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Innovative International Cooperation for Climate

Reconciling urgent action and transformational change

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INNOVATIVE INTERNATIONAL COOPERATION FOR CLIMATE

RECONCILING URGENT ACTION AND TRANSFORMATIONAL CHANGE

Our progress on climate action is too slow, the window is closing fast and an urgent and transformational change is required to stay within the temperature ranges defined by the Paris Climate Agreement

The problem cannot be addressed by a simple juxtaposition of solutions emerging from a mitigation-focused, siloed approach or by a straightforward adoption of technological solutions guided only by cost-effectiveness. Instead, transformations of systems are needed, i.e. a combination of technological and organizational changes that structurally affect the functioning of the economy. These transformations must happen inside all sectors and across them, and in all countries.

This diagnosis is very widely recognized and clearly documented in scientific analyses, as assessed in recent IPCC reports[1]. It is also universally recognized in the international policy realm, as highlighted in the recent synthesis report of the technical phase of the Global Stocktake[2].

The implementation of these transformations faces a number of concrete challenges. They require whole-of-society approaches and an acknowledgment of complex interplays. They involve a diversity of stakeholders, who must have ownership of the collective challenges and coordinate their decisions accordingly. They entail radical changes that threaten vested interests and therefore sometimes trigger resistance. They demand fundamental changes in the governance relationships between all countries and other transnational actors.

1 https://www.ipcc.ch/sr15/
https://www.ipcc.ch/working-group/wg3/

2 file:///C:/Users/87854/Downloads/sb2023_09E.pdf

AN INNOVATIVE APPROACH

Overcoming these barriers requires a fundamental change in the way climate ambition and action are approached: "**Creativity and innovation in policymaking and international cooperation is essential**" (statement 14 the Synthesis report on the technical dialogue of the first global Stocktake)

International cooperative action holds immense potential, much of which is yet to be tapped. Achieving this potential requires overcoming inertia that persists within established paradigms, entrenched structural relationships between key actors and significant disparities in resources and capabilities among these actors. In the climate discussion, international cooperation is essentially approached with a centralized vision, focused on the search for universal solutions, closely structured according to the UNFCCC's separate fields of mitigation, adaptation and means of implementation, with poor accounting of the implications of climate constraints for the development needs of countries and uneven levels of engagement[3]. In particular, in many developing countries, domestic resources constrain the capacity to engage in international platforms and, in consequence, the degree to which issues relevant to those countries can be articulated and advocated.

We argue that fundamental innovations in international cooperation are required to create adequate conditions for countries to scale up their ambition and trigger effective action.

3 https://ddpinitiative.org/wp-content/uploads/pdf/africa_gst_paper.pdf

The innovation lies in promoting a needs-based, sector-driven, solutions-oriented and forward-looking, approach to international cooperation.

"Needs-based" cooperation would ensure solutions are designed to address the priority requirements of countries, taking into account the specificities of different national circumstances. It also recognizes the need to prioritize cooperation solutions that provide local benefits, effectively supporting the development of economic activities in the country and responding to the needs of the local populations. In addition to tackling national transitions in a more effective manner and supporting the implementation of just transitions, such an approach would facilitate the operationalization of equity considerations at a global scale.

"Sector-driven" recognizes the need for sectoral entry points, in order to adjust the solutions and design them to answer and respond to the specific challenges and opportunities pertaining to the transformation of each sectoral system.[4]

"Solutions-oriented" stresses the need to organize international cooperation around concrete decisions that can practically enable systemic transformations. This means notably adopting a holistic approach, considering a large range of tools and actions, and going beyond conventional solutions if needed.

Finally, "forward-looking" highlights the necessity to design cooperative solutions consistently with a clear perspective on the changes that must happen at different time horizons to trigger systemic changes within and across each sectoral system.

OPERATIONALIZATION OF THE INNOVATIVE APPROACH TO INTERNATIONAL COOPERATION

This approach to international cooperation requires adequate conditions for countries to participate in international fora, and for those countries to have their issues adequately articulated, understood and addressed. In particular, enhanced and institutionalized national capacities are essential, both inside governments and with a broader independent community in each country and each sectoral ecosystem. This is a core condition to ensure the emergence of country-driven perspectives, to create conditions for these perspectives to be promoted by the countries in the international context and to ensure continuity of the process domestically and globally. Concrete inputs to international process can be provided through by detailed assessment by countries of the conditions to support their systems' changes consistent with climate and socio-economic goals, as they could notably emerge from LT-LEDS processes[5].

The operationalization of this approach to international cooperation would go through ad-hoc processes involving the diversity of actors relevant to a specific sector in structured conversations. These conversations would seek to build collective ownership of the challenges and identify concrete actions to be adopted at the international level to enable necessary changes at the sectoral level, as identified by country-driven assessments. With a holistic and solutions-oriented perspective, the conversations would consider a wide diversity of tools available to enhance international cooperation and consider innovative solutions that go beyond conventional approaches if they help better address country needs and requirements for the sectoral transformations.

The UNFCCC is not the place where these ad-hoc processes would necessarily develop, but the UNFCCC still has a key role to play to initiate and organize this innovative approach to international cooperation. Notably, the UNFCCC can give the political signal that triggers the processes and gives the sense of direction, build bridges with the diverse initiatives and processes where in-depth conversations can happen, and can help organize collective accountability and continuity in the context of new or existing UNFCCC processes.[6]

4 https://cop21ripples.climatestrategies.org/resources/policy-brief-2/

5 https://www.iddri.org/en/publications-and-events/study/country-driven-perspective-long-term-low-emission-development https://www.iddri.org/en/publications-and-events/report/long-term-strategies-decarbonization-latin-america-learnings-actor

6 https://ddpinitiative.org/wp-content/uploads/gst-lac-iddri-tempus-submission-vf-1.pdf

SECTORAL PERSPECTIVES

This report considers three sectors – steel, freight transport and AFOLU in independent chapters. Each sectoral chapter builds on in-country analyses of deep decarbonization pathways conducted in the context of the Deep Decarbonization Pathways (DDP) initiative[7], from which concrete suggestions of cooperation avenues are derived., according to the above described innovative approach to international cooperation

Primary steel production has long been considered hard to abate. But a technological solution, namely h-DRI technology, has become economically viable in just two years under a well articulated policy package (including subsidies, CO_2 pricing; RD&D support; lead-markets; and protection of producers) enabling a large investment programme at EU locations. This recent evolution is essentially showing a route to sector decarbonisation. Notably, the h-DRI technology allows separating iron and steel production and therefore opens the possibility for separating h-DRI, which could happen in a number of resource- and renewable -rich developing countries, from steel production, which could continue to happen in current production centres. This approach would lower the production costs of net-zero steel, benefitting EU and developing countries and accelerating global decarbonization. No such investments have yet been announced but these can be enabled by an international level playing field for investments in h-DRI plants and measures to expedite cross border trade of h-DRI. These changes involve transformative changes in international sector governance. The level playing field for investments would, for example, involve creating conditions where h-DRI plant investors would experience 'location-neutral externally created conditions', e.g. subsidies, so as to be able to exploit 'location-favourable natural conditions', e.g. low-cost local renewable energy and iron-ore.

