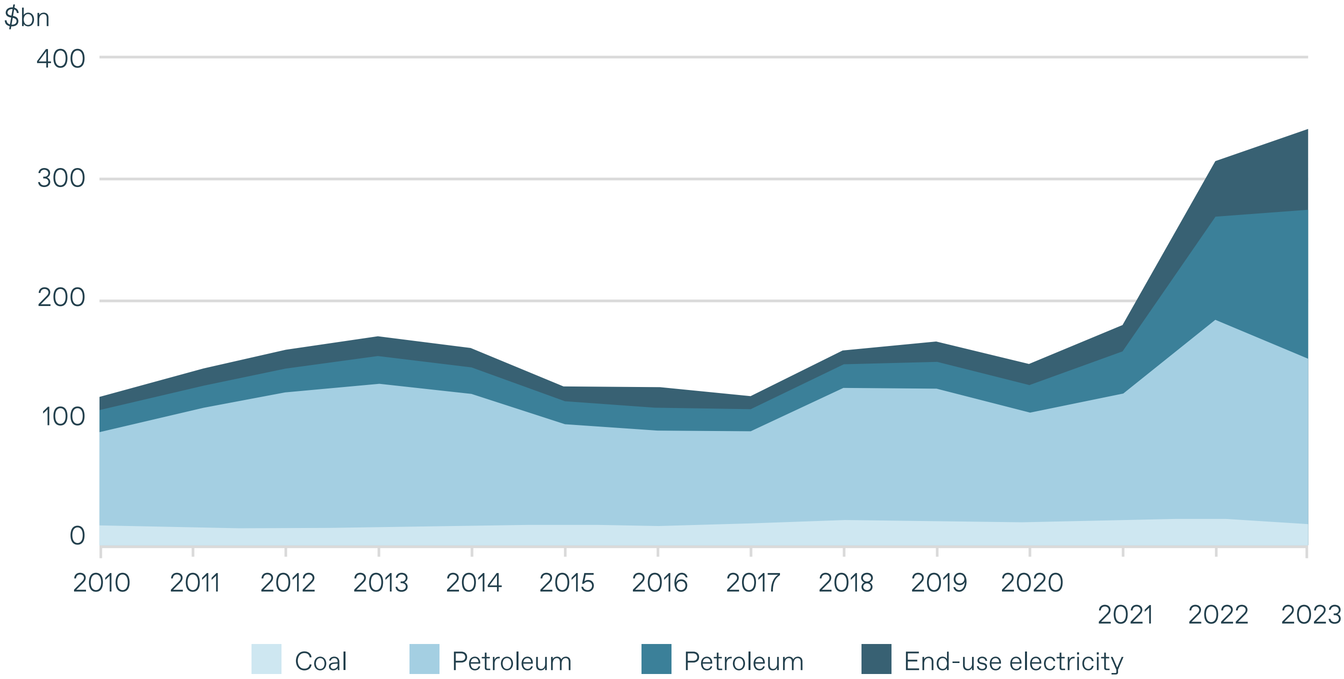
Full harmonization of these standards is unlikely, due to the high level of economic integration that would be required. But closer alignment of technical standards could still help to streamline market entry and foster innovation in clean technologies, helping countries attract foreign investment and develop economies of scale. The WTO Agreement on Technical Barriers to Trade aims to ensure that standards and regulations do not create unnecessary obstacles to trade, including through transparency provisions and offering a space for members to discuss different approaches (Asmelash, 2023). Other international bodies such as the International Organization for Standardization (ISO) are taking action to improve harmonization and interoperability across clean energy value chains, such as the new technical specification for hydrogen technologies unveiled at COP28 in 2023 European Hydrogen Observatory, 2023).

Going forward, greater international cooperation should be prioritized to coordinate standard-setting efforts globally, promote mutual recognition of conformity assessment procedures, and adopt common methodologies for calculating emissions intensity. This will help to grow clean energy markets globally by providing greater certainty for investors.

3. Fossil Fuel Subsidy Reform

Subsidies are one of the most controversial areas at the intersection of trade policy and the energy transition. Despite increasing commitments to phase out fossil fuels, national governments continue to subsidize their production, leading to counterintuitive outcomes. In 2022, public financial flows to fossil fuel production in G20 countries reached a record $1.4 trillion, more than double the amount in 2019 (Laan et al., 2023). When accounting for implicit as well as explicit subsidies, total subsidization of fossil fuels at the global level surges to $7 trillion, equivalent to 7.1% of global GDP (IMF, 2023). Fossil fuel consumption subsidies also increased following the recent energy crisis and are mainly concentrated in emerging markets and developing economies, with more than half of these in fossil fuel exporting economies (IEA, 2022).

Figure 5. Government spending on fossil fuels continues to rise globally



Notes: Data records government spending that provides a benefit or preference for the production or consumption of fossil fuels over alternatives, including budgetary transfers and tax expenditures.

Source: OECD (n.d.) Companion to the Inventory of Support Measures for Fossil Fuels (data updated November 2024).

The subsidization of fossil fuels runs counter to the energy transition, and while global investment into clean energy is also rising, greater subsidization of renewables is needed to accelerate the transition. Well-designed subsidies can counterbalance market failures by accounting for the positive externalities associated with renewable energy production and consumption, as well as levelling the playing field which has historically favoured fossil fuels.

One challenge here is that subsidies are currently assessed under the WTO's Agreement on Subsidies and Countervailing Measures based on their trade-distorting impact, rather than on their environmental consequences. And since renewable energy subsidies tend to have greater adverse effects on international trade flows than fossil fuel subsidies, this makes renewable energy subsidies more vulnerable to legal challenges (Asmelash, 2015). Proposals to address this include introducing a "green box" to categorize subsidies that are sustainability-enhancing and would therefore be deemed permissible under WTO rules (Cima & Esty, 2024), but these ideas are yet to receive political buy-in and would require the consensus of all WTO members.

Another challenge for climate-resilient development is that even if renewable energy subsidies were to be legitimized under trade law, many developing countries would still have limited financial capacity to use them—either due to a lack of public funding or high debt burdens. Solving the legal dilemma would therefore mainly stand to benefit richer countries who can already afford to subsidize their domestic green industries and could therefore exacerbate the inequality created by the global subsidies race.

Despite these challenges, some progress is being made to level the playing field at the bilateral, plurilateral, and multilateral level. The WTO's Fossil Fuel Subsidy Reform initiative encourages members to share information to advance discussions on phasing out fossil fuel subsidies, and some novel trade agreements such as the EU-New Zealand Free Trade Agreement and the ACCTS (see below) include dedicated provisions committing to fossil fuel subsidies reform (European Commission). The Glasgow Climate Pact, signed at COP26, called for the first time for nations to phase down inefficient subsidies for fossil fuels as part of the commitment to reduce coal power (UNFCCC, 2021). And a new coalition formed at COP28 to tackle fossil fuel subsidy reform also commits to greater transparency, evaluation of international agreements, and developing national strategies to phase out fossil fuel subsidization (IISD, 2023).

These initiatives could set a precedent for future international agreements to tackle barriers to fossil fuel subsidy reform and serve as an important step towards redesigning global subsidy rules to align with the goals of the energy transition.

Box 1. Plurilateral Progress: Fossil Fuel Subsidy Reform in the ACCTS

The Agreement on Climate Change, Trade and Sustainability, signed by Costa Rica, Iceland, New Zealand, and Switzerland in 2024, is the first legally binding trade agreement to regulate the use of fossil fuel subsidies by its members.

The agreement recognizes that "fossil fuel subsidies constitute a major obstacle to tackling climate change and undermine sustainable development," with Article 1.1. setting a clear objective of "disciplining and eliminating harmful fossil fuel subsidies in order to mitigate their adverse impact on the environment."

The ACCTS sets out a broad definition of what constitutes a subsidy for fossil fuels—including tax exemptions—and prohibits all types of coal subsidies. Members are also required to make public disclosures of their use of fossil fuel subsidies going forward to help improve transparency and monitoring.

However, the agreement still contains some carve-outs, including exemptions for certain subsidies for oil and gas production, as well as those protected by other international agreements (including aviation, maritime, and fishing).

Overall, the ACCTS serves as a positive signal of progress in this space, but there remains further room for improvement—demonstrating the complexity of reforming the global subsidies landscape, even among the most ambitious countries.

4. Border Carbon Adjustments

Border carbon adjustments (BCAs) are trade policy measures designed to address the risk of carbon leakage by imposing a charge on goods imported from jurisdictions with lower environmental standards. The EU's Carbon Border Adjustment Mechanism (CBAM) is currently in a pilot phase and includes some energy-related products (hydrogen and electricity) within its scope. While the initial goal of CBAM is to avoid carbon leakage, the EU hopes that this measure will also incentivize the decarbonization of carbon-intensive goods in other jurisdictions (European Commission, 2025).

A problem with BCAs is that they are likely to have a disproportionate impact on developing economies due to the regulatory burden and associated costs of complying with the reporting requirements. Studies also suggest that developing economies, particularly countries in Africa, will face the greatest GDP impact from an EU CBAM, due to the emissions-intensity of their exports and because the EU is often a major export destination (African Climate Foundation & London School of Economics and Political Science, 2023). These increased costs will have ramifications for the wider energy transition in developing countries, particularly if those countries have limited opportunities to diversify their export base. This could be exacerbated as additional jurisdictions implement BCAs over the coming years.

One solution to this could be to recycle revenues collected under BCA schemes to support the energy transition in developing economies. But these revenues alone would not be anywhere near sufficient to cover the significant costs of decarbonizing the energy sector.

5. Investment Treaties and Investor-State Dispute Settlement

Investment treaties and the dispute settlement mechanisms within them pose significant barriers to climate action by protecting overseas fossil fuel investments. There are more than 2,500 investment treaties in force globally, most of which protect fossil fuel investments via investor-State dispute settlement (ISDS) provisions, and middle- and low-income countries are currently vulnerable to approximately 60% of ISDS claims (Lee & Dilworth, 2024). ISDS provisions allow investors to bring claims against governments if their business interests are undermined by government policy, including climate measures which might harm fossil fuel projects—meaning that they are directly at odds with global efforts to achieve the energy transition.

There has been a growing trend away from ISDS in recent years, with several countries deciding to withdraw from the Energy Charter Treaty (ECT) since 2022, denouncing its incompatibility with climate ambition.[33] Countries including New Zealand and Australia hold a principled position against the inclusion of ISDS in their new free trade agreements, and the United States and Canada have removed ISDS in the United States-Mexico-Canada Agreement (USMCA). There are also multilateral discussions underway at the OECD to better align investment treaties with climate goals, which could include carve-outs of fossil fuel related investments from the coverage of treaties or excluding climate mitigation policies from ISDS claims.

However, there remains a lack of shared understanding around the need to reform investment treaties in relation to climate action, and there is not yet a consensus on which solution to pursue. Without further reform, these provisions risk delaying the global energy transition by increasing the cost of climate action and encouraging investment in fossil fuels.

33. The ECT is the investment treaty which protects the largest amount of greenhouse gas emissions—over 300 million tonnes in CO2 equivalent annually (Dilworth & Lee, 2024).

4. Opportunities and Challenges for Developing Countries

The energy transition could present new trading opportunities for developing countries, but significant barriers exist which will make it challenging to capitalize on them. Due to their reserves of key raw materials like critical minerals, and their abundant supply of renewable energy resources for solar and wind power, many developing countries should have a natural comparative advantage in the low-carbon economy. But difficulty in attracting international investment, particularly when competing with heavily subsidized green industries globally, mean that many of these benefits may not be realized without intervention and support from advanced economies.

For fossil fuel dependent economies, their source of export revenue will narrow as the global energy transition accelerates. Developing countries that are dependent on fossil fuel rents (which can constitute up to 80–90% of government revenue in extreme cases) face the risk of economic, social, and political instability if they do not diversify their economies as global demand for fossil fuels declines. While wealthier producers have the financial and institutional capacity to respond to these risks, vulnerable producers will need additional support from international partners. As the transition takes hold, high-cost, high-emissions producers will face a revenue squeeze and are likely to drop out of the market first (IEA, 2023d; Walker et al., 2024c).

Emerging energy producers will need to explore alternative development pathways as carbon-intensive growth proves a less viable and increasingly risky option. While many developing countries still regard oil and gas expansion as the only viable development pathway, the overwhelming evidence from countries such as Mozambique demonstrates that this is not the case. A decade after gas was discovered, the promised economic growth never materialized, with international oil and gas companies securing early returns and the Mozambique government left with all the risk and growing debt (Gaventa, 2021).[34] Countries that are just beginning to develop fossil fuel reserves, will be left with stranded assets and heavy debts as the market for their exports dries up. Some countries like Kenya are trying to industrialize through green growth, but for many developing countries the financial and structural barriers are currently insurmountable.

If developing countries dependent on fossil fuel imports fail to reduce their demand quickly enough, they will also face price spikes and market volatility. High fossil fuel price volatility is most damaging to low- and middle-income countries (with a total population of 6.7 million, or 85% of the world's population) who have limited hard currency reserves, are exposed to global interest rates, and cannot invest quickly in low-carbon technology. This volatility could have wide-ranging macroeconomic consequences for developing economies, further diminishing their ability to capitalize on the energy transition.

Developing countries with reserves of critical raw materials will also require support to integrate into higher-value components of the energy supply chain. Africa holds approximately 19% of the global mineral reserves needed for the EV industry, but African economies will miss out on economic opportunities from these assets unless they are able to develop domestic capacity to carry out the processing of the minerals that they are mining (UNCTAD, 2023). Poor mining practices, resulting from improper infrastructure in the extraction of critical minerals, must also be managed to avoid long-term environmental damages from the manufacturing of clean energy technologies.

Developed economies will need to provide technical and financial support to developing countries at scale so they can benefit from the global energy transition. While the goal to mobilize $300 billion a year for

34. External debt as a proportion of GDP trebled following the initial gas discovery, reaching 93% in 2021.70% of the population still lack access to energy and Mozambicans are now on average poorer than they were a decade ago. In contrast to International Monetary Fund (IMF) projections in 2016 for 34% GDP growth in 2021, actual economic growth in Mozambique was around 2.5%.

developing countries agreed at COP29 is woefully inadequate, countries also committed to developing a "roadmap" to scale up finance to reach $1.3 trillion by COP30 in 2025, including through reform of institutions like the World Bank and IMF. Regular monitoring and stocktakes of the scale, quality, and regional distribution of public and private climate financing will provide a new motor for change over the next decade (Mabey, 2024). Aid for Trade can also be leveraged to help reduce trade barriers and encourage private sector participation in the energy transition. Approximately 30% of all aid for trade commitments with climate objectives were related to the energy sector between 2011–2021, totalling $60 billion—but this level of support remains insufficient in the context of total climate finance flows (WTO, 2024).

5. Priorities for an Equitable Energy Transition

The energy transition offers unprecedented opportunities for global development, but greater international coordination on proactive and inclusive policy solutions will be required to ensure that the benefits of the transition are fairly distributed. Developing countries must play a central role in shaping the future of clean energy trade, in order to achieve global climate resilience and sustainable growth.

Diplomatic coalitions are starting to emerge to drive the energy transition forward. But these alliances must improve cooperation and focus on delivery in developing countries, particularly in neglected areas such as production phase-out and support for affected communities and workers. Through these alliances, developed and developing countries should foster long-term strategic partnerships. International governance and careful long-term planning will also be essential to managing the macroeconomic effects of the energy transition and ensure that the benefits reach beyond major economies in an equitable way.

Developed countries must demonstrate leadership by:

1. *Phasing out fossil fuels*: International efforts must accelerate the transition away from the use and production of fossil fuels, while mitigating the negative impacts on fossil fuel dependent economies. Developed countries must take decisive action at home to end consumption and production of fossil fuels as part of their national transition plans. Greater dialogue and cooperation between consumer and producer countries will also help to minimize the impacts of price shocks and market volatility on developing countries as the global energy transition accelerates.

2. *Building renewable energy value chains*: The energy transition will require the restructuring of global supply chains, creating new opportunities to capture economic value at all stages of production, from mining through to manufacturing. Investment into local mineral refining and processing practices in developing countries will be critical to ensuring equitable participating in these value chains. Developed countries should also seek to build new clean energy partnerships with developing countries to capture mutual benefits, helping to increase their green industrial capacity and open up new export opportunities in growing global demand centres.

3. *Reforming trade policies*: Global trade rules must be updated to drive renewable energy adoption, provide new export opportunities for developing economies, and address trade distortions which create harmful incentives. Reforming fossil fuel subsidy rules will be a key step in modernizing WTO law, but developed economies must also address the unequal impact of unilateral trade measures (such as BCAs) by reducing the compliance burden on developing economies. Channelling BCA revenues into climate finance could also support global decarbonization objectives.

4. *Technical and financial support for developing economies*: Developed countries must foster stronger cooperation with developing countries to provide technical and financial support at scale. This includes injecting fresh political capital into the existing toolbox, including Just Energy Transition Partnerships and country platforms. Governments should also explore new ways to mobilize public-private support to finance the energy transition, including new economy-wide partnerships and progress on global tax and debt reform. Climate finance, including aid for trade tools, must prioritize capacity building, infrastructure development, and economic diversification to enable developing economies to take advantage of the transition.

The global energy transition will fundamentally alter trade flows and reshape the geopolitical power dynamics of the future. The success of this transition in driving transformational outcomes will hinge on the inclusion of developing countries in clean energy supply chains, proactive reform of global trade rules to maximize positive externalities, and a significant increase in international investment for clean energy infrastructure and technologies.