Regarding freight transport, organizational changes of production, distribution and consumption are key. While these changes largely depend on national actions and policies, innovative international cooperation driven by local needs could enable and accelerate them. Knowledge sharing should be organized around the specific challenges and opportunities of industrial organization as emerging from the countries' experiences and the process should allow entering into the details of possible solutions, in contrast to skimming at the surface. Technical assistance should be demand-driven, i.e. primarily organized around the specific gaps identified by countries for their organizational transformations, by opposition to a more conventional supply-side approach triggered by technical assistance offers. Finance discussions should focus on the national needs for infrastructure changes in the industrial and transport sectors that are consistent with organizational transformations, as a way to secure adequate finance flows towards such infrastructure. Trade and industrial cooperation should explicitly consider the impact on freight transport emissions to support trade agreements compatible with continental and sustainable industrial value chains and associated logistics, a dimension largely overlooked in conventional trade agreements.

Regarding AFOLU, international cooperation in terms of trade and finance tends to silo projects in-terms of agriculture and forestry. Furthermore, cooperation on finance especially often separates initiatives on biodiversity, adaptation, and mitigation, or on agricultural support to provide income support to farmers and/or ensure food security. Breaking these siloes and organising international cooperation around the systemic transformations of the land use sector, which include both forestry and agriculture and the diversity of objectives the sectoral transformation must contribute to achieving, is central going forward. In terms of trade, this could include going from strict trade agreements and trade regulations to initiatives that combine trade and sustainable development cooperation to achieve goals both regarding the exchange of goods and services and regarding sustainable development outcomes in the trading countries. Altogether, this will require an improved coordination of the plethora of international initiatives on the land use sector.

7 https://ddpinitiative.org/

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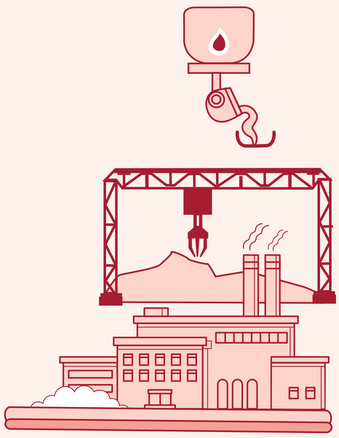

IRON & STEEL

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CONTEXT

FROM 'HARD-TO-ABATE' TO MISSION POSSIBLE

In the lead-up to COP21, DDP country-level research for 16 countries, representing 80% of global GHG emissions in 2014/15, identified which sectors could be economically decarbonized with existing technologies while achieving socio-economic goals. The key finding was that most sectors could be decarbonized through clean electrification and fuel switching, indicating that the 2°C goal was within reach. However, disaggregated results revealed that while industry accounted for 16% of emissions in 2010, it would account for 52% by 2050. Most of these industrial emissions are the result of chemical processes that are difficult to electrify, meaning that the default strategies in these cases are direct carbon capture and storage (CCS) and the absorption of emissions from electricity generation from biomass combustion with the CCS (Bataille et al., 2021). These results were consistent with the conventional understanding of the issue up until 2017 (Abdul Quader et al., 2016; Neuhoff et al., 2014), where steel had been identified as one of the key 'hard-to-abate' sectors, i.e. an economic activity where emissions can only be reduced marginally and which will continue to produce emissions in the long term, forcing the funding of negative emissions to achieve the climate targets of the Paris Agreement.

However, a landmark study (Vogl et al., 2018) has transformed the landscape for primary steel production, the single largest industrial emitter. It found that in the context of current costs, it is becoming increasingly plausible to use hydrogen-based direct reduced iron (h-DRI) technology to decarbonize steel production. Instead of accepting the view that primary steelmaking was hard to abate, the study implied that the sector could be decarbonized with the appropriate, plausible enabling conditions.

Encouraging investment in h-DRI production faces a key challenge: such technology entails significantly increased production costs, without increasing product quality in any tangible way. There is a substantial increase in value in terms of embodied emissions, but this is not yet fungible in existing markets. Monetizing this value can only be achieved via zero-embodied emissions certification, and even then such value only exists under specific and highly 'artificial' market conditions. Thus, for investment in h-DRI plants to be viable, access to markets that value this attribute is a necessity, along with several governance measures to manage the market and support and protect producers.

ENABLING H-DRI INVESTMENT: A REVOLUTIONARY SUCCESS IN THE EU

Since then, the EU has implemented a complex suite of policy measures that has resulted in an investment programme in new h-DRI assets that almost certainly demonstrates a successful move onto a deep decarbonization pathway for the sector, within EU borders, consistent with the Paris Agreement goals.

Europe created these enabling conditions very quickly. In 2017, Sweden became the first country to set a legislated net-zero obligation, which created an immediate challenge for the Swedish steel industry. Sweden had the necessary technological, financial and natural resources to implement h-DRI technology to produce zero-embodied-emissions steel, including suitable iron-ore and abundant low-cost renewable energy. Swedish state-owned companies invested first in a pilot h-DRI plant and then in a commercial scale one - the first of its kind.

EU net zero commitments were also under development. With the Swedish progress, the steel decarbonization challenge evolved from developing a commercial technology to identifying and establishing the enabling conditions for steelmakers to invest at scale in the new h-DRI technology. Extensive techno-economic and policy analysis in the EU had shown that initial attempts failed to encourage heavy industry to make costly lumpy investments to 'jump' to new processes when these attempts were limited to the purely economic measures of simple subsidies and disincentives (e.g. CO_2 pricing). These marginal instruments drove incremental changes. The same analyses made recommendations of what specific additional types of measures were necessary in the EU context. Within a short period of time, the EU established a suite of necessary policy measures.

This was a challenging endeavor for the EU, only made possible by its multifaceted capabilities. Only a comprehensive policy package could convince steelmakers to invest at scale in the new h-DRI technology. After much effort, it has ultimately required the implementation of a comprehensive suite of at least six complementary policy measures. These measures comprise: CO_2 pricing; research, development, and demonstration (RD&D) support; capital subsidies; intricate, complex lead-market policies; and complex measures aimed at safeguarding local producers including carbon border adjustment mechanisms (CBAMs). Each one of these measures is indispensable for enabling steelmakers to invest in h-DRI plants, and all of these measures must be implemented together. They present considerable political, economic, technological, and regulatory challenges for effective implementation and all are still partially under development in a dynamic and evolving policy environment.

It can be considered revolutionary that through this suite of measures, primary steel production changed in just two years, from being viewed as hard-to-abate, to being at the centre of a large investment programme. Between 2021 and 2023, all major EU steelmakers made significant announcements of investments in zero-emissions primary steelmaking plants that utilize h-DRI technology. This amounts to 16 h-DRI projects that are mostly in the >1Mt/year range, representing a substantial proportion of the existing high-emissions blast furnace-basic oxygen furnace (BF-BOF) capacity. This step, in combination with the EU's legal commitments and the commitments of major steelmakers, enables us to conclude that the EU's primary steel deep decarbonization problem has largely been solved.

SEPARATING IRON MAKING AND STEEL MAKING: A TECHNOLOGICAL CHANGE THAT ALLOWS THE SPATIAL ORGANIZATION OF GLOBAL SUPPLY AND PRODUCTION CHAINS TO BE COMPLETELY RECONSIDERED

The predominant method for producing primary steel involves the use of blast furnace-basic oxygen furnace (BF-BOF) technology within extensive integrated steelworks. BFs utilize coke to transform iron ore into molten iron, which is subsequently transferred to a basic oxygen furnace (BOF) that requires the iron to be in a molten state. Iron, in its molten form, is largely impractical for transportation over significant distances and holds limited utility except as an intermediate material for conversion into steel within the BOF. Consequently, BOFs need to be situated in close proximity to blast furnaces.

In contrast, the h-DRI furnace refines solid iron-ore into solid h-DRI, also an intermediate material, to be converted into steel by an Electric Arc Furnace (EAF). In this case, because this solid intermediate material can be easily transported, h-DRI furnaces can be located far from EAFs. This enables a fundamental re-configuration of primary steelmaking. For example, h-DRI furnaces can potentially be located on one continent, feeding many EAFs around the world. This opens up many new market alternatives for iron ore, iron, energy and hydrogen. For this reason, the substitution of BFs by h-DRI technology goes far beyond a 'simple' technology switch. It also allows for the spatial reconfiguration of global supply and production chains.

However, current decarbonization strategies envisage importing iron ore and hydrogen to steelworks located in the EU, where these inputs go into h-DRI furnaces that feed EAFs on the same sites as existing integrated steelworks, in the same spatial configuration as BF-BOFs where all steel production stages are conducted at the same location or nearby.

It is possible for this transformation to take a very different path, one that would entail a fundamental rethink of overall industry structures, which could have multiple benefits.

The alternative would indeed be for h-DRI to be produced in a diversity of countries, from locally produced renewable hydrogen and locally mined iron ore, and then shipped to multiple EAFs in the EU and elsewhere. A large number of EAFs already exist, using mainly recycled scrap as a feedstock. This would profoundly disrupt the existing industry and associated energy and raw material production chains. h-DRI, in the form of solid hot briquetted iron (HBI), which can be stockpiled and therefore easily stored and transported, could become a commodity with a geographically widespread global trade.

This transformative approach has multiple benefits. It increases competition, simplifies highly challenging and costly energy and hydrogen logistics chains, avoids vulnerabilities associated with hydrogen logistics, increases energy security while reducing costs, accelerates the deep decarbonization of primary steel production and reduces the need for hydrogen logistics infrastructure and the unnecessary transport of hydrogen and iron ore. DRI can be easily stockpiled in contrast to the storage of hydrogen, which is costly, and it would also increase the security of supply. Furthermore, this approach enables the exploitation of renewable energy resources at locations where it is cheaper and abundant, therefore supporting local industry and avoiding important additional production costs and energy demand in the EU and other similar electricity markets.

The economic implications, just for iron and steel markets, of separating iron and steel production on a global scale were modelled in a very recent DDP study (manuscript submitted for publication in June 2023). The study modelled a highly plausible 'DRI trade' scenario where h-DRI accounted for 22% of global crude steel production in 2050. In this scenario h-DRI production would be strategically located in global regions with favourable conditions for renewable electricity and iron ore reserves (Bilici et al., 2023). This 'DRI trade' scenario generates cost savings of more than 45 billion dollars annually in 2050, and 535 billion dollars cumulatively by 2050 (Bilici et al., 2023), compared to the 'domestic scenario' where the co-location of primary iron production with steel production is perpetuated.

EXTENDING H-DRI PRODUCTION TO THE GLOBAL SOUTH

At present, the above-mentioned type of credible, tangible transition commitments from steelmakers is limited to primary steel production within the EU. There is currently minimal evidence of h-DRI adoption outside the EU at the pace necessary to meet global sector decarbonization requirements, while the world continues to invest in new blast furnaces at a rate that is entirely inconsistent with 1.5°C. In particular, no developing countries have implemented the type of policies that in the EU have resulted in credible realistic plans from steelmakers. In DDP studies, national level research has found that, especially within their socio-economic contexts, these countries do not have the fiscal resources and legitimate political priorities to create the enabling conditions for substantial investments at scale in h-DRI. This can be seen in the following case studies for South Africa, Brazil and India.

SOUTH AFRICA

South African DDP research work carried out in 2018 confirmed previous scenarios and showed that without transformative change, industry would become the country's biggest emitter in 2050, and that primary steel production would be the largest contributor. The bulk of these emissions would be from blast furnaces (BFs), where fossil fuel carbon is used as a chemical input that reacts with iron ore to form primary iron and CO_2. Until 2018 the production of primary iron without carbon feedstock was regarded as uneconomic, to the point of being impossible. In short, at the time it was generally considered that achieving deep decarbonization in primary steel production would be impossible through the use of existing technologies.

But then, South African DDP research starting in 2018 (Trollip et al., 2022) used Vogl's analysis and results to assess their application in South Africa, and conducted relative costings between plants located in South Africa and Europe. The research found that h-DRI iron could be produced in South Africa and shipped to EAFs in the EU for the steelmaking step at potentially lower costs than the alternative of shipping iron ore to the EU and producing the h-DRI in Europe. The analysis showed that this measure would benefit EU steelmakers, the EU and South African economies. It also found that the (relatively) small South African market would not provide the necessary demand to warrant investment in a new profitable commercial scale h-DRI plant. To take advantage of the potential local and global benefits of h-DRI, a first plant would need to be anchored by a profitable export market. The DDP research also examined other credible enabling conditions that would be required for the first new[1] h-DRI plant. Four key enabling conditions were identified to move to a real-world diffusion of this technology: *"a willing steelmaker [with access to h-DRI technology], fair access to the EU iron market, enabling trade rules, and embodied emissions certification and accounting"* (Trollip, McCall and Bataille, 2022). The central finding was that the plant would need to serve an export market. At present, the only such markets are the EU and the nascent EU-USA market.

BRAZIL

Brazil produces as much steel as the EU's biggest steel producer, Germany, and is a major iron ore and steel exporter.