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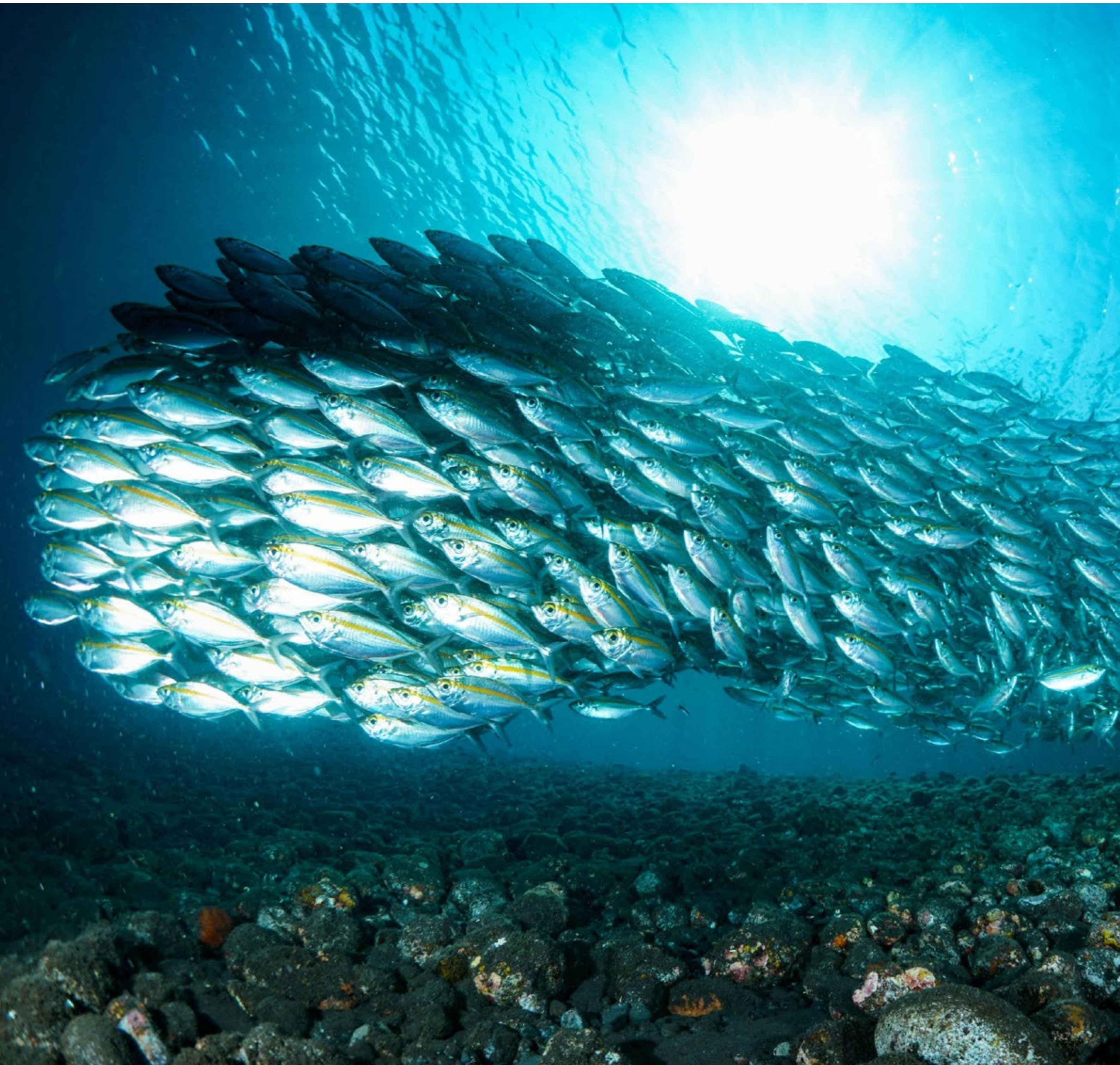
FISHERIES

U. Rashid Sumaila



1. Fisheries in the Nexus of Climate Change, Trade, and Sustainable Development

The fisheries sector is deeply interlinked with the climate crisis in two significant ways. Overfishing exacerbates the climate crisis by depleting fish stocks, leading to excessive carbon dioxide (CO2) emissions, and disrupting aquatic ecosystems, which reduces their resilience to climate change (Sumaila & Tai, 2020). Also, removing large fish through overfishing diminishes marine life's capacity to sequester carbon, further intensifying atmospheric CO2 levels (Lee et al., 2023). On the other hand, the climate crisis negatively impacts fish stocks through rising sea temperatures (Cheung et al., 2021), ocean acidification (Figuerola et al., 2021), deoxygenation (Grégoire et al., 2021; Kim et al., 2023), and sea level rise. These changes cause fish species to migrate, perish, and/or face habitat destruction, such as coral bleaching and loss of coastal nurseries like mangroves. What is more, increased frequency of extreme weather events disrupts fishing activities, damages infrastructure, and causes abrupt environmental changes, further harming fish populations (Mendenhall et al., 2020).

Fisheries are a crucial source of protein and essential nutrients, particularly in developing countries where alternative animal protein is often scarce or expensive. Rich in omega-3 fatty acids, vitamins, and minerals, fish contributes significantly to improved nutrition and food security (Srinivasan et al., 2010; Omukoto et al., 2024). The sector also provides direct and indirect employment to millions of people, from fishers to processors and traders, making it a vital source of livelihood for coastal communities (The & Sumaila, 2013; Scherrer et al., 2024). Additionally, fisheries play a key role in national economies through exports, trade, and revenue generation (Bellmann et al., 2016), with sustainable management enhancing economic stability and growth. Climate action and resilience efforts are essential to protecting fish stocks and ensuring these benefits continue into the distant future, thereby achieving "Infinity Fish" (Sumaila, 2021).

Sustainable and inclusive trade in the fisheries sector could be a long term cornerstone of the global economy, providing essential food, livelihoods, and economic growth into the distant future. Fish trade currently generates significant revenue, especially for large ocean states (or small island developing states – SIDS), with export earnings contributing to national incomes and economic development. Sustainable and equitable fisheries trade would support millions of jobs across the value chain, from fishing to processing, transportation, and marketing. It could also ensure the availability of fish in regions where local production falls short, bolstering global food security. By enabling access to a diverse range of fish species, trade enhances dietary diversity and nutritional intake. For developing countries, access to international markets that are fair and equitable is crucial for the growth of their fisheries sector, offering opportunities for economic expansion through sustainable fair trade agreements and export markets. Moreover, such trade can stimulate investment into value-added processing and supply chain infrastructure, increasing the economic value of fishery products and facilitating the transfer of technology and best practices in sustainable fisheries management from developed to developing countries.

All of the above potential contribution are being threatened by climate change (Sumaila et al., 2011). Greenhouse gas (GHG) emissions, resulting in climate change and its impacts are projected to increase by 2050 and beyond (2). Rising sea temperatures are already disrupting fish distributions and productivity. This is projected to worsen by 2050, leading to increased fishing effort and fuel consumption, which could elevate GHG emissions (Chen et al., 2023). As climate change affects ocean ecosystems, aquaculture is expected to expand, potentially increasing emissions from energy-intensive farming practices and feed production. With these changes, transitioning to low-emission technologies, more sustainable practices, and improving energy efficiency in the fisheries sector will be critical to offset potential emission increases. Projections indicated that the fisheries sector, including both wild fisheries and aquaculture, could contribute a larger share of GHG emissions without significant efforts to decarbonize (Chen et al., 2023). These trends underscore the need for urgent adaptation and mitigation strategies in fisheries management (Cheung et al., 2019; Sumaila et al., 2020; FAO, 2022; Allan et al., 2023).

If global warming exceeds 2°C, the fisheries sector could see a significant rise in GHG emissions due to increased fishing effort, the use of more energy-intensive equipment, and expanded aquaculture. Without mitigation, emissions from fisheries could surpass current levels by up to 30–40% due to these factors, especially as fishing grounds shift and production costs rise. Current sea surface temperatures have increased by about 1.2°C since pre-industrial times. Projections suggest an additional increase of 0.6°C to 3.0°C by 2100, depending on emission scenarios. The warming of oceans has far-reaching impacts on marine ecosystems and fish stock availability. Global fish catches are expected to decline by 3–25% by 2050, with regional impacts varying widely. Tropical developing regions, which contribute relatively less C02 per capita and where fisheries are vital for livelihoods, are projected to experience the most severe reductions due to changing ocean conditions and shifts in species distributions (FAO, 2022; Allan et al., 2023).

Climate actions aimed at resilient supply chains—such as investments in climate-proof infrastructure, species diversification, and sustainable trade policies—can stabilize fish trade and reduce dependency on vulnerable stocks. Integrating carbon pricing and reforming subsidies can incentivize low-carbon practices and support sustainable fisheries. Fair and equitable trade agreements that incorporate climate goals would promote alignment with international targets, while regional agreements can enhance cooperation in managing shared fish stocks and implementing climate strategies. Furthermore, such trade can drive innovation in climate-smart technologies (Santos et al., 2024), such as aquaculture and climate-resilient species, and facilitate global data sharing and research on climate adaptation.

2. Climate Action and Impact Scenarios in the Fisheries Sector

We provide in Table 1 a summary of the global actions proposed overtime to mitigate climate change, help people and nature to adapt, and compensate countries and people of the Global South for the loss and damage they have suffered as a result of climate change. The commitments highlighted in the table demonstrates the global recognition of the need to integrate climate change mitigation, adaptation, and loss and damage considerations into the sustainable and equitable management of the fisheries sector. These efforts are supported by international commitments such as the Paris Agreement, national adaptation plans, and frameworks provided by organizations such as the Food and Agriculture Organization of the United Nations (FAO) and the Intergovernmental Panel on Climate Change (IPCC). Ensuring sustainable fisheries practices, enhancing resilience, and providing support for affected communities are crucial components of these global strategies.

Looking across continents, we see some similarities and differences in the approach to mitigating climate change in the fisheries sector. Across all continents, energy-efficient practices and renewable energy are being adopted in aquaculture as part of mitigation strategies, while comprehensive adaptation strategies are developed to address shifts in fish stock distribution, extreme weather events, and habitat restoration. National adaptation plans (NAPs) and regional frameworks are crucial in guiding these efforts. Similarly, both the Global South and Global North are actively engaged in mitigating and adapting to climate change impacts on the fisheries sector, with similarities including the adoption of energy-efficient practices, renewable energy in aquaculture, and the development of comprehensive adaptation plans aligned with international commitments like the Paris Agreement. However, there are notable differences. The Global North generally has more resources and advanced technologies for implementing these strategies, with robust policy frameworks and funding mechanisms, for example the EU Common Fisheries Policy and the European Maritime and Fisheries Fund. In contrast, the Global South often relies more on regional initiatives and international support, focusing on livelihood resilience and food security due to a higher dependency on fisheries, while the Global North emphasizes technological innovation and sustainable practices.

Comparing key current and expected climate impacts on fisheries across continents, we find that all continents, particularly those on or close to the equator, are experiencing significant shifts in fish stock distribution due to ocean warming, ocean acidification affecting shellfish and coral reefs, and extreme weather events causing damage to fisheries infrastructure. Sea level rise is resulting in habitat loss and coastal erosion, while deoxygenation and the loss of marine biodiversity are common threats impacting coastal communities dependent on fisheries. However, because the Global South is more severely affected by poverty and food insecurity, the climate crisis harms it more. Each continent also faces unique regional characteristics and challenges. For example, the Humboldt Current with its special features is located in South America while the Gulf of Guinea and the Coral Triangle are in Africa and Asia, respectively. Furthermore, the Global North generally has more robust infrastructure, resources, and policies to adapt to these changes, compared to regions in the Global South.

Table 1. Proposed Global Climate Actions, Their Objectives, and Relevance to Fisheries

Agreement	Action	Objective	Relevance to fisheries	Implementation
Paris Agreement (2015)	Mitigation	Limit Global temperatures rise to well below 2°C above pre-industrial levels, with efforts to limit the increase to 1.5° C.	Reducing greenhouse gas emissions can mitigate ocean warming and acidification, which directly impact marine ecosystems and fish populations.	Countries' nationally determined contributions (NDCs) may include specific measures to reduce emissions from the fisheries sector, such as improving fuel efficiency in fishing vessels and reducing carbon footprints in fish processing.
Kyoto Protocol (1997)	Mitigation	Legally binding targets for developed countries to reduce greenhouse gas emissions.	Legally binding targets for developed countries to reduce greenhouse gas emissions.	Invest in low-carbon technologies and practices within the fisheries sector.
Paris Agreement (2015)	Adaptation	Enhance adaptive capacity, strengthen resilience, and reduce vulnerability to climate change.	Supports the development of National adaptation plans (NAPs) that include specific strategies for the fisheries sector to cope with changing ocean conditions, such as shifts in fish stock distribution and breeding patterns.	Encourages the sharing of knowledge and best practices for adapting to climate impacts in fisheries, such as sustainable aquaculture and ecosystem-based management approaches.
Cancun Adaptation Framework (2010)	Adaptation	Enhance action on adaptation, particularly for developing countries.	Facilitates the development of adaptation strategies tailored to the fisheries sector, ensuring food security and livelihoods for communities dependent on fisheries.	Promotes capacity-building, technology transfer, and financial support for adaptation initiatives in the fisheries sector.
Nairobi Work Programme (2005)	Adaptation	Improve understanding and assessment of impacts, vulnerability, and adaptation to climate change.	Provides a platform for sharing information on the impacts of climate change on fisheries and successful adaptation strategies.	Supports research and data collection on climate impacts on marine ecosystems and fisheries, aiding in the development of evidence-based adaptation policies.
Paris Agreement (2015)	Loss and Damage	Recognize the importance of averting, minimizing, and addressing loss and damage associated with the adverse effects of climate change.	Promotes international cooperation and support for addressing loss and damage in the fisheries sector, ensuring resilience and sustainable livelihoods.	Encourages the development of comprehensive risk management strategies and insurance schemes to protect fisheries and fishing communities from climate-induced losses.
Warsaw International Mechanism for Loss and Damage (WIM) (2013)	Loss and Damage	Address loss and damage associated with the impacts of climate change, including extreme and slow onset events.	Acknowledges the need to address economic and non-economic losses in the fisheries sector, such as loss of fish stocks, degradation of marine habitats, and impacts on fisherfolk communities.	Facilitates support for affected communities, including financial assistance, technology transfer, and capacity building to manage and recover from climate-related losses.

Source: Author's elaboration.

3. Trade-Related Trends and Dynamics in the Fisheries Sector

Trade Impacts Resulting From the Physical Impacts of Climate Change

Climate action policies and measures have significant implications for trade trends in fisheries, affecting everything from fish stock availability and distribution in aquatic ecosystems and regulatory environments to economic, social, and technological aspects. While these policies can pose challenges, they also offer opportunities for enhancing sustainability, resilience, and competitiveness in global fisheries trade. Adapting to and mitigating climate impacts will require coordinated efforts and innovative solutions to ensure the long-term viability and prosperity of the fisheries sector in the face of a changing climate.

The climate crisis is already impacting trade in fisheries in many ways, and thereby is influencing every aspect of the industry from biological productivity to economic stability. Biological and ecological impacts include shifts in fish stock distribution because warming oceans are causing many fish species to migrate towards cooler waters, often towards the poles or into deeper waters. This shift can disrupt traditional fishing grounds and lead to changes in the availability of certain species in different regions (Lee et al., 2023; Sumaila et al., 2019; Lam et al., 2020). Changes in water temperature and chemistry can alter the composition of fish communities, impacting biodiversity and the balance of marine ecosystems. This can lead to the decline of some commercially important species and the rise of others thereby altering trade flows. Climate change is also fuelling ocean acidification, which particularly affects shellfish by weakening their shells (Figuerola et al., 2021).

Since the climate crisis affects the biophysics of aquatic ecosystems, it is obvious that it affects life in the ocean including fish populations, and therefore the economic activities that depend on them (Tai et al., 2019). Economic impacts as a result of the climate crisis include changes in the supply and demand and therefore the price of fish (Sumaila et al., 2019), as well as altering migration patterns and changes in fish stock productivity and supply variability. This unpredictability can affect market stability and pricing, influencing international trade. Also, regions that lose their traditional fish stocks, in particular in the Global South, would face economic hardships (Sumaila et al., 2019; Lam et al., 2020), while new fishing opportunities in other regions, for example the Arctic (Tai et al., 2019), may arise, shifting global trade dynamics. These shifts lead to changes in costs and investments in the fisheries sector (Sumaila et al., 2019), as fishers and related industries may face increased operational costs due to the need for climate adaptation measures, including investing in new fishing technologies, changing fishing practices, or relocating operations (Chen et al., 2023). On the other hand, the climate crisis may open new investment opportunities, at least in the short term, in sustainable fishing practices, aquaculture, and climate-resilient infrastructure, which can create novel economic opportunities and trade advantages. Unfortunately, these opportunities would accrue mainly to countries in the Global North, where the highest per capita CO2 emissions are generated, creating inequality reinforcing dynamics where there is a mismatch between those who fuel the climate crises the most (i.e. the Global North) and those who pay the highest price imposed by the crisis—the Global South (Sumaila et al., 2019; Lam et al., 2020).

Closely related to the economic impacts are the social and community effects on indigenous and coastal people worldwide due to the climate crisis. Climate impacts such as sea-level rise and extreme weather events can displace fishing communities, disrupting traditional livelihoods and trade networks, and efforts to diversify livelihoods to reduce dependency on fisheries can lead to changes in labour availability and skills within the fishing industry, impacting trade.

Trade Impacts of Policy Measures Implemented to Address or Respond to Climate Change

The evolving trade-related trends and policies in the fisheries sector are reshaping competitive advantages, trade relations, development strategies, and geostrategic dynamics. Trade relations are being influenced by new standards and regulations, with the potential for both cooperation and conflict. Development strategies are aligning more closely with global sustainability goals, while geostrategic tensions over resources are likely to persist. Addressing these diverse impacts requires a cooperative approach that balances economic, environmental, and social considerations.

Current trends in regulations and sustainability standards include (i) increasing use of eco-labels (e.g. Ocean Wise) to promote sustainable fishing practices and provide market incentives and (ii) national and international regulations requiring adherence to sustainability standards for fisheries management (e.g. EU Common Fisheries Policy). In terms of prospective trends, future policies may enforce stricter sustainability criteria, impacting market access for fisheries that do not comply. Also, efforts to harmonize sustainability standards globally to facilitate trade and ensure uniformity in environmental protection could be accelerated.

The climate crisis is already creating regulatory and policy impacts. It could lead to stricter sustainability standards and regulations aimed at mitigating climate impacts, which can increase compliance costs for fishing enterprises but they can also open access to markets that demand sustainably sourced products. What is more, countries that fail to implement effective climate and sustainability measures may face trade barriers or sanctions from markets with stringent environmental requirements, affecting their export capabilities. An example of this is the EU's carding system via its European Commission Regulation (EC) No. 1005/2008, which aims to incentivize fish and fish product exporters to the EU to act to reduce illegal, unreported, and unregulated (IUU) fishing in their waters (Sumaila, 2019). Several authors have studied the likely impact of climate change on the management of shared fish stocks and they have all concluded that climate change would affect international cooperative fisheries management agreements aimed at sustainable management of shared fish stocks—for example, the International Pacific Halibut Commission's work; the joint management of cod in the Barents Sea; the work of the Benguela Current Convention; and the management of the shared fish populations in the East China Sea ecosystem. These changes that are already visible in many parts of the world would influence trade patterns, potentially leading to less equitable and stable trade relationships between, in particular, countries of the Global South and the Global North.