Brazilian DDP research (Rovere et al., 2022) corroborates findings that Brazil can play a crucial role in accelerating global deep decarbonization of primary steelmaking via the transformed production chains described above. Similar to the South African example above, Brazil also has an abundance of low-cost renewable energy and high-grade iron ore, although in far greater quantities. In fact, Rio Tinto, one of the world's largest iron ore exporters, announced an agreement to supply Brazilian iron ore to Swedish located h-DRI producer H_2 Green Steel. However, no h-DRI production investments have been announced for Brazilian locations. Like other developing countries, there are also national-level characteristics that require specific enabling conditions for investments in h-DRI plants in Brazil. Until certain enabling conditions are in place, the global primary steelmaking industry will not be able to take advantage of Brazil's vast resources of renewable energy and high-grade iron ore. Brazilian DDP work indicates that these conditions would include decreasing the cost of capital, trade agreements, and collaborative technology development (Rovere et al., 2022). These, in turn, require transformations in international cooperation that extend beyond 'climate finance and technology transfer' into formal political agreements between governments. Nearly 50% of Brazil's substantial steel exports go to the USA which is in the process of negotiating an agreement specifically aimed at EU-USA steel trade and aluminium trade, within the context of the EU's CBAM and the USA Inflation Reduction Act, which allows large subsidies for low-emission steel production. Without similar agreements with countries such as Brazil, which has vast resources that enable structurally lower zero-emissions iron production, the deep decarbonization of the global primary steel production industry will be hindered, along with economic losses on both sides: potential exporters and potential importers.

1 South Africa has an existing fossil-fuelled DRI plant that is being converted to h-DRI. This is a different investment case and does not represent the transformative step needed to accelerate primary steel deep decarbonization.

INDIA

India is a major steel producer globally, with a much bigger primary steel production capacity than the EU. Earlier this year, India emphasized the role of Asia in the decarbonization of the steel sector. Ongoing discussions state the need for a market for responsibly produced steel. The Ministry of Steel is committed to the national Net Zero target by 2070. In the short term (FY 2030), it has been recommended that industry focuses on the reduction of carbon emissions in the steel industry through the promotion of energy and resource efficiency, and renewable energy. For the medium term (2030-2047), the focus areas will be around green hydrogen and carbon capture, utilization and storage. In the long term (2047-2070), disruptive alternative technological innovations could help achieve the transition to net-zero.

At the international level, India along with Sweden (supported by the World Economic Forum) launched the Leadership Group for Industry Transition (LeadIT) in 2019 which gathers countries (18) and companies (18) that are committed to action to achieve the Paris Agreement. The industry sector, especially the iron, steel and cement industries, have been classed as 'hard to abate' sectors due to the high capital investment required for transformation. International policies such as carbon border adjustment, domestic policy support and end-use demand in European countries, which have shifted steel processing technologies to produce green steel in Europe, have all encouraged developing countries like India to discuss domestic possibilities.

CONSIDERING GLOBAL DECARBONIZATION BASED ON NATIONAL NEEDS

National assessments in South Africa and Brazil and subsequent research work (Gielen et al., 2020, Lopez et al., 2023, Bilici et al., 2023) have shown that it is possible for other countries, with similar iron-ore and renewable energy resources, to follow the same route: to produce solid h-DRI and supply it to EU steel manufacturers at a lower cost than most EU-based producers, and to supply the nascent EU-USA market and other markets when they are realized. The example of Australian exports to Asian markets is relevant in this context.

If advanced steelmaking market economies were able to access their primary basic materials at lower costs, this would support greater competitiveness of their steel industries, and their economies too, while reducing the overall costs of decarbonization, and consequently accelerating the decarbonization of their economies, and also of many other countries and the global steel sector. Additionally, it would free up zero-emissions energy sources, including green hydrogen, for higher value applications in regions with fewer renewable energy resources, such as the EU.

These observations concerning specific countries and the EU market have been generalized for the economic dimension in a study by Bilici et al. (2023). Potentially huge economic benefits can be realized, where economically rational, if primary iron production is separated from steel production and h-DRI production is strategically located in global regions with favourable conditions for renewable electricity and iron ore reserves. In terms of cost reductions for the steel production chain alone, savings could amount to some 535 billion dollars cumulatively by 2050 (Bilici et al., 2023). This does not include other substantial benefits such as a more efficient allocation of energy resources, transport costs, infrastructure costs, energy security and industrial development in areas with favourable resources and needs for economic development.

INTERNATIONAL COOPERATION PERSPECTIVES

INTERNATIONAL COOPERATION IS NECESSARY TO TRANSFORM THE PRIMARY STEEL SECTOR TO MEET THE GLOBAL 1.5˚C GOAL

The single innovation that has triggered a technology transition process in the EU has involved highly complex and advanced supportive measures that were possible due to the EU's economic and governance capacities, including the combined size and capacities of the economies of EU countries, fiscal resources, the governance and regulatory capabilities of individual countries and, very importantly, the uniquely powerful cooperative governance and government capabilities built over decades as part of the inter-governmental EU project. This latter dimension can be viewed as a transformation in the history of international government. Broader international governance is now required to emulate some of the capabilities developed by the EU bloc to achieve global climate change governance goals.

However, enabling the governance transformations needed to reconfigure production chains and markets in the ways described above is likely to be even more challenging than the issues encountered during similar developments of intra-EU bloc governance processes. The steel industry is heavily involved with state intervention and support, while being a part of global value chains that continue to be subject to highly sophisticated national and international regulations that have been established over decades, many of which will require reorganization. Governance transformation involves the classic political challenge of enabling a redistribution, between countries and also between intra-country actors, of existing patterns of resource exploitation and the locations of production, and of the allocation of economic benefits among a diversity of actors. All this must be carried out with the aim of realizing both greater overall economic benefits and the global collective social goal of accelerating deep decarbonization.

Key results of recent research and actual practical experience, including from the DDP Network, have found that despite impressive successes, national/bloc-level approaches are not sufficient on their own and that global sectoral governance measures will also be required (Bataille et al., 2021; Bilici et al., 2023; Hermwille et al., 2022; Rovere et al., 2022; Trollip et al., 2022; Wang et al., 2022; Witecka et al., 2021) (Oberthür et al., 2021). There is also an established literature devoted to the challenges faced by nationally influential industries, such as iron and steel, that are characterized by global value chains (Dallas et al., 2019; Davis et al., 2018; Horner, 2017; Ponte et al., 2019).

In 2019, Hermwille et al. (2019) found that: *"If the EU were to create a lead market for low- and zero-emission steel through labelling and/or public procurement, through establishing a level playing field using GHG standards or BCAs, through providing sustainable finance for technology development and production facilities, including South Africa in such a scheme would enable the country to develop low-carbon steel production. In the short term that industry would supply primarily European lead markets at relatively competitive prices, but in the medium to long term would substitute current domestic steel production and ultimately cater to the strong demand for primary steel across Africa."* Further research (Åhman et al., 2020, Hermwille, 2019, Hermwille, 2020, Oberthür et al., 2021) led to very specific proposals for international cooperation arrangements (Hermwille et al., 2022; Trollip et al., 2022).

RECOMMENDATION FOR INTERNATIONAL COOPERATION

The key conclusion of the research is that, although conventionally envisaged cooperation through 'climate finance' and technology transfer remains a minimal requirement, many additional areas of cooperation are needed to support the decarbonization of steel production in developing countries, and hence to put the global industry on track to achieve decarbonization consistent with 1.5°C.

National level DDP work identifies three core outcomes for international cooperation to create the necessary conditions for the deep decarbonization of steel in developing countries:

- It is crucial to guarantee that developing countries benefit from comparable investment enabling conditions for hydrogen-based direct reduction iron (h-DRI) production plants, mirroring those currently being implemented in the EU. This alignment is essential to establish a level playing field, in line with the principles advocated by dominant advanced market economies.
- Governance and regulatory capacities in many developing countries are significantly lower than those in the EU. Consequently, regulatory policies and governance, particularly concerning trade, must consider and accommodate these differences.
- International cooperation is required to especially address the particular challenges in developing countries such as fiscal demands to addressing the high levels of poverty and the requirement to invest heavily in basic needs provision. Fiscal and political spaces for subsidizing an accelerated transformation to low-emissions primary steel production are more constrained than in the EU and thus need explicit acknowledgement and specific attention.

Practical measures that relate to international cooperation and could help achieve these outcomes include:

- Internationally equitable allocations of state support in financing of production plants, and associated inputs, are essential to provide investors with assurances of a level playing field for a highly traded international commodity. However, there are indications that countries like South Africa, Brazil, and India may not, and cannot, match EU and USA subsidies due to limited fiscal space, differing socio-economic spending demands and related differing political priorities. As a result, the formal operationalization of the 'international level playing field,' as advocated by dominant industrialized market economies, will require a transformation in international cooperation.
- Lead market strategies, i.e. conditions for "a geographical market, constructed with policy, where local demand preferences and social goals support the emergence of an innovation design that diffuses globally" (Quitzow et al);
- Assurances of protection from carbon leakage for h-DRI producers, in the form of trade regulations (similar to the EU's use of the CBAM) or trade agreements.
- International trade agreements to facilitate the 'fair' flow of zero-emissions h-DRI across international borders;
- Technical measures to certify and monitor embodied emissions in relevant h-DRI commodities and related goods;
- Access to markets that have established special measures enabling h-DRI investments so that trade with these markets is not unreasonably impeded by tariff or non-tariff barriers.

The groundbreaking advancements in deep decarbonization of steel at the EU level underscore the need for extensive efforts to extend these transformations globally. Developing practical measures for achieving deep decarbonization in global primary steel production demands substantial additional endeavors. This involves considering national economic and policy scenarios within the intricate realms of international relations, governance, and trade. Addressing these complex factors represents a crucial next step in the pursuit of comprehensive global steel decarbonization.

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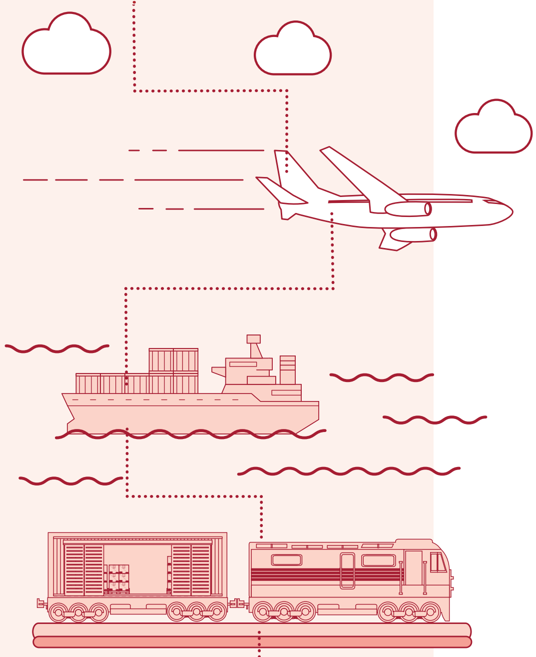

FREIGHT TRANSPORT

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INTRODUCTION

Transport emissions represent about 15% of total greenhouse gas (GHG) emissions, equivalent to 9 $GtCO_2eq$ each year. Transport-related emissions have shown continuous growth since 1990 at an annual average of 2%, increasing faster than for any other end-use sector (IPCC, 2022b). Freight emissions account for about 40% of all transport GHG emissions (ITF, 2021a; SLOCAT, 2021a) and are increasing. This is mainly due to accelerating demand and global supply chains, which could lead to almost a tripling of tonne-kilometres by 2050 (ITF, 2021a), and due to a strong fossil fuel dependency.

Current medium-term objectives and strategies for freight as reported in Nationally Determined Contributions (NDCs) under the United Nations Framework Convention on Climate Change, are far from sufficient. Recent analyses highlight that freight transport measures are largely overlooked and very limited compared to passenger transport actions (ITF, 2021b; SLOCAT, 2021b), while reinforcing sectoral details and granularity should be a priority (Gunfaus & Waisman, 2021; Hermwille, Obergassel, & Fragkos, 2022). Most freight decarbonization measures focus on the development of new technologies, such as advanced biofuels, electric vehicles and new digital technologies, to improve energy efficiency and reduce emissions. They neglect, however, organizational changes and related actions including the development of infrastructure and incentives for rail and waterways, without mentioning specific actions to lower the transport demand, either by shortening supply chains or reducing the number of deliveries and tonnes transported inefficiently (SLOCAT, 2021b).

However, the latest IPCC Special Report on Global Warming of 1.5°C and the Sixth Assessment Report highlight that reaching carbon neutrality by the mid-century will require unprecedented, rapid, and far-reaching systemic transitions in energy systems but also in land, urban, infrastructural and industrial systems, and imply deep emission reductions in all sectors. To reverse the freight sector's current emission trend and to achieve structural reductions, the IPCC states that technological innovations will not be sufficient and that complementary organizational transformations are required. Such organizational changes could enable a systemic shift that would bring about a reduction in tonnes transported and kilometres travelled, as well as a reduction in the role of road freight in logistics, while facilitating the expansion of alternative low-carbon vehicles and fuels.

The following section shows examples of organizational changes, provided by research members of the Deep Decarbonization Pathways network as they are - or could be - implemented in their countries and that could influence freight-related emissions. These evidences are based on national analyses of the net-zero transition and on work around long-term low-emission development scenarios (Gonçalves, D. N. S. et al., 2022; Briand et al., 2019; Gupta & Dhar, 2022; Emodi, N.V. et al., 2022; Ahjum F. et al., 2020).