The climate crisis poses significant challenges to the fisheries sector, affecting biological resources, economic stability, regulatory environments, social structures, technological advancements, and geopolitical relations. However, it also presents opportunities for innovation, sustainability, and international cooperation. Adapting to these changes will require comprehensive strategies that integrate environmental, economic, and social considerations to ensure the long-term viability and prosperity of global fisheries trade. The key point to note is that the distributions of costs and benefits being generated by the climate crisis, between and within countries, continents, the Global North and Global South, are the defining moral, ethical, economic, and social challenges and potential opportunities stemming from the ongoing climate crisis.

The push for traceability and transparency is currently taking the form of electronic catch documentation schemes to track the origin and legality of fish products; including through adoption of blockchain technology for traceability in the supply chain to prevent IUU fishing. Looking into the future, regulations mandating comprehensive traceability systems to ensure sustainable and legal sourcing of fish products seem to be in the card. In addition, the development of integrated global systems for monitoring and reporting fisheries data in real time may well be accomplished. However, it is worth noting that these developments may only happen to a significant level in the Global North because of the skewed distribution of currently available global resources towards these countries.

Subsidies have always been a big part of global efforts to make trade fairer more generally. However, in terms of the fisheries sector, they have taken greater relevance because most of the subsidies provided by governments to the sector are harmful in the sense that they can catalyse overcapacity and overfishing (Sumaila, Skerritt, et al., 2019; Sumaila et al., 2021). Hence, there has been a big global effort via the World Trade Organization (WTO) and other bodies to reduce or eliminate subsidies that contribute to overfishing and environmental degradation. In addition, some countries are reforming their subsidy programmes to eliminate incentives for harmful fishing practices. The current effort to remove harmful subsidies would continue in the future until strong enough global agreements to phase out harmful subsidies are reached. A really important point that should motivate governments is that current harmful subsidies can be redirected towards sustainable practices and conservation efforts to promote resilience in the fisheries sector, as well as improve the livelihoods of fishers and non-fishers alike.

Environmental tariffs and border measures are important trade tools (Bellmann et al., 2016). Currently, preferential tariffs for sustainably sourced fish products under preferential trade agreements (PTAs) and regional trade agreements (RTAs) are deployed. Prospective trends would likely include the introduction of tariffs or trade measures to penalize unsustainable practices and promote eco-friendly products. It is also possible that carbon border adjustment mechanisms would be deployed to account for the carbon footprint of imported fish products. Non-tariff measures are also useful tools currently used to support sustainable trade. For example, sanitary and phytosanitary (SPS) measures are employed to ensure that imported fish products meet health and safety standards to protect consumer health and prevent the spread of invasive species. In addition, regulations on labelling, packaging, and processing standards for fish products are used in this regard. Peering into the future, we expect stricter standards that enhance SPS and technical barriers to trade (TBT) measures focusing on sustainability and climate resilience. Efforts to harmonize non-tariff measures internationally to facilitate trade while ensuring environmental and health protections would likely be intensified with time.

Shifts in fish populations due to climate change are already impacting existing international joint agreements for managing shared stocks (Killer et al., 2013), and should lead to more changes to these agreements into the future. Potential new multilateral agreements focused on climate-resilient fisheries management and trade should also become more common with time. Greater international cooperation to address the impacts of climate change on fisheries, including data sharing and joint conservation efforts, would be highly desirable as the climate crisis intensifies as expected. We expect future RTAs to include more comprehensive clauses addressing climate change, sustainability, and resilience in fisheries trade, including the expansion of regional initiatives aimed at promoting sustainable fisheries and mitigating climate impacts. As the climate crisis intensifies, these trends are likely to continue, with increased emphasis on sustainability, transparency, and international cooperation. The success of these policies will depend on global collaboration, innovation, and the commitment of all stakeholders to integrate climate resilience into the fisheries trade framework.

4. Opportunities and Challenges for Developing Countries

Potential Trade Opportunities

A crucial avenue for trade opportunities is value addition. Developing countries should engage more in the processing and packaging of their fish and fish products for local, regional, and international trade. They need to invest in local processing facilities that can increase the value of raw fish products, creating jobs and retaining more economic benefits within the country and in the Global South. To succeed, developing countries have to aim for high quality products that meet international processing and packaging standards as doing so would open up new markets and export opportunities. Developing countries can enhance their export revenues by focusing on value-added products such as fillets, canned seafood, and ready-to-eat items. Tightly connected to value addition is the need for developing countries to invest in innovation to help them develop new products that cater to health and wellness trends, such as omega-3 supplements, fish protein powders, and organic seafood so they can help meet growing consumer demand for such products. Adequate investment in non-traditional fish species and developing unique culinary products can differentiate offerings from these countries in the global market, thereby putting them in a position to tap into emerging trends and diversify their export portfolios.

An area of great opportunity for developing countries is digital transformation and traceability. More specifically for fisheries, investing in blockchain technology can improve traceability, ensuring the legality and sustainability of fish products, and thus open up new markets both domestically and internationally. Similarly, investment in smart fishing technologies can increase productivity and sustainability, creating new trade opportunities.

Developing countries have a unique opportunity to deploy nature-based solutions to the climate crisis because of the diversity and richness of their aquatic ecosystems. This could be achieved by restoring mangroves and coastal ecosystems to enhance biodiversity, which, in turn, supports fisheries, and provides coastal protection. Ecosystem restoration can improve fishery productivity and create new revenue opportunities through ecosystem services and carbon markets. These countries can also deploy indigenous wisdom such as the Seventh Generation Principle—to think of the seventh generation after you in your actions and to remember the seventh generation who came before—to help ensure that the fisheries sector is both sustainable and equitably conserved and used to the benefits of all generations.

Last but not the least, developing countries should increase their active participation in regional and global collaborative fora tackling the climate and biodiversity crises because these do provide platforms for them to influence policies and secure favourable trade terms. Important to regional and global collaboration are trade agreements. There is an opportunity for developing countries to negotiate trade agreements that include provisions for sustainable fisheries as well as make room for preferential market access. Engaging in international trade agreements can also bring technical assistance and capacity building and information sharing opportunities, thus allowing developing countries to strengthen their contribution to trade agreements in ways that can help open new markets while providing support for developing sustainable fisheries practices.

Trade-Related Challenges

Developing countries are sure to face big challenges as the climate crisis rages on. Not only because its impacts would hit these countries' fisheries more severely, but also because these countries have limited access to appropriate technology, such as global positioning systems, sonar systems, and blockchain for traceability, which are often expensive, making it difficult for small-scale and artisanal fishers to afford them. Limited access to

Table 2. Critical Steps in Trade Policies and International Cooperation Agreements That Can Help With the Transition Towards Climate-Resilient Development in the Fisheries Sector

Strategy	Action	Benefit
1. Strengthening Trade Policies		
a. Implementing Preferential Trade Agreements	Negotiate and enter PTAs that include provisions for sustainable and climate-resilient fisheries.	PTAs can provide developing countries with better market access, reduced tariffs, and support for sustainable practices, enhancing competitiveness.
b. Incorporating Environmental Provisions in Trade Agreements	Ensure that new trade agreements include strong environmental and climate provisions, promoting sustainable fisheries management.	These provisions encourage the adoption of sustainable practices and ensure long-term resource availability, supporting climate-resilient development.
2. Enhancing International Cooperation		
a. Engaging in Regional Fisheries Management Organizations (RFMOs)	Actively participate in RFMOs to manage shared fish stocks sustainably and address challenges like overfishing and climate change impacts.	RFMOs provide a platform for cooperation, knowledge sharing, and coordinated actions, improving resource management and resilience.
b. Forming Strategic Alliances	Form strategic alliances with other developing countries to advocate for fair trade practices, technology transfer, and financial support.	Collective bargaining can lead to more favourable trade terms, increased support for sustainable development, and better access to resources.
c. Accessing International Funding and Technical Assistance	Leverage international funding mechanisms (e.g. Global Environment Facility, Green Climate Fund) and technical assistance programmes.	Financial and technical support can help developing countries implement climate-resilient practices, enhance infrastructure, and build capacity.
3. Building Domestic Capacity		
a. Investing in Education and Training	Develop education and training programmes focused on sustainable fisheries management, advanced technologies, and climate adaptation.	Building human capital ensures that the workforce is skilled and capable of implementing and maintaining sustainable practices.
b. Developing Infrastructure	Invest in infrastructure improvements, such as modern ports, processing facilities, and cold storage.	Enhanced infrastructure reduces post-harvest losses, improves product quality, and facilitates access to international markets.
c. Promoting Research and Development	Encourage research and development in sustainable aquaculture, resilient fish species, and innovative fishing techniques.	Research and development can lead to new solutions that enhance productivity, sustainability, and climate resilience in the fisheries sector.
4. Facilitating Access to Technology and Finance		
a. Technology Transfer Agreements	Negotiate technology transfer agreements with developed countries and international organizations.	Access to modern technologies improves efficiency, sustainability, and resilience, helping developing countries compete in global markets.
b. Creating Financing Mechanisms	Establish financing mechanisms such as microcredit schemes, grants, and subsidies for small-scale fishers and aquaculture enterprises.	Improved access to finance enables investments in sustainable technologies and practices, promoting long-term growth and resilience.
c. Encouraging Private Investment	Create a favorable investment climate through policies and incentives that attract private sector investment in sustainable fisheries and aquaculture.	Private investment can drive innovation, expand production capacity, and improve market access, contributing to economic development and resilience.
5. Enhancing Market Access and Diversification		
a. Exploring New Markets	Identify and develop new export markets for sustainably sourced seafood, including emerging markets.	Market diversification reduces dependency on a few markets and spreads risk, enhancing economic stability and growth opportunities.
b. Developing Value-Added Products	Focus on producing value-added seafood products, such as fillets, canned fish, and ready-to-eat meals.	Value addition increases profitability, creates jobs, and supports economic development while meeting diverse consumer preferences.

Source: Author's elaboration.

modern technologies can hinder the ability of developing countries to compete in global markets that demand sustainable and traceable seafood products. A related challenge is the lack of adequate technical expertise and skilled personnel to operate and maintain advanced fishing technologies.

Lack of finance is the graveyard of good ideas and initiatives; without access to capital, developing country fisheries, especially small-scale fishers and aquaculture enterprises, are unable to invest in sustainable practices, infrastructure, human capacity enhancement, and technology, thereby limiting growth and development in the fisheries sector. Financial institutions may perceive investments in fisheries as high risk due to factors such as fluctuating fish stocks (Sumaila, Walsh, et al., 2021), climate change impacts, and market volatility, which can result in higher interest rates or denial of credit, further constraining access to necessary funding. Other trade-related challenges in the fisheries sector include technological, financial, infrastructural, regulatory, labour, market access, environmental, and geopolitical issues.

Addressing these challenges requires approaches involving investment in technology and infrastructure, capacity building and information sharing, regulatory harmonization, and improved labour conditions as well as international cooperation. By overcoming these barriers, developing countries can enhance their competitive position and fully realize their potential in the global fisheries market. Furthermore, developing countries can strategically put together trade policies and international cooperation arrangements that can help them navigate the transition towards climate-resilient development in the fisheries sector. To achieve this, they will need to implement the critical steps set out in Table 2. The actions listed in the table can strengthen these countries to overcome trade-related challenges, enhance their competitive advantages, and ensure sustainable and resilient fisheries development on the road to 2050.

5. Priorities for Policy Engagement and Future Analysis

The following priorities for policy engagement if implemented by developing countries would position them to engage more effectively in equitable trade that is sustainable even in the face of climate change:

1. Promote sustainable fisheries management because without the fish it is game over. Countries should address overfishing by integrating sustainable practices that reduce the depletion of fish stocks, thereby mitigating CO2 emissions and preserving aquatic ecosystems' resilience to climate change.

2. Enhance climate-resilient fisheries by implementing NAPs and other regional frameworks that focus on adapting to climate-induced changes in fish stock distribution, extreme weather events, and habitat restoration and deploying nature-based solutions and strategies.

3. Strengthen climate-proof infrastructure, including those based on preserving natural habitats such mangroves. Encourage investments in human and nature-based infrastructure that can minimize the impacts of climate change, including species diversification in aquaculture, to stabilize fisheries and ensure the continued availability of fish as a food source.

4. Incentivize low-carbon practices by, among other things, integrating carbon pricing and reforming harmful subsidies to motivate the adoption of low-carbon practices within the fisheries sector and promoting sustainability and alignment with international climate goals.

5. Promote equitable and sustainable fisheries trade. Engage in policies that support fair and sustainable fisheries trade, ensuring access to international markets for developing countries and promoting economic growth through sustainable trade agreements.

6. Foster innovation in climate-smart fisheries by encouraging the development and adoption of climate-smart technologies, such as sustainable aquaculture and climate-resilient species, by facilitating global data sharing, research, and technology transfer and information sharing between developed and developing countries.

7. Support livelihood resilience as well as food and nutritional security. This entails prioritizing policies that enhance the resilience of coastal communities, particularly in the Global South, by ensuring food and nutritional security, livelihood protection, and equitable access to resources in the face of climate change impacts on fisheries.

Future research and analyses that would be necessary to support developing countries as they engage in fish trade under climate change include:

1. Understanding and quantifying the carbon sequestration role of marine life.

2. Conducting more in depth studies of the impact of climate change on fish stock distribution within the waters of developing countries as currently most studies are undertaken in the waters of the Global North.

3. Understanding the long-term effects of rising sea temperatures, ocean acidification, and deoxygenation on the migration patterns, breeding, and survival of various fish species across different regions, in particular in the waters of Global South countries.

4. Focusing on assessing the socio-economic vulnerabilities of coastal communities that rely heavily on fisheries, particularly those in developing countries. This would include evaluating their capacity to adapt to climate change impacts, such as extreme weather events and habitat loss.

5. Identifying best practices and highlighting areas where international cooperation and support are needed; comparing and analysing the effectiveness of different adaptation strategies employed by countries in the Global North and Global South.

6. Exploring the role of sustainable trade in climate adaptation.

7. Conducting comprehensive economic analyses to assess the direct and indirect costs of climate change on global fisheries, including the loss of biodiversity, changes in fish stocks, and the socio-economic impacts on communities. Armed with this research, countries would have a basis for developing targeted policies and compensation mechanisms in support of sustainable and equitable fish trade.

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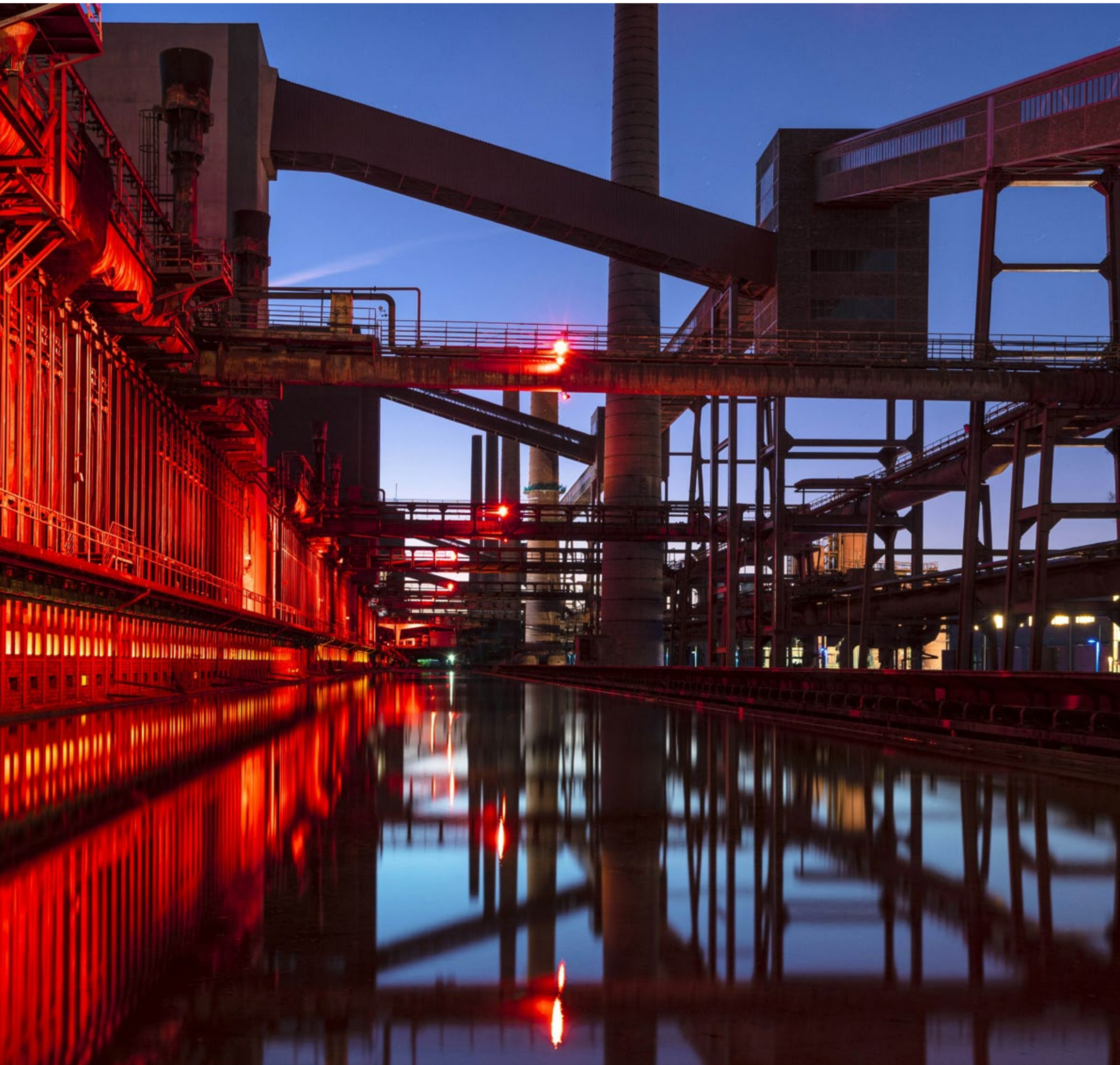
HEAVY INDUSTRIES

Johanna Lehne



1. Heavy Industries and the Trade, Climate, and Sustainable Development Nexus

Energy-intensive industrial sectors, such as steel, aluminium, cement, and chemicals are major contributors to climate change. The chemical and thermal combustion processes involved in the production of these materials account for roughly 17–20% of global greenhouse gas (GHG) emissions and are responsible for 15% of global final energy demand (IRENA, 2024). As energy and water-intensive sectors, these are also vulnerable to climate-related disruptions. Industrial plants are often located close to rivers and are dependent on them for inputs and moving final products, making them vulnerable to flooding and droughts.

At the same time, these sectors are expected to play a vital role in the climate transition, especially in emerging economies. Steel, cement, aluminium, and chemicals are key inputs into infrastructure, buildings, wind turbines, electric vehicles (EVs), and appliances. The bulk of the growth expected in the demand for these commodities is set to happen in emerging markets as they urbanize and build out their clean energy infrastructure. Cement demand, for example, is projected to increase by three to fourfold in developing countries in Asia by 2050 (Imbabi et al., 2012).

Industrial sectors are facing a significant expansion in demand at a time when their emissions need to fall fast. With the Paris Agreement goal of limiting global warming to 1.5°C, heavy industry sectors are now expected to rapidly decarbonize, approaching net zero by mid-century.

Meeting this goal requires overcoming the "trade-trapped" nature of these sectors. Steel, cement, and chemicals are traded across borders and face fierce international price competition. This makes it harder for producers to pass through the additional costs of investing in more expensive, cleaner technologies without impacting competitiveness. Policymakers have been wary of introducing policies that could affect the competitiveness of their domestic industrial sectors and risk carbon leakage.

Trade policy and international coordination are, therefore, key to successfully decarbonizing these sectors. The global nature of industrial sectors and their supply chains limits the effectiveness of measures targeted just at the national level. Moreover, several of the key industrial decarbonization policies being explored by countries—such as public procurement targets, product requirements, green industrial subsidies, and carbon border measures—run into challenging trade law territory and risk provoking tensions if not designed carefully, coordinated, and justified adequately.

2. Climate Action and Impact Scenarios in Heavy Industry Sectors: The Road to 2050

International Commitments Related to Industrial Decarbonization

In recent years, there has been a proliferation of platforms and initiatives providing opportunities for cooperation on industrial decarbonization. These initiatives have focused on cooperation on roadmaps for industrial decarbonization (LeadIT and Mission Possible Partnership), procurement (SteelZero, ConcreteZero, First Movers Coalition, Industrial Deep Decarbonisation Initiative [IDDI]), innovation (Mission Innovation), finance (Industrial Transition Accelerator), and trade policy (the Climate Club, the EU-US Global Arrangement on Sustainable Steel and Aluminium) among other things. Such initiatives cover a set of broad commitments to progress ambition in this space. Under the Steel Breakthrough, for example, members have committed to ensuring that "near-zero emission steel is the preferred choice in global markets, with efficient use and production established and growing in every region by 2030" (IEA, 2023a).

Table 1. Landscape of Key International Initiatives on Industry Decarbonization

<table>
<tr><th>Function</th><th colspan="60">Key International Initiatives</th></tr>
<tr><td>Landscape Coordination</td><td colspan="60">Steel Breakthrough</td></tr>
<tr><td>Long-Term Vision & Action Plans</td><td colspan="15">Leadership Group for Industry Transition</td><td colspan="15">Mission Possible Partnership / Industry Transition Accelerator</td><td colspan="15">World Steel Association</td><td colspan="15">Climate Club</td></tr>
<tr><td>Demand Creation & Management</td><td colspan="15">IDDI</td><td colspan="15">First Mover Coalition</td><td colspan="15">SteelZero</td><td colspan="15">Climate Club</td></tr>
<tr><td>Finance & Investment</td><td colspan="20">Industry Transition Accelerator</td><td colspan="20">Leadership Group for Industry Transition</td><td colspan="20">Climate Club</td></tr>
<tr><td>Research & Innovation</td><td colspan="30">Mission Innovation’s Net-Zero Industries Mission</td><td colspan="30">IEA’s Industrial Energy-related Technology and Systems</td></tr>
<tr><td>Standards & Certification</td><td colspan="12">Responsible Steel</td><td colspan="12">First Movers Coalition</td><td colspan="12">G7 Industrial Decarbonisation Agenda</td><td colspan="12">IDDI</td><td colspan="12">Climate Club</td></tr>
<tr><td>Trade & Competitiveness</td><td colspan="15">OECD Steel Committee</td><td colspan="15">WTO Trade and Environmental Sustainability Structures Discussions</td><td colspan="15">Steel Standards Principles</td><td colspan="15">Climate Club</td></tr>
</table>

Source: E3G elaboration on IEA et al. (2022).

While these are welcome developments, they require the backing of ambitious national policies and commitments to deliver on the stated objectives. On an individual basis, very few countries have set emissions reduction targets for these sectors in their nationally determined contributions (NDCs). France and South Korea have dedicated steel decarbonization strategies, but both fall short of setting specific emissions reduction targets for steel. France has set a 31% emissions reduction by 2030 target for its chemicals sector (IRENA, 2024). Canada is the only country to have projected a decarbonization trajectory for its cement and lime sectors in its mid-century strategy (a 93% reduction on 2015 levels by 2050).

Projected Decarbonization Trajectories and Policies for Industrial Sectors

Emissions from energy-intensive industries need to fall by roughly 30% by 2030 (on 2022 levels) and by over 90% by 2050 (IEA, 2023c). So far progress has been lacking: after steep annual increases in emissions up to 2010, industrial emissions have largely flatlined in the last decade as demand for industrial products has reached the saturation level in most advanced economies (IEA, 2023b).

There has been little robust policymaking to drive change to date, especially in comparison to the energy sector. Characterized as "harder to abate" due to their trade-exposed nature and the lack of readily available alternatives, industry sectors had largely been on the back burner for policymakers. As products from these sectors are globally traded and face strong price competition, policymakers have been reluctant to introduce stringent climate policies that could affect their competitiveness and risk carbon leakage.[35] For example, under the EU Emissions Trading System (ETS), industrial sectors continue to receive most of their emission allowances for free (ERCST, 2024). This has dampened the carbon price signal and, therefore, the incentive to invest in cleaner production processes.

In recent years, however, two important factors have changed, ramping up momentum for industrial decarbonization. First, the political narrative has started to shift. "Carbon leakage" concerns have been replaced by "low carbon

35. Carbon leakage can occur when economic activities are displaced, or investment or consumption patterns change, for reasons of costs related to climate policies. This could directly or indirectly cause GHG emissions to be displaced to other countries with no or laxer emissions constraints in place.

leakage" concerns. Previously policymakers worried that domestic industries would be undercut by carbon-intensive production abroad. The concern now, especially in the wake of the US Inflation Reduction Act (IRA) and with China ramping up investment in its clean tech sectors, is that domestic industries will be overtaken by cleaner production elsewhere. Decarbonizing production processes is now recognized as a prerequisite for continued competitiveness, the creation of decent jobs, and economic growth. Second, increasing technological maturity and the rapid decrease in the costs of renewable power mean that the technological solutions for industry decarbonization are now either already commercially available or in sight (IRENA, 2024).

Growing confidence in the feasibility of industry decarbonization has opened the political space for more concerted policy efforts internationally. More countries are introducing or adapting existing carbon pricing mechanisms, such as the emissions trading system in the EU, South Korea, China, and other emerging economies like India. The EU also recently introduced the Carbon Border Adjustment Mechanism (CBAM), which will also result in the phasing out of free emissions allowances for industry sectors in the EU ETS. The IRA in the US has unleashed huge amounts of green investment, including in hydrogen, carbon capture and storage (CCS) and conversion to electric arc furnaces (EAFs). Germany recently a €4 billion carbon contracts for difference (CCfD) scheme to support energy-intensive sectors to shift to cleaner production processes. Governments are also starting to introduce green public procurement schemes and develop ambitious standards to grow demand for lower carbon steel, cement, aluminium, and chemicals. The US Buy Clean Initiative will be expanded to include steel in the near future. Canada has set a target to reduce embodied carbon of structural materials used in major public construction projects by 30%, starting in 2050.

Importantly, policymakers only have a narrow window in which to act. Energy-intensive industrial sectors are characterized by "lumpy" investment cycles over long time periods. Industrial facilities typically operate between 20–50 years, with reinvestments and refurbishments only required every 15–25 years (Material Economics, 2029). Between 30% and 53% of the EU's cement, steel, and steam cracker plants, for example, will require major reinvestments this decade (Agora Energiewende, 2021). Asset owners will need to decide what to do with ageing fleets and how to minimize employment and other social impacts from those decisions. The key question for this reinvestment wave is how to give asset owners the confidence and support to invest in low-carbon processes instead of locking in three more decades of carbon-intensive production. Given this fleeting window, it is paramount that the right policy signals are sent in the coming years. Early action is also critically important in China and India. China faces the challenge of a large and comparatively young existing emissions-intensive industrial base and will need to explore options for retrofitting and early retirement. India is on the precipice of a major growth in industrial capacity where the crux will be to ensure that new plants are "net-zero-ready," in other words able to accommodate clean technology retrofits once these are available.

Potential Shifts in Industrial Supply Chains and Production by 2050

The shift to near-zero emission industrial production has the potential to reorganize global supply chains, with new production, processing, and trading hubs emerging for low-carbon steel, aluminium, cement, and chemicals production. Countries with abundant, low-cost renewable electricity and access to critical materials, such as Australia, Brazil, and Chile and South Africa and Middle Eastern countries, are looking to position themselves as potential major winners from this transition.

While the technological transition pathways for energy-intensive industries differ by sector, they each broadly combine four main levers: i) energy efficiency; ii) alternative fuel use and direct electrification; iii) material efficiency and demand reduction; and iv) carbon capture and storage. Each of these levers has different potential implications for industrial supply chains and the future of trade flows in these sectors (Table 2).

Table 2. Technological Decarbonization Pathways for Industry Sectors and Potential Implications for Trade Flows

Lever	Description	IMPACT	Description of Trade Impact	Example
Energy Efficiency	Upgrading equipment, processes and plants to ensure less energy is used in production.	Low	1) Shifts in production and processing hubs: Efficiency largely reflects the age of equipment and investment cycles, which vary by geography, e.g. generally older fleets in Europe and the US vs. emerging and developing economies but are unlikely to cause large shifts in production locations or nature of industrial products traded. 2) Shifts in commodities traded: Emphasis on lower CO2 intensity in border measures or product standards could shift trade flows, but as energy efficiency measures generally only allow for incremental emissions reductions this effect is unlikely to be very large.	The Indian cement industry is one of the most energy-efficient in the world, with average thermal energy consumption of approx. 3.0 GJ/tonne of clinker (WBCSD, 2016).
Alternative Fuel Use & Direct Electrification	Shifting from fossil fuels to lower carbon fuels and/or direct electrification.	High	1) Shifts in production and processing hubs: The production costs of lower carbon fuels (e.g. renewable-based hydrogen) and renewable electricity will vary considerably by geography, incentivizing shifts in production to locations with abundant low-cost renewable capacity. 2) Shifts in commodities traded: Increased import demand for renewable-based fuels (e.g. green hydrogen and its derivatives, green iron), reduced import demand for fossil fuels.	Near-zero emission chemicals production has the potential to reorganize global supply chains. Currently mainly reliant on highly transportable fossil fuels like oil and gas as feedstocks and a source of energy, the production of green chemicals will likely happen where clean energy is both abundant and cheap. Saudi Arabia's "Vison2030" envisages significant investments in green chemicals to leverage its abundant solar potential and diversify its economy from fossil fuels (Industrial Info, 2024).
Material Efficiency & Demand	Reducing demand for industrial materials by taking new approaches to design, using higher-quality materials, using alternative materials, improving the efficiency with which the materials are used and increasing the share that is reused and recycled.	High	1) Impact on raw material flows: Reduced import demand for raw and processed materials. 2) Impact on manufactured goods: Emphasis on durability, modularity, and recyclability in product design standards may impact trade flows. 3) Impact on secondary material flows: Increased import demand for secondary materials, reduced exports of secondary materials.	As countries scale up secondary steel production via EAFs, there will be increasing demand for scrap. Countries are likely to act to try to secure their own supply and restrict exports with knock-on impacts for the steel transition in trade partners.
Carbon Capture and Storage	Capturing the emissions at the production site/plant and then securing and storing these.	Medium	1) Shifts in production and processing hubs: Access to CO2 storage and transport infrastructure will vary by location, and dispersed sites may be disadvantaged. 2) Shifts in commodities traded: Increase in CO2 transport to storage locations.	Norway has been positioning itself as a future hub for storing CO2 captured from its own and other European industrial installations. The Longship Project, Europe's first complete CCS value chain, is currently under construction and set to start storing CO2 from cement, waste incineration, and ammonia plants starting from 2025 onwards.

Source: Author's elaboration.

3. Trade-Related Trends and Dynamics in Heavy Industry Sectors

The global nature of energy-intensive industrial sectors and their supply chains means that domestic decarbonization policies set in any one country or jurisdiction have spillover effects in other geographies. Building on the analysis in Table 2, policies geared towards accelerating the technological shifts captured by the four decarbonization levers will also reinforce the trade trends set out above. As noted in section 1, moreover, several of the key industrial decarbonization policies being explored by countries—such as public procurement targets, product requirements, green industrial subsidies, and carbon border measures—run into challenging trade law territory and risk provoking tensions if not designed carefully, coordinated, and justified adequately.

This section maps and reviews current and future trends in industrial decarbonization policies and the implications for trade trends in the current geopolitical context.

Carbon Border Measures

Although carbon border measures have a long history in globalization and trade discourse, there have historically been very few examples of practical application. This is now changing. In 2022, the EU passed legislation to introduce a CBAM, which will eventually impose a charge on goods imported into the EU from foreign producers who operate without a carbon price. The measure aims to protect the EU's domestic producers, who face a carbon price, from being undercut. The sectoral scope is narrowly focused, with an emphasis on energy-intensive sectors: iron and steel, aluminium, cement, fertilizers, electricity, and hydrogen. The EU CBAM pilot phase started last year with importers required to start reporting and flagging issues with accompanying administrative costs. Importers will start being charged in 2026.

International Implications

The introduction of the EU CBAM has given a regulatory push internationally to carbon pricing for the sectors covered. It also signals that a major market will for the first time give preferential treatment to lower carbon industrial commodities, with the aim of incentivizing industrial decarbonization efforts more broadly. The UK, US, and Canada are exploring introducing their own CBAMs. In response to the EU CBAM, China is also progressing with inclusion of cement and steel in its ETS, with reporting requirements starting in 2023.

The EU has also faced considerable push-back from trade partners on the design, fairness, feasibility, and legality of the measure. Countries like China, India, South Africa, Australia, and Russia, but also the US pushed back openly against the idea. Countries worry that this measure will negatively impact their industrial producers and not adequately recognize domestic climate efforts.

These tensions came to a head at the 2023 UN Climate Change Conference (COP28), when the BASIC group of large emerging countries—Brazil, China, India, and South Africa—launched a campaign to denounce unilateral measures in the text of the global stocktake (Kerstens, 2023). This campaign was particularly focused on the EU CBAM, criticizing the EU for its failure to provide any kind of flexibility or financial support to developing countries or consider the perceived discriminatory burden on their economies. For example, analysts have questioned why the EU is not committing CBAM revenues to support decarbonization efforts in emerging and developing economies (EMDEs), tying into broader discussions on the lack of climate financing for EMDEs.

International Coordination

There is a broad recognition that common approaches need to be developed on how to deal with carbon in traded goods, including exploring common principles and coordination on carbon border measures. A recent example of such an initiative is the Climate Club. In June 2022, under the German presidency, G7 leaders committed to establishing an "open, cooperative international Climate Club" by the end of that year. This initiative was formally launched at COP28 with a programme spanning 3 pillars: converging on ambition, sectoral cooperation, and engagement with developing countries. One of the main workstreams of the Climate Club has been on coordination on carbon leakage measures.

Product Standards and Procurement Measures

Building demand for low-carbon steel, cement, and chemicals is crucial to creating a more attractive business case for investment in lower carbon production processes. Without a clear incentive, it is likely that new investments will otherwise be stifled. Governments have a critical role to play in building that demand through green public procurement and by helping to define what qualifies as "low-carbon," "near-zero," and "net-zero" steel, cement, or aluminium in partnership with industrial stakeholders and civil society actors. Ambitious definitions and product requirements tied to transparent and trusted processes for certifying adherence to those definitions and standards are key tools in driving industrial decarbonization.

Canada, Germany, and the UK have all demonstrated clear ambition on this front.[36] Canada, as noted, is setting out to reduce the embodied carbon of structural materials used in major public construction projects by 30%, starting in 2025 (Treasury Board of Canada Secretariat, n.d.). The German government has launched a voluntary green steel labelling system known as LESS (WV Stahl, 2024). The German steel association WV Stahl plans to start certifying steel producers with the LESS label by the end of 2024. In its 2023 public consultation on a UK CBAM, the government held a consultation on the adoption of mandatory product standards for industrial sectors and IDDI green steel procurement pledges (Industrial Deep Decarbonisation, 2023).

International Implications

Standards for near-zero emissions industrial products set at the national level, such as those that have been presented for public consultation in the UK and have been developed in Germany, could contribute to setting international benchmarks for the supply chains of these industrial products globally. Mandatory product requirements could also be applied at the border, requiring adherence from both domestic and foreign producers. Changes in green public procurement requirements would also affect what products from foreign producers are eligible for procurement in the country adopting more stringent standards, creating a demand pull internationally for cleaner industrial materials.

A potential flashpoint in this space could be the increasing use of local content requirements attached to green public procurement (and broader industrial policy measures). The US included several local content requirements in the IRA. Other examples of local content requirements, mainly related to the deployment of renewables like wind and solar, can be found in countries like South Africa, Canada, Brazil, and China (Peterson Institute for International Economics, 2021). Tendencies towards protectionism in green public procurement frameworks may end up being counterproductive. While green protectionism can be useful for initially enticing national public spending to support clean technologies, it could end up delaying the transition and increasing costs.

36. Canada, Germany, the UK, and the US issued public announcements about their current procurement initiatives and how they align with different IDDI pledge levels at COP28 in December 2023. At the point of publication, we are still waiting for public information on which pledge levels they are officially committing to. See Industrial Deep Decarbonisation (2023).

Guaranteeing a minimum level of openness of new green product markets to all countries and non-discrimination between domestic and foreign producers of green products is essential for global-scale decarbonization.

International Coordination

Interoperability of standards for near-zero emissions industrial products and harmonized procedures and methodologies for reporting on the emissions intensity of production processes improves transparency and data collection, ensures a level playing field, and, ultimately, facilitates the greening of industrial supply chains globally. Multiple international initiatives and organizations are focused on trying to provide a space of greater alignment: including the International Energy Agency (IEA), the Industrial Deep Decarbonisation Initiative, and the World Trade Organization (WTO) Secretariat. At COP28, standard-setting bodies, international organizations, and steel associations came together to launch the Steel Standards Principles, setting out principles aimed at aligning how GHG emissions are measured in the steel sector (WTO, 2023).

Subsidies and Technology Deployment

Many of the technology options for decarbonizing steel, cement, and chemicals are more expensive than conventional production processes and investments in innovative production sites carry higher levels of risk. Even in jurisdictions with higher carbon prices, like the EU with its ETS, break-even carbon prices for these technologies are considerably higher than those for carbon-intensive production. Some form of direct support will be required to cover higher operating and capital costs, although the costs of these technologies will decrease as they scale up. The exact means of how such support is given varies in different national contexts, reflecting different levels of fiscal resources and different production costs (Devlin et al., 2023). Table 3 provides some examples of public support for steel decarbonization projects in different jurisdictions, showing the scale of financial support on offer.