EXAMPLES OF NATIONAL ACTIONS AIMING AT ORGANIZATIONAL CHANGES FOR FREIGHT DECARBONIZATION

BRAZIL THE USE OF FREE-FLOW ROAD TAXATION SYSTEMS AS A MECHANISM TO SUPPORT A MODAL SHIFT FOR LONG-DISTANCE TRANSPORT AND URBAN FREIGHT DECARBONIZATION

Law No. 14,157, approved in June 2021, outlines the conditions for the introduction of toll collections on highways and urban streets using free-flow systems.

Since then, several ongoing projects such as BR 101 and BR 470, connecting the states of Rio de Janeiro and São Paulo, as well as the inland areas of the state of Rio Grande do Sul, have been working towards implementing tolls in this new format. The National Land Transport Agency (ANTT) intends to adopt the technology in all new and renewed concessions, as this would reduce implementation costs (NSLT, 2022). Currently, many highways in Brazil are toll-free, but where tolls exist, payment collection systems are manual or electronic (both with physical barriers), causing long queues and increased delivery times (CNT, 2020). In an extensive implementation scenario applied to the 25,000km of Brazil's highways that experience the heaviest volumes of freight traffic (ANTT, 2023), the cost of road freight for long-distance transport would be increased. This would provide an incentive for cargo consolidation, for the reduction of empty trips and potentially the increased use of rail freight, while at the same time decreasing congestion.

Moreover, the current outdated toll collection system would be impossible to implement at the city level, while a free-flow system could facilitate the development of city tolls. Brasilia, the country's capital, is currently analysing the introduction of a free-flow system as one of the mitigation measures supporting the development of a low-emission zone in the current decade. The city aims to limit the use of individual motorized vehicles (particularly the more polluting cars) in specific congested areas, while also creating new loading and unloading zones in these areas, with a focus on energy-efficient freight vehicles. This example is expected to inspire other Brazilian cities to embrace green low-emission zones as a mitigation tool, an aspect that has been neglected in the current version of Brazil's NDC. The measure has the potential to change the use of urban space, while encouraging the adoption of more energy-efficient modes.

BRAZIL ARE TRAVEL DISTANCES BEING REDUCED? THE CURRENTLY UNKNOWN IMPACT OF TAX REFORMS ON BRAZILIAN LOGISTICS FLOW PATTERNS

According to our analysis, for some supply chains, shortening delivery distances between consumption and production could support Brazilian decarbonization. Such systemic change would require action on the taxation system, for example, by incentivizing industries to move their locations nearer to centres of consumption.

This resonates with an ongoing parliamentary discussion about Tax Reform (Bill No. 45/2019), which outlines revisions to consumption taxes. Under the new law, five taxes (IPI, PIS, COFINS, ICMS, and ISS) have been merged into a dual system: a federal Goods and Services Contribution (CBS) and a Goods and Services Tax (IBS) for states and municipalities. One of the major amendments to the existing legislation is the shift of the tax base. While the tax is currently based on the product and levied in the state of origin, it has been suggested that the tax could be levied in the destination state. This modification would directly affect the ability of states to use tax incentives for specific sectors to attract investments (Federal Audit Court, 2023). However, it is important to evaluate the equilibrium between employment generation and revenue collection in the affected states.

According to the proposal, exporting enterprises would be exempt from CBS payments, providing advantages to the Brazilian agricultural sector and some segments of the industrial sector. This situation could therefore strengthen the main agricultural producing states, reinforcing the existing logistical corridors, especially those designated for exports.

In addition, the impacts on national trends in the location of industries remain uncertain. Beyond export-oriented enterprises, one possibility is that more production facilities will be concentrated around areas of high industrialization and consumption, to the detriment of more remote regions. This would potentially shorten the journeys made to supply these centres, while lengthening journeys to supply more remote states. Evaluating the exact impact in terms of transport activity (tonne-kilometres) will depend on the concentration factor expected and the localization of these centres; additional simulations and analysis will be necessary.

FRANCE DECARBONIZING PRODUCTION AND FREIGHT REQUIRES THE DEVELOPMENT OF LOCAL AND CIRCULAR ECONOMIES, AND AN INCREASE IN FREIGHT ON NON-ROAD MODES.

France has recently established a General Secretary for Ecological Planning, which has been responsible for publishing a long-term plan for the decarbonization of all private and public sectors (SGPE, 2023), which confirmed some of the key structural changes that must be implemented for freight, as demonstrated in previous research (Briand et al., 2019). It is based on a four-pronged approach: virtuous logistics, lower demand, more non-road modes, cleaner road transportation.

A paradigm has shifted: freight transport emissions are now being tackled from the perspective of production and logistics, in a chapter called “better producing”. Regarding production, consumption and supply chains, the plan includes the objectives to develop a circular economy to produce and transport less, to produce and transport less raw materials by improving the durability of products and the recycling and reuse of second-hand products, to produce and transport less waste, and therefore to change our production processes and consumption behaviours. It also highlights the need to develop local consumption and supply. Finally, regarding the organization of logistics, the plan includes objectives to increase the share of rail transport from 11% in 2021 to 18% in 2030 (an 80% increase of rail freight traffic in 7 years), but also to improve logistics and energy efficiency, and to strongly encourage the development of battery electric HGVs and LCVs.

Unfortunately, several of these areas either lack clear corresponding policy instruments, or a credible assessment of such tools. To develop and implement additional policies, the role of industry is critical, in terms of producers, consumers, and transport service providers. The commitment of industry is directly aligned with the credibility of public policies, which in turn will have to contend with the macroeconomic impact of the ecological transition and its political fallout. It is interesting to note that the French Prime Minister has asked for a report on this specific issue (Pisani-Ferry, Mahfouz, 2023).

FRANCE INFORMING CONSUMERS ABOUT THE REPAIRABILITY AND LONGEVITY OF PRODUCTS TO REDUCE TONNES TRANSPORTED AND KILOMETRES TRAVELLED

In 2020, France adopted the anti-waste law for a circular economy (Law AGEC, 2020) which aims to accelerate the shift of the French production and consumption model to reduce waste, to limit the use of natural resources, and to lessen the impact of economies on biodiversity and climate. For example, this new law has introduced an obligation for producers and distributors to use a repairability index to inform consumers about how easily a product can be repaired. This index, which is mandatory for certain products, takes into account whether a product can be disassembled, whether producers provide advice related to its use, maintenance and repairability, and whether producers make spare parts available at acceptable prices. In 2024, this repairability index will evolve to a durability index, which will include other dimensions such as product reliability and robustness, and will cover an additional range of products (Repairability Index, 2023).

Combined with other policies of the AGEC law that support the development of local production-consumption ecosystems, this information policy could contribute to a structural change in the way we produce and consume. If product lifespans are extended, or if products can be fixed by buying spare parts, and if local consumption ecosystems emerge, this could lead to a reduction in the overall tonnes of products transported, as well as a shortening of the distances between production, consumption and repair sites.

INDIA POLICIES TO SHIFT FINANCING FROM ROAD INFRASTRUCTURE TO RAILWAYS

With the goal of achieving self-sufficiency in meeting economic demand and hence enhancing its export capacity, India is likely to witness rapid growth in freight transport. India has experienced a steady shift from rail to road over the last three decades, with road freight representing today about 70% of overall goods transport (Ministry of Railways, 2020).

However, according to our analysis, reducing emissions from freight transport along with removing the current inefficiencies in the logistics sector will require an urgent transformational shift to develop an efficient multimodal system, in which rail will have to play a more significant role.

To achieve this shift, a change in current planning and financing trends is required, trends that have driven huge growth in highway construction of more than 300%, compared to limited growth in rail construction of only 5%. These trends have also restricted the development of last mile connectivity for rail freight, which is necessary for the transition, and always prioritized passenger transport over freight. Policy interventions are therefore necessary to bring about such a systemic change in freight transport.

There are two areas where the government can intervene to facilitate a modal shift towards rail. First, there are hardly any regulations around multimodal transport, such as uniform rules that apply from the origin of freight to its destination. Even though the national logistics policy (Prime Minister's Office, 2022) provides the initial direction, there is a gap around governance mechanisms for seamless connectivity across all modes, such as real time information on the movement of goods and last mile delivery facilities. Second, current financing trends place insufficient focus on the transport capacity of rail, particularly the cross subsidizing of passenger transport, thus leading to an overburdened and outdated rail network. Hence, there is a need to provide finance support through innovative investment mechanisms for developing rail technology and expanding rail capacity.

NIGERIA SETTING NEW GOVERNANCE AND INVESTMENT RULES TO DEVELOP RAIL FREIGHT AND LIMIT THE DEPENDENCY ON ROAD FREIGHT

Nigeria's freight transport is dominated by road transport, which represents 99% of goods traffic. This heavy reliance on road transport has led to issues such as traffic congestion, infrastructure degradation, and high emissions. In Nigeria, the rail network has historically been underutilized and underdeveloped, and according to our national analysis, this must change (Akujor C.E. et al., 2022; Emodi N.V. et al., 2022).

First, central government should take the lead in the planning process and prioritize network routes that maximize economies of scale for the country and enable regional connections with neighbouring countries. This could allow Nigeria to develop major production corridors and enhance its role in regional trade partnerships. Such centralized planning would prevent the emergence of a fragmented and inefficient network, which is likely to result if regional politics and decisions are the main drivers. However, regional and central government should join forces to reduce regional security threats, which have been a barrier to the development of an efficient national railway network and service, particularly in the northeast, and which constitute a potential risk for southern coastal lines.

Second, a new framework law for rail development should be developed with the best-in-class standards to attract investments, to ensure safety and efficient operations, as well as to support national development. For example, the government could open railway investment opportunities to private and international investors through public private partnerships. This could attract new financing and encourage competition between Nigerian actors and the foreign private sector. However, to ensure rail projects contribute to inclusive and sustainable development, the rules governing investments should set some obligations for private investors to employ local workers and companies for construction, but also to train workers to develop long-term skills for operating and maintaining infrastructure. Furthermore, national companies should remain within the project structure to allow some level of technology transfer. In addition to the direct impacts of new rail investment, the revitalization of the rail system can bring benefits and jobs to upstream industries, and also to manufacturing and logistics industries.

Finally, in terms of governance, a new framework law must define a key role for the central state in the planning process, as mentioned above, but should also offer opportunities for broader inclusive governance. For example, a new rule could establish a national obligation to reach a consensus regarding large-scale projects, to support the participation of Nigeria's indigenous peoples in national development and the deep decarbonization of the transport sector.

SOUTH AFRICA CHANGING THE GOVERNANCE OF RAIL INFRASTRUCTURE AND ASSETS IS A KEY PRIORITY TO ENABLE THE DEVELOPMENT OF RAIL FREIGHT

Shifting road freight to rail has the largest potential to decarbonize freight transport in South Africa in the short, medium and long terms. The much more challenging systemic transformation to achieve this shift relies on our capacity to implement existing official policies announced in 2022, namely the White Paper on National Rail Policy (Department of Transport of South Africa, 2022). The core policy is to open state-owned railway infrastructure to all train operators, state and privately owned. This is explicitly not a privatization of the industry but a concessioning out of severely underutilized track and rolling assets to operators that successfully bid to operate concessions (Trollip, 2022).

According to our analysis, opening the rail system to private train operators will be a major systemic transformation because there has been conflict within the tripartite ruling alliance, and hence in the ANC-led government for more than 30 years about the roles of state-owned enterprises and the private sector. This policy has become necessary because of the ongoing and deteriorating performance of the state-owned monopoly, Transnet, to the point of collapse, which has been confirmed by the National Planning Commission (NPC) after an in-depth investigation into Transnet (NPC, 2020).

A special department in the Presidency has been established to fast-track implementation but has encountered a challenging implementation environment. Indeed until very recently, allowing privately-owned trains onto the state-owned monopoly railway system was against the overarching policies of government and the ANC, which labelled any such move as privatization.

CONCLUSIONS

These country-specific examples highlight four different organizational shifts and related examples of enabling conditions that must be established to bring about deep reductions in freight transport emissions (see **Table 1**).

Table 1. Four organizational shifts and related examples of enabling conditions

Organizational shifts	Enabling conditions	Country examples
Producing and consuming sustainably	• New governance to allow cross-cutting measures between energy, transport, and industrial systems • Consumer information about repairability and product lifetimes • Involvement of large private industries to allow effective policies on logistics	France
Producing goods closer to consumers	• Adapted production tax;	Brazil
Developing more and better railway infrastructure, integrated into the logistics organizations	• Shifting road infrastructure finance to rail infrastructure • Multimodal logistics reforms to standardize transport regulations across national regions • Rail governance reforms centralizing infrastructure planning decisions and opening infrastructure finance to private and foreign investors • Involving large private industries to allow effective policies on logistics • Involving indigenous peoples to allow appropriation and adapted infrastructure development	India Nigeria
Reinforcing the competitiveness of rail services in terms of costs, time and quality compared to road services	• Revised road taxation systems; • Rail governance reforms opening access to railway infrastructure to private rail freight service operators	Brazil South Africa

HOW INTERNATIONAL COOPERATION COULD SUPPORT THE IMPLEMENTATION OF THESE ORGANIZATIONAL CHANGES

The effective implementation of the above-mentioned organizational changes identified as crucial for the decarbonization of freight transport largely depends on national actions and policies. However, international cooperation could play an important role in catalysing and accelerating these changes. Specific attention should be given to structured experience-sharing on best practice policy-making between countries, organizing technical assistance, directing international finance towards tangible industries and transport infrastructure, and modifying the contents of commercial and trade agreements (see **Table 2**).

In all these examples, the critical innovation lies in approaching cooperation in a way that directly supports national development and net-zero transformations, taking the diversity of country-specific sociocultural, economic and policy contexts into account.