Table 3. Examples of Green Steel Projects From Across the World

Company, country	Capacity	Public Investment	Private Investment
ArcelorMittal, Spain	2.3Mt DRI, 1.1Mt steel**	$0.5bn**	$0.6bn**
H2GS, Sweden	2.1Mt DRI, 5.0Mt steel*	$0.3bn**	$6.7bn**
Techint Group, Mexico	2.1Mt DRI, 2.6Mt steel*	Not stated	$2.2bn*
Saltzgitter, Germany	2.0Mt DRI, 1.9Mt steel**	$1.1bn**	$0.8bn**
Vulcan Green Steel, Oman	2.5Mt DRI, 5.0Mt steel*	Not stated	$3bn*

Note: Mt stands for megatonne (one million tonnes) and DRI for direct reduced iron.

Sources: *Global Energy Monitor (n.d.); **Public Citizen (2024). Table originally published in Whitwham (2024).

International Implications

Direct support for technology deployment could bring down learning costs on these technologies for other countries. However, a more assertive industrial policy in wealthier countries like the US and in the EU may also impact on the diffusion of technology abroad and/or impact on the ability of other countries and regions to build up their competitiveness in these areas. Given these considerations and the challenges that developing countries already face in accessing and deploying industrial decarbonization technologies, assertive industrial policies in wealthier countries could be considered in conjunction with technology transfer initiatives to accelerate the uptake of these technologies in developing countries.

International Coordination

There have been several proposals developed for putting forward a shared set of principles for green industrial subsidies and agreeing permissible forms of direct state support in order to avoid future trade tensions and give political cover for pursuing ambitious green innovation and industrial policies. For example, subsidies could be assessed based on whether they are sustainability enhancing and trade distorting—subsidies that produce positive sustainability outcomes and have limited trade distorting effect would be categorized under a "green box" and as a result would be permissible and would not be countervailable (Cima & Esty, 2024). However, these proposals have not extended beyond the academic space to date and are yet to receive political buy-in, particularly as many of them require consensus of all 166 WTO members and a new workstream on industrial policy can easily be blocked by one member (Kerstens, 2024). Instead, progress on a bilateral or plurilateral level, focusing on the largest subsidizing countries like the US, EU, China, and India and key emerging country members such as Brazil and South Africa may be more likely. If not a set of principles, enhancing transparency on green industrial subsidies with a view to building trust and analysis of their effectiveness is increasingly being prioritized (IMF, 2023).

Transition finance is another area that will be key for addressing inequities and tensions over green industrial subsidies. Capital costs and access to skills and finance vary massively between geographies. OECD countries have a key role in scaling up investment, mobilizing targeted support and technical assistance for industrial decarbonisation, and bolstering international climate finance to facilitate the industrial transition internationally.

Scaled up technology cooperation and transfer to developing countries could also help to mitigate some of these tensions. However, most of the technology cooperation efforts to date have focused on early-stage research and development for breakthrough technologies rather than on deployment of existing pre-commercial technologies, and they largely focus on cooperation between industrialized economies. The Net-Zero Industries Mission (NIM), for example, includes Australia, Austria, Canada, China, European Commission, Finland, Germany, Republic of Korea, UK, and US. The aim of the NIM is to accelerate the development of new and radical breakthrough low-emissions industrial technologies (Net Zero Industries Mission, 2022).

While advancing the technology frontier, as the NIM seeks to do, continues to be crucially important for industrial decarbonization, we also have a suite of technologies like hydrogen electrolyzers, thermal heat batteries, and industrial scale heat pumps that are at a higher stage of technology readiness and becoming ready for widespread commercialization. There is a gap in our understanding of the barriers to adoption of these technologies in developing countries, whether this stems primarily from a lack of finance or instead barriers around intellectual property and licensing, skills and capacity, or how suitable these technologies are to different contexts. In recognition of this gap, the NIM is now also looking to recognize innovation projects in EMDEs as part of its Net-Zero Industries Award. In May 2023, the United Nations Industrial Development Organization (UNIDO) also launched the Accelerate-to-Demonstrate Facility to accelerate the commercialization of innovative technologies, including for industrial decarbonization, through demonstration projects in EMDEs. These represent promising but early-stage efforts to try to close the gap on technology cooperation with EMDEs.

Trade Policies Supportive of Circularity and Waste Management

Material efficiency, circularity, and waste management policies are critical to industrial decarbonization, as they help lower how much steel, cement, and basic chemicals we use. The IEA Net Zero by 2050 report estimates that material efficiency alone can reduce demand for cement and steel by 20% in 2050 (IEA, 2021). Beyond mitigation potential, circular economy levers also have the potential to address wider environmental challenges, including biodiversity loss and pollution (Forslund, 2021).

For EU member states, the EU Circular Economy Action Plan released in March 2020 is critical in this regard. It includes a revised Ecodesign for Sustainable Products Regulation, which highlights steel as a priority product for future regulation. China has also explicitly connected steel with its circular economy initiatives, setting steel scrap use targets as part of its fourteenth Five-Year Plan for the Development of the Circular Economy (China Briefing, 2021).

International Implications

As countries scale up material efficiency and recycling of industrial materials, there will be increasing demand for secondary materials and recycling feedstock. Countries are likely to act to try to secure their own supply and restrict exports with knock-on impacts for transition in trade partners. The last few years have seen a growing number of trade restrictions on steel scrap in Africa, the Middle East and North Africa region, and Asia (Manthey, 2023). The EU will introduce restrictions of scrap exports to non-OECD countries from 2027 unless they can demonstrate sustainable practices.

International Coordination

There has been a notable gap in efforts to improve international coordination of circular economy and waste management policies. Under its G20 presidency in 2023, India launched the Resource Efficiency Circular Economy Industry Coalition and released a technical paper entitled "Knowledge Exchange on Circular Economy in Steel Industry." Deeper dialogues with trade partners on potential impacts of regulatory changes alongside support in-country will be key.

Tariffs

Toxicities around trade, including concerns about excess capacity and dumping, continue to result in trade restrictions targeting industrial products, in particular steel and aluminium. In 2018, the Trump administration invoked "risks to national security" to justify imposing tariffs on steel and aluminium under section 232 of the Trade Expansion Act to all trade partners including the EU (CRS, 2022). In retaliation, the EU introduced rebalancing measures while also initiating a legal proceeding at the WTO (European Commission, 2018).

The background for these tariffs was the lack of progress emerging from multilateral efforts, including in the G20 Global Forum on Steel Excess Capacity, to resolve the challenge of global overcapacity in steel markets. This problem is largely seen as having been driven by the unprecedented non-market driven build-up of steelmaking capacity in China (OECD, 2023).

International Implications

The US recently ramped up its tariff rate on steel and aluminium products from China once again under Section 301 (White House, 2024). With rising steel excess capacity and increasing Chinese exports, more trade defence actions are expected, with likely negative spillovers for international coordination on industrial decarbonization.

International Coordination

Given the long history of tensions over steel excess capacity and ensuing trade measures, there have been several attempts at international coordination in this space with mixed success. The OECD Steel Committee brings together members accounting for 40% of global steel production to address evolving challenges and opportunities in the global steel industry. The Global Forum on Steel Excess Capacity was launched in 2016, with membership from all G20 countries and interested OECD countries with the aim of allowing countries to share information and track the underlying causes of overcapacity. China, India, and Saudi Arabia all disengaged from the forum's work in 2019.

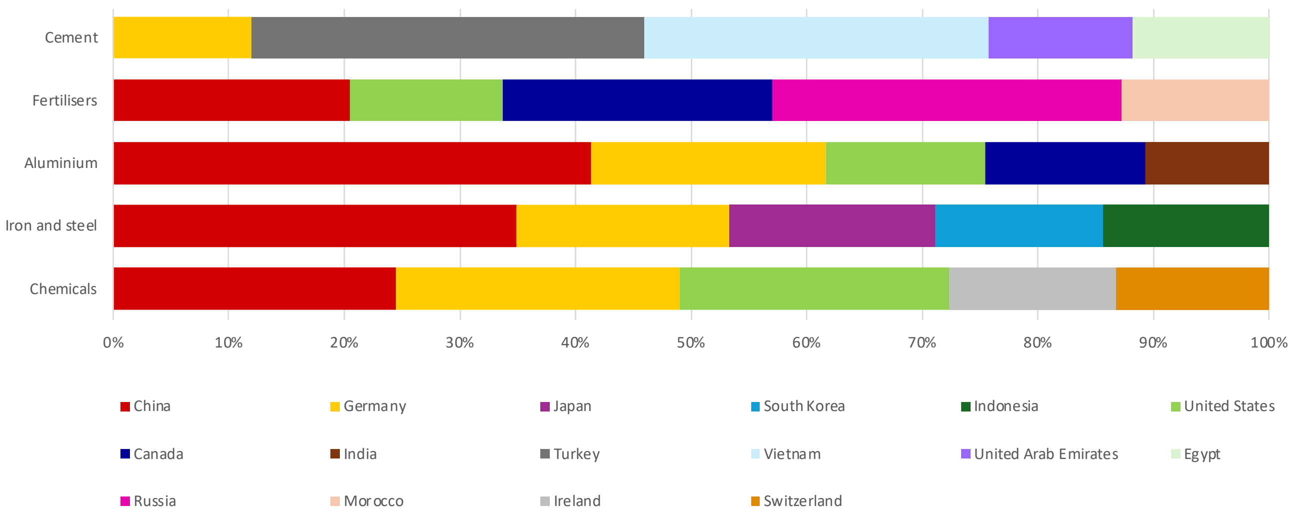
The most recent example of bilateral coordination on steel tariffs is the Global Arrangement on Sustainable Steel and Aluminium, launched in 2021 by the EU and US to resolve their ongoing tariff dispute over steel and aluminium, address challenges related to global overcapacity, and accelerate decarbonization of the steel and aluminium sectors. These negotiations proved challenging and stalled in early 2024 with both sides remaining far apart. One of the key sticking points was around how to structure a potential sectoral arrangement on steel and aluminium: what sanction or incentive to apply to membership of such an arrangement. The US, which is unlikely in the current political climate to adopt a domestic carbon price, favoured a tiered tariff system aimed at shielding domestic markets from global overcapacity. The EU preferred a price-based system more in line with its existing emissions trading system to avoid undermining its CBAM. These positions were informed by the different starting points both jurisdictions have in terms of their domestic policy frameworks

4. Opportunities and Challenges for Developing Countries

Today, close to 90% of steel, aluminium, and cement production occurs in non-OECD countries (37% excluding China), which will also see the highest future growth (Rimini et al., 2023).[37] The vast majority of planned capacity expansions in industrial sectors in the coming decade are set to occur in developing economies. These can either lock in carbon-intensive pathways for decades or kick-start a green industrial revolution. As set out in the previous two sections, regulatory ambition and trade policy set by OECD countries will have spillover effects and will play a huge role in determining which of these pathways EMDEs end up on.

This section assesses the opportunities and challenges faced by developing countries as industry sectors transition on the road to 2050 and what policies and initiatives they can use to navigate this transition. Figure 1. gives an overview of the top five exporters across the key industrial commodities considered, with Vietnam, Indonesia, India, Morocco, and Egypt standing out as key developing country exporters.

Figure 1. Market Share of Top Five Exporters of Key Industrial Commodities in 2022



Source: E3G based on Observatory of Economic Complexity (n.d.) 2022 data.

37. Author's analysis based on USGS (n.d.) 2023 data for cement, aluminium, and raw steel production.

Trade Opportunities

The main opportunity for developing countries is around the emergence of new export markets and increased demand for certain green commodities. Developing countries with abundant renewable energy, access to critical raw materials and/or skills, and assets to position themselves as remanufacturing or reprocessing hubs will be in a strong position to capitalize on the shift to lower carbon industrial manufacturing. Brazil and South Africa, for example, with their low-cost renewable electricity and access to iron ore resources, are looking to become major green iron hubs in the shift to decarbonized steelmaking. Developing green hydrogen and green iron and steelmaking capacities for export would bring jobs and further growth opportunities as these foundational sectors could support the development of additional manufacturing sectors further downstream. As industrial processes increasingly electrify and rely on lower carbon fuels, those developing countries that can provide low-cost renewable electricity will find themselves at a major competitive advantage for green industrialisation.

The second key opportunity for developing countries lies in improved energy and material security. The shift to lower carbon and more circular industrial production processes will also allow countries to reduce their import dependence on certain commodities. India, for example, is currently very dependent on imports for its metallurgical coal use: 85% of demand is met through imports (Arora, 2024). A shift to non-coal-based steelmaking would greatly improve the resilience and economic security of the domestic steel sector as it would allow the sector to rely on domestic abundant renewable energy sources, making it less vulnerable to international commodity price spikes.

Trade-Related Challenges

As indicated in section 3, developing countries already face a wide set of trade-related challenges because of the measures and policies being pursued in industrialized economies and it is likely that these trends will be reinforced. These challenges include:

- *Lower demand for fossil-based exports:* Reduced import demand in developed countries for fossil-based products from developing countries. As production processes for industrial products shift towards lower carbon fuels/inputs, electrification, and more circular processes, developed countries with strong export markets based on fossil fuels will likely see a reduction in demand for these products. As noted, there are new industrialization opportunities for certain countries, but this will require alternative development pathways and the capacity support and finance to pursue these.

- *Impact on imports:* Reduced exports of secondary materials from developed to developing countries. As developed countries scale up material efficiency and recycling of industrial materials, there will be increasing demand for secondary materials and recycling feedstock and, as a result, a likely decrease in exports of these commodities to developing countries. This can be a substantial challenge for certain countries that have whole industries predicated on waste sorting and scrap recycling. Turkey, for example, is a major importer of scrap steel that could face challenges due to trade restrictions on scrap exports.

- *Reduced market access:* Changing regulations, norms, and standards favouring lower carbon industrial production processes may impact the ability to export from certain developing countries. The most concrete example of this is the EU's CBAM, which reduces market access for high-carbon intensive goods but also requires monitoring, reporting, and verification processes to allow exporters to access the single market. Similarly, product standards applied at the border or green procurement measures (even those not stipulating local content requirements) will affect export markets from developing countries. Without access to lower carbon technologies or the skills and financial assets to convert processes, these types of measures will be a disproportionate burden for developing countries (Ravikumar, 2020).

5. Priorities for Policy Engagement and Future Analysis

Industrial sectors face particular challenges (e.g. high capital expenditure, long investment cycles, competitiveness and trade issues, and lack of markets for green products) which act as strong barriers for countries to move ahead without international coordination. Luckily, momentum on coordinated policies for industrial decarbonization is growing, as is evident by the steady stream of initiatives launched over the last few years.

Among these initiatives, there is a strong recognition that engagement with and support for developing countries will be a critical lever for accelerating industrial decarbonization internationally. The Climate Club launched at COP28, for example, has a dedicated pillar on boosting international support for industrial decarbonization in EMDEs (Climate Club, 2024). However, this is still an area where there has been less concrete action to date.

In this context, key priorities for these initiatives and for bilateral cooperation to support climate-resilient industrial development could include:

- *Open policy dialogues about the potential impact and pathways:* Deeper dialogues with developing countries about the potential impacts of regulatory changes alongside support in-country. Open and inclusive dialogue could be pursued at a bilateral and plurilateral level in parallel to the multilateral.
- *Accelerating actions on widely accepted trade policy challenges:* This could include a more concerted focus on lowering non-tariff barriers, ensuring interoperability of low-carbon industrial product standards, and addressing the lack of clarity on rules that apply to different waste and secondary materials.
- *Strengthening the empirical base:* Many of the trends identified in the analysis above are still largely uncertain. A stronger understanding of the trends and opportunities deriving from industrial decarbonization and the range of policy options as well as scenario analysis to identify appropriate responses for developing countries would be key.

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* This sectoral briefing note was co-published with E3G.

SHIPPING

Eleanor Croswell, Sophie Deyon, and Ludovic Laffineur

1. Shipping and the Trade, Climate, and Sustainable Development Nexus

Shipping plays a key role in our globally interconnected economy, transporting close to 90% of internationally traded goods (Harrison et al., 2024). The sector accounts for about 3% of global greenhouse gas (GHG) emissions, which, if it were a country, would place it as the world's sixth largest emitter between Germany and Japan (Bullock et al., 2020).

Developing economies account for the majority of global seaborne trade, albeit with significant geographical variance. In 2021, Asian developing countries alone discharged 50% and loaded 35% of the world's total cargo (UNCTAD, 2023a). Singapore, the United States, the United Arab Emirates, the Netherlands, Russia, the Republic of Korea, and China account for the biggest portions of international shipping bunkering (IRENA, 2021). Container shipping is responsible for over a quarter of international shipping's energy consumption and bulk carriers for just under a quarter. The remaining 50% comes from oil, liquefied natural gas, and chemical tankers, among others (IRENA, 2021).

Maritime trade volume is expected to grow at a slow pace (UNCTAD, 2023b), and although shipping still relies on an ageing fleet that uses highly polluting fossil fuels, it remains the most carbon-efficient method of transporting goods over long distances (Harrison et al., 2024). The legacy of the Covid-19 pandemic and disruptions to trade and supply chains resulting from geopolitical tensions raise many challenges, with major uncertainties for shipping on its path to decarbonize (IRENA, 2021). Efforts have been made to reduce the sulphur content in marine fuels (IMO, 2020). While such efforts give rise to other issues in the near future (Carbon Brief, 2023), they indicate the potential for regulation to reduce harmful GHGs. However, much more is needed to shift and define the sector's pathway to net zero across GHGs as a whole.

The global regulator for shipping, the International Maritime Organization (IMO), set clear targets for the sector's full decarbonization by 2050 in its 2023 GHG reduction strategy (IMO, 2023a). Concrete measures—both economic and technical—for delivering on this strategy are expected to be approved in April 2025. They are likely to shape the shipping industry for decades and influence global trade patterns, with implications for all nations, particularly developing countries, least developed countries (LDCs), and small island developing states (SIDS).

Full decarbonization of the sector by 2050 will require huge investments and is expected to lead to higher maritime logistics costs, raising concerns for vulnerable, shipping-reliant nations like SIDS. Notably, UNCTAD (2023b) has outlined how developing countries, LDCs, and SIDS may experience higher domestic inflationary pressures due to limited capacities to mitigate the pass-through effects of energy transition costs in shipping and the associated increase in maritime logistics costs.

Although the interplay between trade and climate change mitigation efforts has gathered some attention in recent years, crucial elements of the trade, climate, and shipping interface have remained largely unexplored. This briefing note examines some of these interactions, with a specific focus on the regulation of shipping's GHG emissions following the revised IMO (2023a) reduction strategy, including implications and considerations for developing countries.

2. Climate Action and Impact Scenarios in Shipping: The Road to 2050

Global Policy Framework

Unlike many economic sectors, international shipping is not included in the Paris Agreement adopted under the United Nations Framework Convention on Climate Change (UNFCCC). Shipping's decarbonization trajectory is set by its global regulatory body, the IMO, which is a specialized UN agency.

In 2023, IMO members agreed on a new GHG strategy that set an end date for fossil fuel consumption by targeting net-zero GHG emissions "by or around, i.e. close to, 2050," with indicative emission reduction targets for 2030 and 2040 (IMO, 2023). A key additional target for 2030, endorsed in 2021 by the Getting to Zero Coalition and since adopted by the IMO, is the breakthrough target of 5% uptake of zero and near-zero emission fuels, with a stretch goal of 10%.[38] This target underscores the importance of early action and is a critical indicator of the sector's progress towards meeting global climate goals. While the ambitions set out in the IMO's strategy are not fully aligned with the Paris Agreement's goals, it calls on members to pursue efforts towards these goals.[39]

The IMO's revised GHG reduction strategy initiated the development of a so-called "basket of mid-term measures" that includes two categories: technical measures (or direct regulatory approach) and economic measures. Technical measures such as a global fuel standard mandate progressive reductions in fuel or energy GHG intensity over time, supporting the energy transition by setting clear requirements and a more predictable emissions reduction pathway.

Economic measures aim to financially incentivize member states, shipping companies, and other stakeholders to align with the IMO's overarching goals, which include safety, security, and sustainability. Such measures could include market-based instruments, financial support mechanisms, or funding for research and development.

Economic measures can create two different types of incentives for the energy transition:

- When acting on GHG prices, they can increase the cost of higher GHG intensity fuels and thus increase the competitiveness of more expensive lower GHG intensity fuels.
- When acting on GHG prices in combination with revenue disbursement mechanisms, they can also function as a fuel/energy subsidy to stimulate the early uptake of scalable zero-emission fuels (SZEF).

Several policy measures and combinations thereof are currently under discussion at the IMO. Proposals include a global GHG levy, which imposes a fixed cost on emissions; a fuel intensity target with a funding and reward mechanism that incentivizes greener practices; and feebate systems, which penalize high-emission ships while rewarding those with low emissions.

The global nature of the shipping industry underpins the need for a fully global transition towards zero-emission goals, a level playing field, and the adoption of measures that facilitate a just and equitable transition, as stipulated in the IMO's 2023 GHG reduction strategy. To support such a transition, the strategy underscores the importance of financial assistance, technology transfer, and capacity building for developing countries, particularly LDCs and SIDS.

38. The target was identified by the UN High Level Climate Champions and the Global Maritime Forum. The Getting to Zero Coalition is an alliance of more than 200 organizations in the maritime, energy, infrastructure, and finance sectors (Global Maritime Forum, n.d.).
39. The Paris Agreement seeks to strengthen the global response to the threat of climate change by keeping global temperature rise to well below 2oC above pre-industrial levels by 2100 and to pursue efforts to limit temperature rise to 1.5oC.

However, achieving equity in the transition poses several challenges. Many LDCs and SIDS rely heavily on maritime trade and lack the financial capacity to meet stricter regulatory requirements or invest in advanced technologies. Without adequate support, these nations could face disproportionate economic burdens, such as increased shipping costs that affect their imports and exports. Additionally, access to new low-carbon technologies and fuels often remains limited in developing regions. Ensuring inclusive decision-making processes and providing targeted financial mechanisms, such as reinvesting revenues from levies into developing country infrastructure and training programmes, will be essential to addressing these disparities and enabling a fair, inclusive, and just transition.

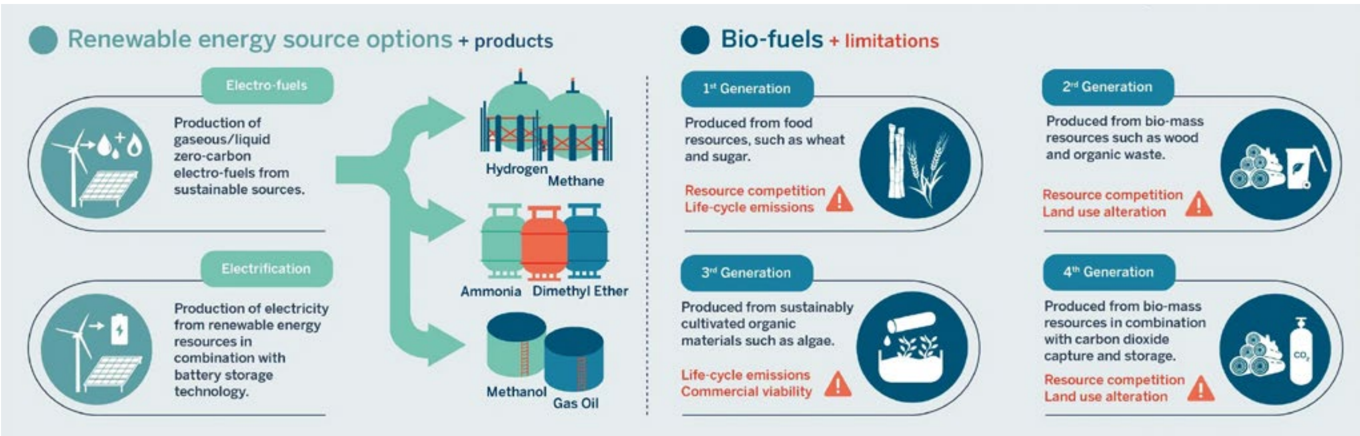
The potential impacts of different measures on countries and the global fleet are currently being assessed. A combination of measures is expected to enter into force in 2027 at the earliest. This means that the strategy alone will have a limited effect on unlocking private sector investments before the second half of this decade. Investment decisions must therefore be made before then (Global Maritime Forum, 2023b).

Technology and Fuel Deployment

A wide range of technologies can help reduce GHG emissions from shipping. Short-sea or domestic ships can be suitable for electrification in certain circumstances, while fuels that support a low-carbon transition include electrofuels (e-fuels), such as hydrogen, methanol, and ammonia, and biofuels (see Figure 1). Variations in production methods among these fuels result in differing carbon intensities and other environmental impacts. For example, blue hydrogen is produced from fossil fuels (like natural gas), but carbon capture and storage technologies limit the carbon intensity of the process, whereas green hydrogen is produced using renewables and does not emit any carbon. Other technologies include wind-assisted propulsion, which can reduce fuel needs, as well as batteries and nuclear power. Improving the energy efficiency of vessels and digitalizing key processes also contribute to fuel reductions.

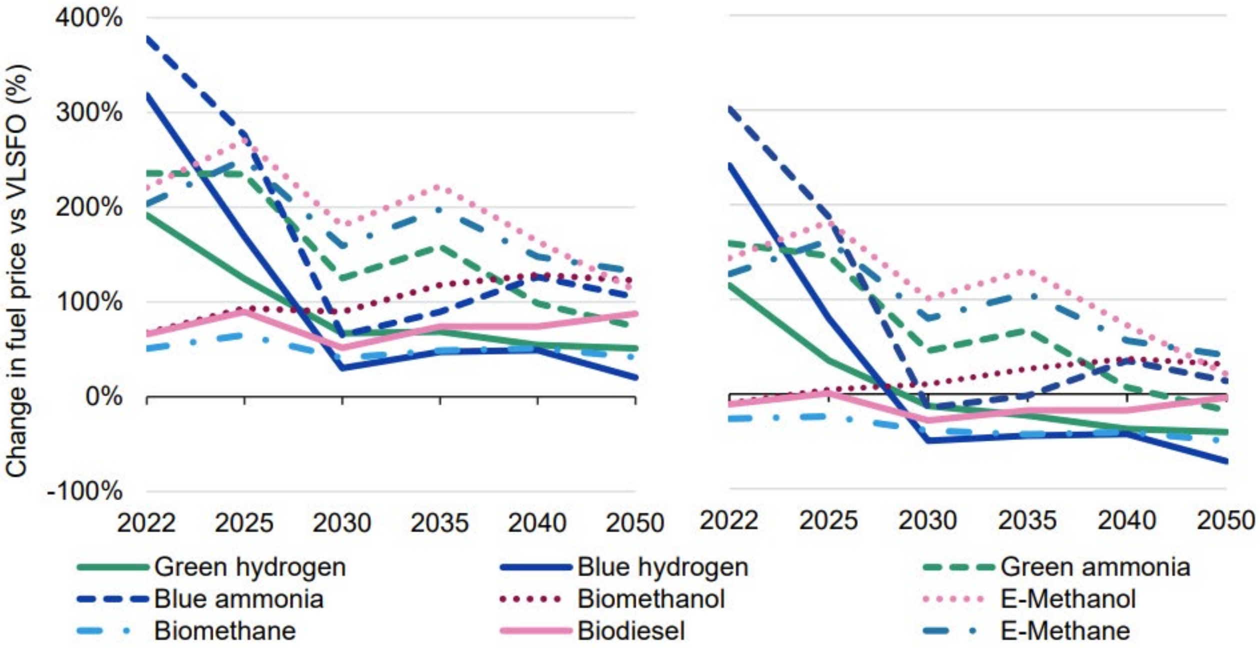
The uptake of SZEF—i.e. fuels able to meet rapid demand driven by decarbonization targets between 2030 and 2050—is at the heart of the challenge. The fuels most likely to be scalable are those that rely primarily on electricity as an input, or the so-called e-fuels like e-methanol and e-ammonia. However, there is a sizable cost gap between SZEF and fossil fuels. Figure 2 shows fuel cost forecasts relative to very low sulphur fuel oil (VLSFO) for a range of fuels

Figure 1. Zero-Carbon Fuels for Shipping



Source: UMAS (n.d.).

Figure 2. Forecast of Fuel Costs Relative to Very Low Sulphur Oil



Note: Forecast of fuel costs relative to VLSFO after accounting for the impact of additional energy efficiency measures, without a €100/t carbon price (left), and with a €100/t carbon price (right).

Source: IMO (2023b).

Although Figure 2 indicates the anticipated reduction in fuel costs, comparing scenarios with and without a carbon price, it is important to underline that the costs of SZEF remain uncertain. There are expectations that biofuel prices will go up as demand exceeds sustainable supply and e-fuel prices will come down—but both will remain more expensive than fuel oil in the long term.

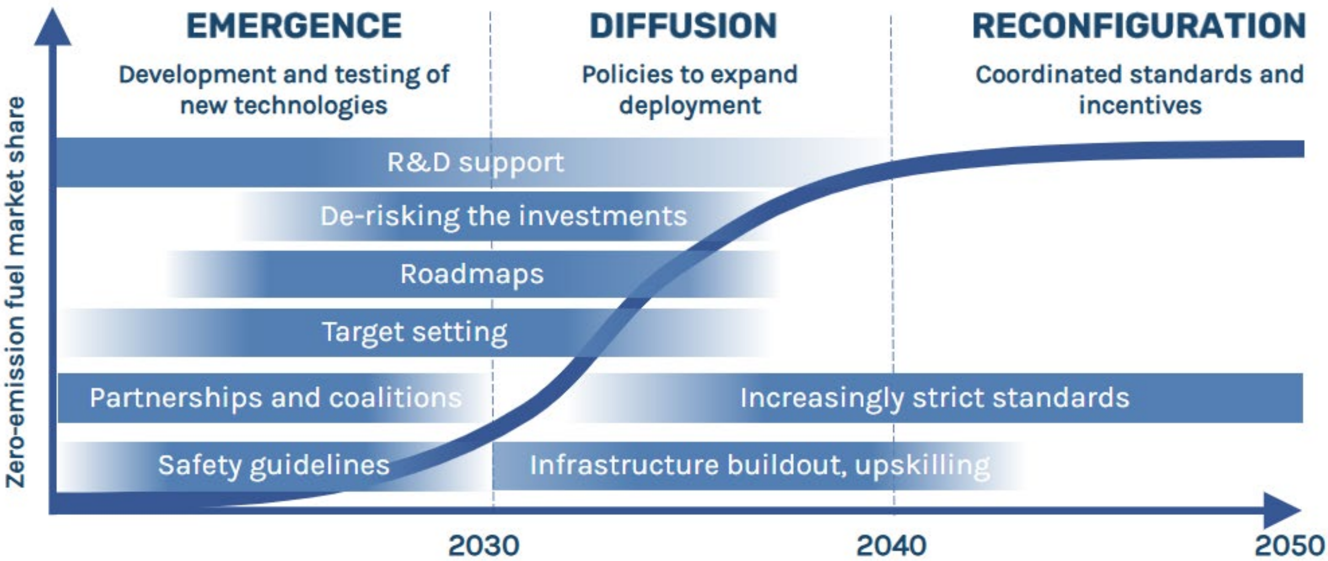
In the short term, ensuring that supply and demand can be matched (i.e. solving the "chicken and egg" problem) so that fuel production projects can reach a final investment decision is crucial to reaching the IMO 2030 SZEF targets, with lead-in times of 5–7 years. However, scaling the fuel is not only a challenge in terms of volume but also in ensuring its broad uptake across geographies and availability across sectors. Technological inclusivity—a concept coined by the IMO—is pertinent here. In the context of discussions on securing a just and equitable transition, the transfer of technologies to developing countries and regions is as important as ensuring that these countries have access to affordable zero-emission technologies—for example, vessels capable of running on SZEF or the ability to produce and bunker such fuels.

Progress So Far

The IMO strategy provides the industry with a clear pathway for shipping decarbonization by pointing to the need to invest at scale in zero-emission fuels and technologies. However, reaching net zero cannot be driven by the IMO strategy alone. To deliver on a just and equitable energy transition, the strategy needs to be backed by ambitious national and regional policies as well as industry initiatives to support investments in zero-emission shipping.

Figure 3 illustrates the non-linear nature of technological transitions in which the speed of adoption follows an S-curve rather than a straight line. Shipping is currently in the middle of the emergence stage along the S-curve, with policy needs specific to this stage that must also shift over time.

Figure 3. Technological Transitions and the S-Curve



Source: Global Maritime Forum (2023c).

In the emergence stage, research and development policies that are guided by the transition targets and other signals of long-run intent are key. Towards the end of the emergence phase, when the first generation of promising technologies has crystallized, policy needs gradually shift towards facilitating market introduction. At this stage, successful policies contribute to matching supply and demand by bridging the cost gap and de-risking the initial commercial roll-out. The diffusion stage requires policies that support the build-out of infrastructure, followed by the reconfiguration stage which should see the universal implementation of green technologies.

An increasing number of industry-led alliances have been established around low-carbon objectives, such as the Getting to Zero Coalition and the First Movers Coalition,[40] which enable, encourage, and support their members in the emergence phase. These alliances commit to decarbonization trajectories consistent with IMO targets and offer space for collaboration on key challenges.

Green corridors are also proving suitable for the emergence phase. These specific trade routes where zero-emission solutions are demonstrated and supported by public and private action cut through some of the complexities in coordinating shipping decarbonization efforts. Green corridors allow policymakers to create an enabling ecosystem with targeted regulatory measures, financial incentives, and safety regulations. For developing countries, participating in green corridor initiatives offers the opportunity to connect to significant demand sources for zero-emission fuels while collaborating on key barriers to scaled production in response to this demand, such as low-cost financing, bankability, and standards. The Global Maritime Forum leads or supports the delivery of a number of green corridors and monitors overall progress on these specific routes

40. The First Movers Coalition is a global coalition of companies leveraging their purchasing power to advance emerging climate technologies to decarbonize the world's heavy emitting sectors, including shipping (World Economic Forum, n.d.).

annually (Global Maritime Forum, 2023a). Notably, the South Africa-Europe Iron Ore Green Corridor is exploring the opportunity of a decarbonized iron ore route, investigating synergies between the greening of this corridor and the production and export of green hydrogen and ammonia from southern Africa to Europe for use in steelmaking, among other industries.

Increasing work to develop aggregation mechanisms can also help solve the persistent "chicken and egg" problem in the uptake of SZEF. By aggregating demand or supply, concerns over matchmaking can be offset and risks shared. Aggregation can be carried out on the supply side (e.g. fuel producers) and/or the demand side (e.g. liners, cargo owners) and with third parties such as governments (Global Maritime Forum, 2024a). For developing countries, supply and demand matchmaking schemes (e.g. between the Global North and South) supported by capital from multilateral development banks could incentivize the development of strong investment rationales for fuel production. Another potential opportunity for developing countries is to mobilize cargo owners' willingness to pay to cover all or part of the cost gap for SZEF. The Zero Emission Maritime Buyers Alliance is making important steps in this space, recently announcing the results of its first auction process (Zero Emission Maritime Buyers Alliance, n.d.). In the future, directing such schemes or their equivalent to developing countries could help address the cost gap.

Finally, recent actions on the part of governments and the European Union, including the adoption of the FuelEU Maritime initiative and the launch of the Clydebank Declaration for green shipping corridors, challenge the long-standing assumption that international shipping lies outside of the jurisdictions of individual countries (Global Maritime Forum, 2023c). Meaningful government support is essential, with policy pathways for each country determined by a combination of domestic strengths, ambitions, and current and envisioned position in the global shipping ecosystem. Such government support needs to happen at a much larger scale across a wider set of geographies, including through the initiation of and participation in first-mover initiatives, unblocking regulatory hurdles, incentivizing the uptake of alternative fuels, and providing financial assistance, not least in developing countries.[41]

3. Trade-Related Trends and Dynamics in Shipping

Recent Trends

With the value of global maritime trade estimated at $14 trillion in 2019, maritime transport, in particular container shipping, underpins the global economy (International Chamber of Shipping, 2021). Trade impacts the volume, value, composition, patterns, and trends of international shipping.

Beyond the challenges associated with decarbonizing the sector, international shipping faces multiple disruptions, including heightened trade and geopolitical tensions. The Covid-19 pandemic, the war in Ukraine, and tensions in the Horn of Africa have had significant impacts on global shipping over recent years, leading to disrupted supply chains and rising trade costs and consumer prices. The global energy and cost-of-living crises will impact global shipping for years to come. Additionally, national responses to these dynamics have seen the proliferation of trade protectionism and inward-looking policies, with economic implications for developed and developing economies (International Chamber of Shipping, 2022).

The World Trade Organization (WTO) plays a key role in the governance of shipping trade. An important issue in relation to the decarbonization of international shipping will be the response, in the WTO context, to the implementation of IMO mid-term GHG reduction measures, including possible carbon pricing instruments. In

41. An example of effective government support is the H2Global initiative, which combines some of the elements described above as a cost-effective method for closing the cost gap (H2Global Stiftung, n.d.).

previous rounds of negotiations, some IMO member states have argued that existing WTO law could limit the ability of the IMO to implement carbon pricing for shipping—or at least some forms of pricing. In practice, this will depend on the legal instruments and procedures employed by the IMO to adopt a GHG pricing instrument. Existing analysis would indicate, however, that there are probably limited grounds to challenge an IMO GHG pricing instrument under WTO law—especially if the GHG price is implemented as a direct payment from vessels to an international fund (Dominioni, 2024).

Climate Action, Trade, and Implications for Developing Countries

The cost of zero- or near-zero-carbon fuels for international shipping is significantly higher than conventional fuels like heavy fuel oil. The additional requirement of retrofitting or building new vessels capable of running on these fuels, as well as developing the infrastructure for bunkering and transporting them, further raises the cost of the transition. With shipping generally operating with low profit margins, liner companies are unlikely to absorb increased costs unless their clients (e.g. cargo owners) are willing to pay more or pass the extra costs on to consumers. IMO regulations, along with national or regional policy measures, will make fossil fuels more expensive over time. It is estimated that approximately $3.2 trillion of investment, supported by effective regulation and subsidy schemes, is needed to achieve the low-carbon transition in the near term (Global Maritime Forum, 2024b).

There is significant debate at the IMO about the implications of such measures and how to make the transition just and equitable. Core principles include addressing the disproportionate negative impacts of policy measures, allowing equal access to the required infrastructure and technologies, reducing GHG emissions to minimize further impacts of climate change on vulnerable states, supporting wider climate adaptation and climate mitigation efforts, and unlocking global opportunities for fuel production.

The 2023 IMO GHG reduction strategy requires a comprehensive impact assessment to evaluate the potential effects of the proposed measures on the global fleet and individual states before they are adopted. Assessing the impact on states is especially crucial for developing countries, particularly LDCs and SIDS. The comprehensive impact assessment has examined the economic, social, and environmental impacts of the proposed basket of mid-term measures, including a marine fuel standard and a GHG emissions pricing mechanism. The results of this assessment, presented at the 82nd session of the Marine Environment Protection Committee in September 2024, will continue to inform decision-making before the measures are finalized and adopted in 2025.[42]

The assessment of the impacts on states conducted by UNCTAD explored the simulated impacts on imports, exports, gross domestic product (GDP), and consumer prices resulting from the increase in shipping time and maritime transport costs at three points of time: 2030, 2040, and 2050 (IMO, 2024). These projections are based on hypothetical policy measures and consider the potential allocation of generated revenues.[43]

As a result of the policy measures to discourage the use of fossil fuels, maritime logistics costs are expected to increase over time. It is probable that a global fuel standard would affect lower income countries the most. Research indicates that that these impacts will likely differ across geographies and over time in the transition (Transport & Environment, 2022). Notably, a levy is expected to entail higher costs earlier in the transition but decrease towards 2050 compared to scenarios without a levy. However, revenue disbursement, if combined with a high levy, has the potential to economically support developing countries, LDCs, and SIDS. Alongside a levy that provides for revenue disbursement, clear support for early adoption and scaling of SZEF is essential. As discussed below, demand for new fuel production in developing countries with renewables capacity may also create economic and trade opportunities for these countries.

42. The Marine Environment Protection Committee addresses environmental issues under the IMO's remit.
43. The projections have been disputed by several member states.

4. Opportunities and Challenges for Developing Countries

Trade-Related Opportunities

There are several trade opportunities for developing countries in the low-carbon transition, in particular the production of low-cost hydrogen and its derivatives. Indeed, geographies with significant potential in solar energy or other renewables could produce low-cost hydrogen and derivative hydrogen fuels (e.g. e-methanol and green ammonia) that shipping will rely on for its decarbonization. In addition to using these fuels to power maritime transport at ports in developing countries, exporting the fuels could provide a significant economic opportunity, with demand for e-fuels projected to exceed 500 million tonnes by 2040 (Global Maritime Forum, 2024b). Green ammonia trade, in particular, is likely to be more diversified in its production locations due to its specific characteristics that enable long-distance transport from low-cost production regions to key bunkering hubs (Zero-Emission Shipping Mission, 2024).

However, there are concerns that substantial public funding for hydrogen-related investments in Europe and North America could place projects in emerging markets and developing economies at a disadvantage, with the disparity in renewable energy financing between developed and developing countries having increased significantly over recent years (IRENA, 2023). Geographical location will be an important factor in the ability to exploit the potential to become a major fuel supplier, with countries closer to key markets likely to have a competitive advantage.

Carbon pricing can help level the playing field between fossil fuels and zero-carbon bunker fuels while generating revenues that can be used to support the creation of a global zero-carbon energy supply infrastructure for shipping. Elements in the different combinations of policy measures being considered— e.g. revenue disbursement and flexibility mechanisms—could also help ensure a just and equitable transition by addressing some developing country concerns (Global Maritime Forum, 2024d). According to the World Bank (2021), targeted investments towards developing countries that are well positioned to produce zero carbon bunker fuels could help allay some existing controversies in the policy debate around common but differentiated responsibilities and respective capabilities, a guiding principle of both the UNFCCC and the IMO GHG reduction strategy.

If a revenue distribution mechanism is agreed upon by the IMO, developing countries may be able to access financial support to develop their hydrogen potential alongside projects implemented through country programmes with official development assistance or through multilateral development banks. The hydrogen economy could contribute significantly to the economies of developing countries and regions. For example, it is estimated that the hydrogen industry in South Africa could generate 1.9–3.7 million jobs and contribute $60 billion to GDP by 2050 (Business Tech Africa, 2023). Globally, the decarbonization of the global maritime industry could support the creation of up to four million jobs by 2050 (Global Maritime Forum, 2024b).[44]

Key Challenges

Establishing significant export volumes of green hydrogen-derived fuels will come with some challenges. Attracting finance and investment requires bankable projects, which remains a key barrier to the deployment of renewable energy (ESMAP, 2023). Responding to this challenge requires coordinated support from governments and multilateral

44. Among a number of projects being announced, a green hydrogen production project in Namibia is expected to see N$70 billion ($4 billion) in investment over the next five years (The Brief, 2024).

development banks, targeting country risks and establishing effective regulatory environments. An important issue here is the need for subsidization and other market-based measures to be compatible with WTO disciplines.

Harnessing the potential for employment creation in the transition to zero-emission fuels in shipping will also require retraining and upskilling across renewable energy generation, as well as hydrogen and e-fuel production (Global Maritime Forum, 2024c). Knowledge and technology transfer will also be crucial to ensuring the development of suitable safety protocols for the handling and use of e-fuels in shipping.

Cooperation for the Net-Zero Transition

One of the key opportunities for developing countries to engage and cooperate on the low-carbon transition is through the IMO negotiations on the development of mid-term measures. As discussed, the comprehensive impact assessment sought to understand how different groups of countries may be impacted, positively or negatively, by the measures being proposed in their various combinations. An additional assessment on the implications for food security is ongoing within the IMO. As noted, some options are more advantageous than others when it comes to the impacts on trade of developing countries, LDCs, and SIDS. Participating in this process, while exploring the opportunities that the low-carbon transition brings in other aspects (e.g. fuel production potential) will enable the co-creation of improved solutions.

International cooperation on shipping decarbonization, including through knowledge exchange platforms, coordinated innovation efforts such as the Zero Emission Shipping Mission,[45] or green corridor initiatives, can improve knowledge exchange and share the risks associated with the low-carbon transition as well as maximize the opportunities.

By testing and deploying fuels, vessels, and infrastructure in a coordinated manner, corridors between developed and emerging and developing economies and regions could provide a framework for supporting investment in zero-emission shipping in developing countries, serving as an additional channel for climate finance. This could take the form of bilateral funding for shared corridor assets and/or commercial arrangements designed to leverage the greater creditworthiness and access to capital of companies in developed economies (Global Maritime Forum, 2023a). The South Pacific and South Atlantic regions have witnessed an increase in activity in this regard, with new initiatives emerging in South America and Africa, although the numbers remain low. Notably, the World Bank is completing a feasibility study on the potential for green ammonia production in the Saldanha Bay region of South Africa, which is also under exploration for an iron ore green shipping corridor (Salgmann et al., 2024; Global Maritime Forum, n.d.).

5. Priorities for Policy Engagement and Future Analysis

Trade and shipping are intricately linked. With multiple possible pathways to net zero, significant financial and technical challenges in the use of SZEF, and major regulatory decisions lying ahead, the shipping sector faces serious challenges on its path to reaching net zero by 2050. Upcoming decisions at the IMO will have important implications for shipping's low-carbon transition and therefore international trade.

Securing this transition is essential, with the cost of inaction far outweighing the necessary investments. Managing the implications of projected shifts in trade and ensuring that this transition is just and equitable are critical policy challenges. These issues will require consideration of the impacts of measures on different countries and regions as well as the development of policy frameworks that address the opportunities and needs of developing economies.

Achieving these opportunities will require developing port infrastructure that is both climate-resilient and fitted for the transition, notably in LDCs and SIDS, while exploring strategies such as the production of hydrogen or e-fuels that

45. The Zero Emission Shipping Mission is a global initiative of 23 countries and the European Commission (on behalf of the European Union) whose goal is to demonstrate commercially viable zero-emission ships by 2030 (Mission Innovation, n.d.).

could bring economic and trade benefits. Adequate retraining and reskilling, including that of the more than two million global seafarers, will also be an integral part of a successful transition. Efforts are needed now to define a clear pathway to zero-carbon shipping that helps meet global climate targets and ensure climate resilience for growth and sustainable development.

Building on the analysis in this briefing note, there are three key policy engagement opportunities to seize for developing countries:

1. Engage productively in IMO discussions to ensure a just and equitable transition that achieves decarbonization objectives.
2. Explore hydrogen production potential in anticipation of maritime decarbonization efforts from 2030 when demand for zero-emissions fuels is expected to grow rapidly.
3. Cooperate with a diverse range of stakeholders in the value chain to maximize technology transfer and knowledge exchange, including through participation in relevant initiatives like green corridors.

Finally, it is important to note that decarbonized shipping positively impacts the transition of other economic sectors and can help achieve the climate and sustainable development goals of many countries. The growing focus on Scope 3 emissions is notably driven by corporate decarbonization targets and is heavily reliant on the shipping industry's ability to reduce emissions from transport.[46] Low-carbon shipping can help decarbonize hard-to-abate industries such as steel or cement by unlocking fuel production and zero-emissions infrastructure and offering early offtake of hydrogen-derived fuels.

Looking ahead, further research is needed on the interplay between trade and shipping regulatory frameworks in achieving net-zero pathways, including on the opportunities and challenges of carbon pricing, carbon border adjustment measures, and green fuels development as well as on ensuring a transition that is just and equitable. This could help inform the development and implementation of effective and sustainable decarbonization policies in the maritime sector and offer insights into broader climate change governance.

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46. Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly affects in its value chain (EPA, n.d.).

TEXTILES AND GARMENTS

Patrick Schröder

1. Trade, Climate, and Sustainable Development Nexus in the Textile and Garment Sector

The textile and garment sector plays a significant role in the global economy, particularly for developing countries. Global trade and liberalization of market access for garments and textiles have generated significant welfare gains for developing countries. At the same time, however, the sector is also a major contributor to environmental degradation, with significant greenhouse gas (GHG) emissions across different stages of its value chain (Samant et al., 2024). From the cultivation of cotton and other raw materials to the production, spinning, transportation, retail, use, and eventual disposal of garments, each stage contributes to the sector's substantial carbon footprint. The production phase, which involves energy-intensive processes like spinning, weaving, and dyeing, is particularly emissions intensive.

The quantification of GHG emissions across the global textile and garment value chain has been the subject of various studies and reports, leading to differing estimates. At the lower end, the World Resources Institute estimates that 1.025 gigatonnes (Gt) of carbon dioxide equivalent (CO2e) were emitted in 2019, or roughly 2% of annual global GHG emissions (Sadowski & Cummis, 2022). Material production, such as knitting, weaving, dyeing, and finishing, contributes to over 50% of these emissions. Upstream raw material production, such as cotton farming and oil and gas extraction for synthetics, creates roughly another quarter of emissions. Another estimate by McKinsey & Company and Global Fashion Agenda (2020) estimates the textiles value chain accounting for 4% of global emissions (2.1 Gt CO2e) in 2018—about the same quantity of GHG emissions per year as the entire economies of France, Germany, and the United Kingdom combined. At the top end of estimates, the global fashion industry is responsible for up to 10% of annual global carbon emissions, more than all international flights and maritime shipping combined. This estimate includes indirect emissions across the life cycle, such as those from transportation and energy use in retail (European Parliament, 2021; Leal Filho et al., 2022).

The sector is intricately linked with the climate crisis in multiple ways, not only through its emissions. It is also vulnerable to the impacts of climate change, such as water scarcity, extreme weather events, and changing agricultural conditions that affect raw material supplies. For developing countries, where the textile and garment industry often represents a large share of industrial activity and employment, these climate impacts pose significant risks to economic stability and employment. Extreme heat and flooding have been identified as key threats to international apparel hubs, with four countries—Bangladesh, Cambodia, Pakistan, and Vietnam, which collectively account for 18% of global apparel exports—risking losing one million jobs and facing losses of $65 billion by 2030, equivalent to a 22% decline in export earnings. By 2050, continuing current practices in the four countries leading production could result in 68.8% lower industry earnings and the loss of 8.6 million jobs, a 34.5% employment drop (Catt, 2023).

Furthermore, climate-induced disruptions can affect supply chains and shipping, leading to increased costs and trade uncertainties. Leading apparel retailers are beginning to assess the potential risks to company suppliers from a wide range of climate events, including hurricanes, droughts, and wildfires (S&P Global, 2024). This is because a significant portion of raw and finished fabric used in a company's manufacturing processes is sourced from providers in developing countries, which often have high climate-related vulnerabilities.

Given its importance for low- and middle-income countries, the textile and garment sector has a critical role to play in both climate mitigation and climate-resilient development. Sustainable and circular practices within the industry can reduce emissions, promote efficient resource use, and enhance resilience to climate impacts. As a key driver of economic activity in this sector, trade intersects with climate actions in complex ways: international trade policies can either support or hinder climate objectives. Understanding these interlinkages is thus essential for crafting effective strategies for the sector that promote decarbonization, trade, employment creation, and climate resilience.

2. Climate Action and Impact Scenarios in the Textile and Garment Sector: The Road to 2050

International commitments related to climate change, such as the Paris Agreement, emphasize the need for significant reductions in GHG emissions. Large textile and garment producer countries, including China, Bangladesh, the European Union (EU) (Germany, Italy, Spain), India, Pakistan, Türkiye, the United States, and Vietnam, are beginning to establish sectoral GHG emission reduction targets, most of which are, however, not mandatory. For the textile and garment sectors in these countries, some key commitments include those related reducing emissions through energy efficiency in manufacturing and investing in renewable energy. In China, for example, carbon emissions of the textile and apparel industry stand at about 230 million tonnes annually, accounting for 2.8% of national industrial emissions. A decarbonization roadmap to 2030 has been laid out and the sector is expected to reduce carbon emissions through market-oriented approaches such as carbon trading mechanisms. (Zhu, 2023). In 2022, the textile sector was included in the Guangdong provincial carbon trading scheme (King & Wood Mallesons, 2023). In Bangladesh, the ready-made garment (RMG) sector contributes 15.4% of the country's GHG emissions while the textile sector emits 12.4%, which poses a challenge to achieving the South Asian nation's GHG reduction targets (Shuvra Halder & Raju, 2024). In its updated Nationally Determined Contribution from 2021, Bangladesh has committed to a 6.73% GHG reduction in the unconditional scenario and an additional 15.12% reduction in the conditional scenario with international support by 2030 (Bangladesh Ministry of Environment, Forest and Climate Change, 2021).

When it comes to countries' nationally determined contributions (NDCs) submitted as obligation under the Paris Agreement, out of the 10 major exporting countries, only Pakistan's NDC includes a mention of the textile and garment sector, where it plans to promote bottom-up actions by the private sector and develop plans for emission reductions from textiles and garments. Overall, the information on national textile sector GHG emissions is not very robust, as there is a lack of standardized methodologies applied internationally, resulting in significant data gaps. (Table 1).

At the 2028 UN Climate Change Conference (COP24), global fashion brands and producers signed the Fashion Industry Charter on Climate Action committing to 30% aggregate GHG emission reductions in scope 1, 2, and 3 by 2030 (UNFCCC, n.d.-a). While this is an ambitious commitment, to be compatible with a 1.5 degree pathway, the global textile and garment sector would need to cut its GHG emissions even further—by almost 0.5 to 1.1 billion tonnes of CO2e by 2030. But growth calculations show that the industry is set to overshoot this target by almost twofold, with estimated emissions of 2.1 billion tonnes of CO2e in 2030 unless it adopts additional abatement actions (McKinsey & Company & Global Fashion Agenda, 2020). Reducing emissions in the sector at the scale and speed needed will require engagement with thousands of suppliers across multiple countries to measure emissions and identify and implement reduction measures.

Textile and garment manufacturing countries have significant challenges to reduce scope 2 emissions from the energy use for manufacturing activities.[47] In most countries the share of fossil fuels in primary energy consumption is well above 80% (Table 2). Maximizing energy efficiency in processing, especially spinning and

47. Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling.

Table 1. Trade Volumes, Export Shares, GHG Emissions (Estimates), and NDC Commitments of Major Textile and Garment Exporting Countries

Country	Trade Volume ($ billion)	Share of Global Exports (%)	Textile and Garment Annual Emissions / Share of Total Emissions	Included in NDC as Sector
China	303	32.2	230 million metric tonnes of CO2, 2.8% of national industrial emissions (Zhu, 2024)	No
Bangladesh	57.7	6.13	RMG sector contributes 15.4% of national GHG emissions, textile sector emits 12.4%	No
Vietnam	48.8	5.18	5 million metric tonnes CO2 (Vienam.vn, 2023)	No
India	41.1	4.36	No national data found	No
Germany	40	4.25	2 million metric tonnes CO2e direct emissions (overall footprint 38 million tonnes CO2e) (Oxford Economics, 2023)	No (as part of EU NDC submission)
Türkiye	36.7	3.9	No national data found	No
Italy	36.7	3.9	No national data found, but included in EU 121 million tonnes CO2e (EEA, 2024)	No (as part of EU NDC submission)
United States	29.8	3.17	445 million tonnes of CO2e (Normand, 2023)	No
Pakistan	22.1	2.35	9.5% of national GHG emissions (Sattar & Akhtar, 2022)	Yes (support for public-private and bottom up private sector action)
Spain	20.3	2.16	No national data found, but included in EU 121 million tonnes CO2e (EEA, 2024)	No (as part of EU NDC submission)

Sources: World Population Review (n.d.); UNFCCC (n.d.-b).

weaving, and eliminating coal for heat generation in manufacturing and shifting to renewables for electricity will be key solutions. Furthermore, rooftop solar panels are a primary way garment factories can invest in clean electricity; such initiatives can help to reduce the carbon footprint of the electricity supply and are often influenced by sourcing brands. For heat generation, bio-based feedstocks such as risk husk boilers can provide low-emission heat sources in supplier factories to directly reduce the use of coal (H&M Group, 2024).

Furthermore, initiatives around scope 3 emissions in the textile and garment sector is intensifying as brands, regulators, and consumers increasingly recognize the importance of addressing these indirect emissions, which often constitute the majority of a brand's carbon footprint.[48] In the textile and garment industry, Scope 3 emissions are particularly significant due to the globalized nature of supply chains and will require collaboration across multiple jurisdictions. Regarding methodologies to measure scope 3 emissions, the Science Based Targets initiative (n.d.)

48. Scope 3 emissions include all indirect emissions that occur in a company's value chain both upstream and downstream, such as those from raw material production, transportation, retail, product use, and disposal.

Table 2. Primary Energy Consumption in Selected Textile and Garment Producer Countries by Share of Fossils Fuels (%) and Fuel Type (Exajoules) (2023)

Country	Share of Fossil Fuels	Oil	Natural Gas	Coal	Nuclear	Hydroelectric	Renewables	Total
Bangladesh	98.9%	0.52	1.01	0.28	0	0.01	0.01	1.83
China	81.5%	32.73	14.57	91.94	3.90	11.46	16.13	170.74
India	89.3%	10.57	2.25	21.98	0.43	1.39	2.38	39.02
Indonesia	83.4%	6.65	3.33	4.54	0.70	0.70	1.49	17.40
Pakistan	81.9%	0.78	1.36	0.62	0.20	0.35	0.06	3.37
Türkiye	81.1%	2.30	1.74	1.65	0	0.60	0.71	7.00
Viet Nam	77.1%	1.20	0.26	2.32	0	0.76	0.36	4.89

Source: Energy Institute (2024).

provides a framework for companies to set emissions reduction targets in line with climate science. Many fashion brands are now setting scope 3 reduction targets under this initiative, which encourages companies to engage with their upstream suppliers and stakeholders to achieve these goals.

However, to achieve the global ambition of reaching net zero by 2050, the sector will need to undergo significant transformations that go beyond decarbonization of energy systems used in production and manufacturing. Current data and trends indicate that a growing focus needs to be placed on sustainable materials, material efficiency, and waste reduction. Several interventions can be implemented to reduce emissions across the textile and garment supply chain such as enhancing materials efficiency and circularity through reuse and recycling of materials, shifting to next generation materials and alternative materials e.g. hemp, bamboo (Sadowski & Cummis, 2022). Policies promoting circular economy principles—such as reuse, second-hand markets, and recycling of textiles—are highly relevant for the textile and garment industry. In developing countries, regional trends vary, but common themes include increasing adoption of sustainable agricultural practices for cotton production and investment in green technologies for manufacturing

By 2050, these technology and material innovations, supported by policies, have the potential to transform the sector substantially. We can expect to see a shift towards more circular and resilient supply chains, a greater emphasis on eco-friendly production processes, and the development of new products designed with circularity in mind. The sector may see a decline in traditional, high-emission production methods, while innovative, low-impact processes and materials gain prominence. These changes will not only influence the sector's environmental footprint but also its economic dynamics, potentially reshaping global trade patterns and competitive landscapes.

3. Trade-Related Trends and Dynamics in the Textile and Garment Sector

Textile and garment trade represented 3.9% of international merchandise exports in 2022, the world's seventh most traded product category, with a total trade value of $941 billion (OEC, 2023). Based on the current trajectory, latest growth estimates of the market volume of textiles and garments indicate that the global apparel market could grow by 3–4% annually post-2023, reaching approximately $2 trillion by 2030 (McKinsey & Company, 2024). In terms of volumes, total clothing trade and sales could reach 175 million tonnes in 2050—more than three times the amount traded in 2015 (Ellen MacArthur Foundation, 2017).

In the absence of decarbonization measures, emissions and environmental impacts across the textile and garment value chain can be expected to increase accordingly. Continued growth at the current pace of 3–4% per year would see the fashion industry's GHG emissions increase to approximately 2.99 Gt CO2e under a 3% annual growth rate and around 3.36 Gt CO2e under a 4% annual growth rate by 2030 (based on 2.1 Gt CO2e in 2018). Due to the growing demand for clothing, exacerbated by the proliferation of the fast fashion business model, it is projected that by 2050 the fashion industry could account for approximately 25% of the world's carbon budget associated with a 2oC global warming limit (Ellen MacArthur Foundation, 2017).

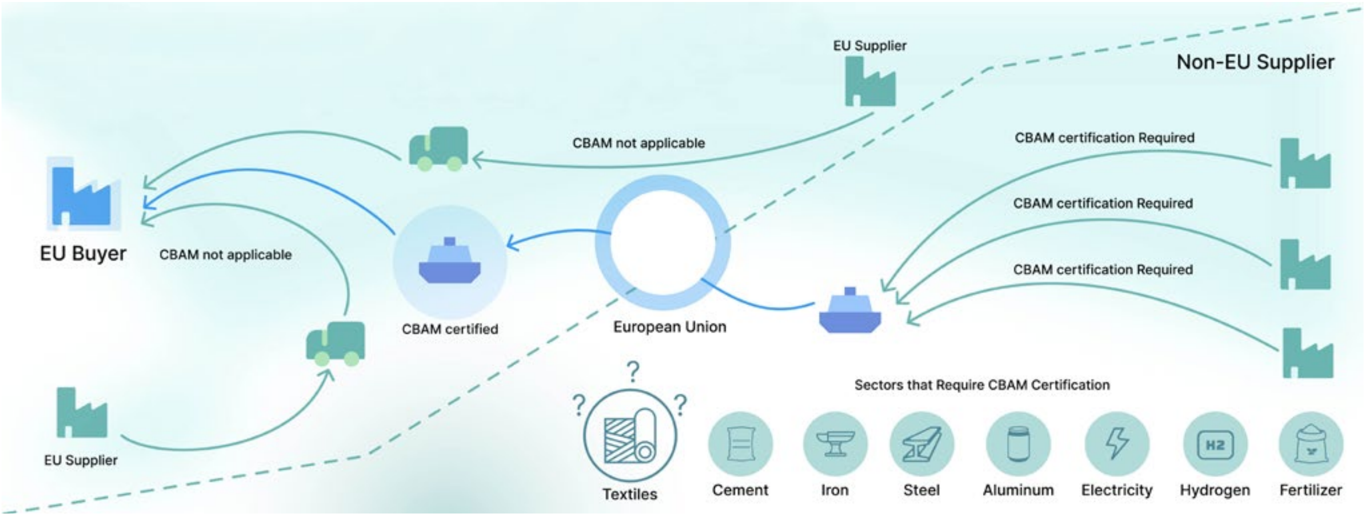
National climate mitigation policies and measures in the major consumer markets are expected to have implications for trade trends in the textile and garment sector. Mitigation efforts, such as carbon pricing and emission reduction targets, may increase production costs, influencing global trade flows and competitiveness.

In the United States, the Climate Corporate Data Accountability Act (SB 253), a new California state law that requires large textile and apparel companies (with more than $1 billion in annual revenue) to report their scope 3 emissions, which often account for the majority of a fashion brand's carbon footprint and occur outside the United States, will take effect in January 2026. The first reports will be due in 2027 (Lüttin, 2024).

Data and reporting on scope 3 emissions will be necessary for the introduction of border carbon adjustments (BCA). This could significantly affect textile and garment trade, particularly for countries that are major exporters to regions like the EU, which has introduced its Carbon Border Adjustment Mechanism (CBAM). The United Kingdom is considering the introduction of a BCA from 2027 (HM Treasury, 2024). In its current transitional phase (2023–2026), the textile and garment sector is not part of the EU's CBAM, however, given the emissions involved in the manufacturing process of textiles, it might come under its umbrella in the years following application of the definitive regime (2026–2034) (GreenStitch, 2024; Fibre2Fashion, n.d.).

BCAs would impose additional costs on textiles and garments imported into consumer markets such as the EU from countries with lower or no carbon pricing mechanisms. The estimate for textile unit production cost increases from carbon pricing (assuming a carbon price of $50 per tonne in 2030) would be 2–3% for China and the US, and about 9% for India (significantly lower than for other sectors such as iron and steel and non-ferrous metals) (Keen et al., 2021). On a product level, for a t-shirt manufactured and exported to the EU for example (assuming an average price of $60/tonne of CO2), a BCA could add about 20 cents, with the cost of carbon emissions alone accounting for 30–40% of processing costs (Vietnam.vn, 2023) (see Figure 1 for a depiction of the potential implications of a CBAM transition for the textiles sector).

Figure 1. CBAM Transition: Opportunities and Challenges for the Textiles Sector



Source: GreenStitch (2024). © 2024 GreenStitch Technologies Pvt Ltd

As noted, in addition to measures that target sector emissions, there are also efforts underway to create a more circular textiles economy that focuses on material efficiency and reduction of material throughput and waste generation. The EU, for example, is advancing policies to promote circular textiles, focusing on integrating recycled content into products to reduce waste and resource consumption. A key policy initiative is the EU Strategy for Sustainable and Circular Textiles launched in 2022 (European Commission, n.d.-b).

Another policy train that is being rolled out over the next years in the EU is the Ecodesign for Sustainable Products Regulation (ESPR), which entered into force in July 2024 (European Commission, n.d.-a). This policy enables the setting of performance and information conditions—known as ecodesign requirements—for almost all categories of physical goods, including textiles and garments. While the detailed ESPR work plan is still being developed (expected to be adopted in the first half of 2025), the new ecodesign requirements for textiles (including garments and footwear) will likely cover the design of textiles, ensuring they are more durable, reusable, repairable, and contain a significant proportion of recycled materials. Furthermore, the adoption of the first ESPR rules to operationalize measures on the destruction of unsold consumer products goods will happen in the first year of the ESPR.

Additionally, the ESPR will introduce a Digital Product Passport (DPP)—a digital identity card for products, components, and materials, which will store relevant information to support the sustainability of products, promote their circularity, and strengthen legal compliance. This tool is expected to enhance the textile industry's traceability, circularity, and transparency. The information will be accessible electronically, making it easier for consumers, manufacturers across different supply chain tiers, and authorities to make informed decisions related to sustainability, circularity, and regulatory compliance. It would also allow customs authorities to perform automatic checks on the existence and authenticity of the DPPs of imported products.

Given the complexity and technical requirements of a DPP for textiles and garments, there would be a step-by-step scenario for the deployment of a DPP in three phases (this is currently hypothetical and not mandated by legislation) (European Parliamentary Research Service, 2024):

- Phase 1. Deployment of a "minimal and simplified DPP" for textiles on a short-term horizon of 2027. This proposed minimal and simplified DPP is mainly based on the dissemination of mandatory information, completed with additional information that would be useful for life cycle analysis.
- Phase 2. Deployment of an "advanced DPP" for textiles on a mid-term horizon of 2030. This advanced DPP could be progressively extended to other stakeholders with more information collected across the life cycle, based on the findings from the first phase and the results of experimentation.
- Phase 3. Deployment of a "full circular DPP" for textiles on a long-term horizon of 2033. During this last phase, a full circular DPP could be deployed to promote circularity in the textile sector.

While these measures aim to enhance decarbonization and circularity, there is a risk they could inadvertently create trade barriers, particularly for manufacturers in developing countries that may struggle to meet these stringent criteria. The shift towards circular textile products in consumer markets like the EU, California (through its extended producer responsibility legislation), and the United Kingdom potentially introduces a range of non-tariff trade barriers such as restrictive measures on imports of "linear" textile products—for example import licensing requirements, complex technical regulations, standards, and certification requirements, differing labelling or traceability requirements, and specific packaging requirements (e.g. biodegradable materials instead of single-use plastic packaging).

The downstream, post-consumer value chain includes the second-hand textile trade, which has long been a complex issue, particularly when it leads to the dumping of textile waste in developing countries. While trade in second-hand clothing can offer economic opportunities and affordable clothing options in these regions, it also has significant downsides, especially when the volume of waste exceeds the local capacity to manage it. In many cases, textiles that are unsellable or of extremely low quality are shipped under the guise of second-hand clothing, leading to environmental and social issues.

4. Opportunities and Challenges for Developing Countries

This second-hand garment trade poses many challenges to developing countries. One issue is the misclassification of textile waste and used textiles and garments under the Harmonized System (HS) codes. Often, what is labelled as "second-hand clothing" may in fact be unsalvageable waste, deliberately mislabelled to bypass trade regulations. According to the UN Comtrade database, in 2022 alone, over 9.7 million tonnes of used textiles and worn clothing were exported globally for a value of $9.5 billion, with a significant portion of the low value waste textiles ending up in Africa and South America (circulareconomy.earth, n.d.).[49] For instance, the Atacama Desert in Chile has become a notorious dumping ground for unsold and discarded textiles from around the world (Shipley & Alarcon, 2024). Chile imported over 150,000 tonnes of used clothing in 2022.[50] These dumpsites not only scar the landscape but also contribute to environmental degradation, as synthetic fibres release microplastics and toxic chemicals into the soil and waterways, exacerbating climate change and pollution.

The misdeclaration of textile waste as second-hand goods not only undermines the intended purpose of recycling and reusing textiles but also shifts the burden of waste management to developing countries, which often lack the infrastructure to process such waste safely and sustainably. As a result, these countries are left with massive accumulations of textile waste, leading to health hazards and environmental damage. Textile waste dumping also further exacerbates climate impacts through the release of greenhouse gases as textiles decompose or through open burning at dumpsites.

49. See the results for world textile imports and exports in 2022 in the circulareconomy.earth (n.d.-a) dataset developed by Chatham House.
50. See the results for Chile textile imports in 2022 in the circulareconomy.earth (n.d.-b) dataset.

On the positive side, developing countries stand to gain new trade opportunities in the textile and garment sector on the road to 2050. By embracing sustainable practices, circularity, and low-carbon manufacturing processes, they can enhance their competitiveness in the global market. Investment in green production methods, sustainable cotton farming practices, and circular economy models can ensure access to existing markets while producing higher quality and more durable garments.

However, these opportunities come with challenges. Transitioning to sustainable practices requires significant investment and capacity building. Developing countries must address issues such as limited access to finance, technology, and expertise. Additionally, they must navigate complex international trade regulations and standards that increasingly emphasize sustainability and circularity.

Trends towards nearshoring and reshoring manufacturing to shorten supply chains and reduce emissions as well as potential climate-induced disruptions could have significant implications for least developed countries like Bangladesh, Cambodia, and Ethiopia, which are heavily reliant on textile exports. These regions may face economic volatility as production capacities shift and comparative advantages change. To remain competitive, supplier countries will need to enhance efficiency, add value to their garment industries, and diversify their economies.

As trade policies increasingly incorporate climate considerations, such as carbon emission regulations, eco-design product standards, and incentives for green technologies, the competitive landscape will be reshaped. Policies like the EU's CBAM and new eco-design criteria for textiles and garments could favour sustainable practices, but also impact existing trade relations and development strategies. Developing countries will need to navigate these evolving trends carefully, balancing new opportunities with the challenges posed by shifting global trade dynamics.

In conclusion, the interplay between trade, climate action, and the textile and garment sector presents both significant opportunities and challenges. For developing countries, proactive strategies that integrate climate-resilient development and sustainable trade practices will be crucial for leveraging the benefits and mitigating the risks associated with these dynamic changes. By 2050, the sector's transformation can contribute to global climate goals while promoting sustainable development in some of the world's most vulnerable regions.

5. Priorities for Policy Engagement and Future Analysis

In the short-term, a priority should be to include the textile and garment sector in the next update of the NDCs for the 2025 UN Climate Change Conference (COP30), with specific sectoral targets for emission reductions. This will be an important policy signal for international brands and the industry. Furthermore, financial, technological, and capacity building support will be needed from the international community to achieve any of these potential targets.

In parallel, it is becoming imperative for producer countries to implement national policies to address the environmental impact and carbon footprint of domestic textile and garment manufacturing. Setting clear, short-term targets for emission reduction in the textile and garment industry will not only accelerate decarbonization efforts, but also promote sustainable practices in manufacturing, raw material sourcing, and supply chain management. These targets would not only mitigate the sector's climate change impact, but also encourage innovation and enhance resource efficiency.

Government policies for textile and garment manufacturing hubs will be critical in supporting decarbonization of production. Financial support through tax breaks, subsidies, incentives and lower loan rates, as well as providing renewable energy infrastructure are required (Leal Filho et al., 2022). Additionally, new financial mechanisms such as circular textiles funds or preferential trade agreements for garments with recycled content could be explored to support investments in resource efficiency, waste minimization, and decarbonization of textile manufacturing

As the global textile and garment industry seeks to decarbonize, it is crucial to prioritize policy engagement and future analysis, particularly in relation to trade aspects. A coordinated approach at the World Trade Organization (WTO) will be essential to ensure that decarbonization efforts are harmonized across borders and do not lead to protectionism or trade distortions and unfair discrimination. The WTO can play a pivotal role in developing frameworks that encourage the adoption of carbon pricing mechanisms for the global textile and garment value chain, while ensuring they are consistent with global trade rules. This includes facilitating constructive dialogue among member states to create transparent, non-discriminatory policies that support ambitious climate goals, but without unfairly penalizing developing countries.

To avoid restricting market access for trading partner countries in the upstream textile and garment value chain, the EU should consider implementing supportive measures, such as technical assistance, capacity building, and financial support, to help developing country producers comply with the new standards under the ESPR and other policies related to textiles circularity. Producers often lack the financial resources and technological capabilities to transition to lower carbon production methods or to implement traceability requirements such as the Digital Product Passport. This approach would not only ensure a level playing field but also promote global collaboration in the transition towards more circular textile production and consumption.

Future analysis should examine the potential impacts of trade policies on these countries, including the risk of carbon leakage and the economic consequences of BCAs on their export competitiveness. Moreover, it is vital to explore how global supply chains can be realigned to ensure that decarbonization efforts lead to inclusive growth and socially just transitions, rather than exacerbating social inequalities that are already widespread in the sector. This includes assessing the role of multinational corporations and brands in actively supporting sustainable practices, and ensuring that the costs and benefits of decarbonization are equitably distributed across all levels of the value chain.

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