This requirement forces a revisiting of conventional approaches to the different building blocks of cooperation listed above:

- Knowledge sharing should be organized around specific challenges and opportunities of industrial organization as emerging from the countries' experiences and the process should allow entering into the details of possible solutions, as opposed to skimming at the surface.
- Technical assistance should be demand-driven, i.e. primarily organized around the specific gaps identified by countries for their organizational transformations, as opposed to a more conventional supply-side approach triggered by technical assistance offers.
- Finance discussions should focus less on the overall perspective of financing flows, and instead start from the consideration of national needs for infrastructure changes

Table 2. Four organizational shifts and related examples of cooperation tools

Organizational shifts	Experience sharing on policies	Technical assistance	Financing	Trade requirements
Producing and consuming sustainably	• producer responsibility for the longevity and repairability of products, • consumer information	• planning and adaptation of sustainable production processes	• more sustainable industrial manufacturing processes	• repairability, longevity and recyclability of products
Producing goods closer to consumers	• local sourcing mandates, • tax incentives based on local content of products	*	• industries enabling local supply of semi-finished goods and alternative raw materials	• local content of production • social and economic conditions for workers to favour social development • taxes on production to avoid fiscal competition
Developing more and better railway infrastructure, integrated into the logistics organizations	• planning and public consensus	*	• rail, multimodal and logistics infrastructures	• regional rail interconnection and interoperability associated to regional trade
Reinforcing the competitiveness of rail services in terms of costs, time and quality compared to road services	• rail privatization and concessioning	• rail operations and system optimization	*	• technology transfer of innovative technologies reducing operation time and costs

*Blank squares are not an indication that relevant tools do not exist, just that no example has been provided.

in the industrial and transport sectors that are consistent with organizational transformations. This would help secure adequate finance flows towards such infrastructure and encourage the discussion to focus on the country-specific and infrastructure-specific financing barriers and solutions.

- Trade and industrial cooperation should explicitly consider the impact on freight transport emissions to support trade agreements compatible with the development of regional, continental and sustainable industrial value chains and associated logistics, a dimension largely overlooked in conventional trade agreements.

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Innovative International Cooperation for Climate

Reconciling urgent action and transformational change

AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)

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THE TRANSFORMATION OF AGRICULTURE, FORESTRY AND LAND USE MUST MEET OBJECTIVES ON MITIGATION, ADAPTATION, BIODIVERSITY, FOOD SECURITY AND RURAL LIVELIHOODS

The stakes are high for the transition of the agriculture, forestry and other land use (AFOLU) in a world facing climate and biodiversity crises conjointly with increasing food insecurity and income inequalities.

- The land use sector (AFOLU) is the source of 22% (13GtCO_2eq.) of global annual greenhouse gases (GHGs). The main sources of CO_2 emissions derive from the conversion of forests, peatlands, and other carbon-rich ecosystems to agriculture; from the methane emissions of livestock production and rice cultivation; and from N_2O emissions related to fertilizer use (IPCC, 2022(a)). If all emissions from other sectors associated with the functioning of the global food system are included (i.e. upstream emissions to produce inputs such as fertilizers and machinery, and downstream emissions associated with the transport and retail of food and other products), the share of global GHG emissions amounts to 34% (Crippa et. al., 2021). Furthermore, terrestrial ecosystems also bind carbon from the atmosphere in biomass and soils, thereby acting as a carbon sink.
- Terrestrial ecosystems are vulnerable to climate change, and agricultural yields have been negatively impacted by climate change over the last decades, reducing food and water security (IPCC, 2022(b)). Future risks include the reduced capacity of these ecosystems to bind carbon, the loss or degradation of much of the world's forests (due to climate and non-climate drivers), further losses to agriculture yields, intensive agricultural expansion that reduces the resilience of ecosystems, the loss of productive land due to desertification and increasing sea levels, reduced water availability, and the emergence of new forest- and crop pests and diseases (IPCC, 2022(b)).
- Conversions of natural biodiversity-rich ecosystems into managed landscapes and agricultural land, especially under extensive management, are the main drivers of biodiversity loss globally. Other causes, also related to land use, include the exploitation of wildlife and chemical pollution (IPBES, 2019).
- The agrifood system provides employment to 1.23 billion people, and contributes to the livelihoods of 3.83 billion people worldwide (Davis et. al., 2023). Agriculture, and primary production in particular, is the predominant employer especially in low-income countries (Davis et. al., 2023). Furthermore, poor communities with limited access to basic services are more vulnerable to climate change than others (IPCC, 2022).
- Agriculture and forests play a vital role in ensuring food security worldwide. However, global food insecurity is increasing, with 9.2% of the current world population classed as undernourished. Furthermore, global agrifood and land use systems are failing to provide affordable and healthy food for all, with 42% of the world's population unable to afford a healthy diet (FAO, IFAD, UNICEF, WFP and WHO, 2023).

The transformation of the AFOLU sector must therefore meet objectives on climate mitigation, adaptation and resilience, biodiversity conservation, rural livelihoods, and food security. This requires systemic transformations of the sector, including increasing ecosystem preservation and restoration, a transformation of agricultural practices, reducing food loss and waste, and further demand-side action on diets (Svensson et. al., 2021). The national pathways and policies best suited to achieving these aims depend on eco-climatic and geophysical conditions, as well as national political, socio-economic and institutional circumstances and priorities.

Globally, progress toward objectives on mitigation, adaptation, biodiversity, food security and rural livelihoods is currently insufficient. Consequently, there must be an increase in long-term ambition, while short and medium-term policies and plans must accelerate action to meet global targets (IPCC, 2022(a); IPCC, 2022(b); IPBES, 2019; IPCC, 2019). By considering the situations in Brazil, Colombia, India, Indonesia and Senegal, this chapter focuses on the main areas of international cooperation required to transform the land use sector to meet these objectives.

NATIONAL PATHWAYS AND POLICY MIXES THAT MEET TARGETS BASED ON NATIONAL CIRCUMSTANCES

BRAZIL

Land use, land use change and forestry (LULUCF) emissions account for 38% of Brazil's GHG emissions, and reducing deforestation is key for Brazil to meet its net zero emission target, and to halt the loss of biodiversity-rich and resilient rainforest and savannah ecosystems. The main driver of deforestation is agriculture, and hence reducing deforestation requires the transformation of not only forest management and governance, but also of the agricultural sector.

To reduce deforestation, Brazil's agriculture must continue its transition from highly land-extensive practices to more advanced, scientifically-driven, and innovative approaches. Recent research shows a potential for increasing agricultural output in monetary values (by 84% 2020-2050) while limiting agricultural land expansion (in the same scenario, agricultural land surface increases by 8% until 2050). The achievement of these results relies on many agricultural and forestry transformations, including the increase of livestock stocking rates and productivity, and the sustainable restoration of degraded pastureland for renewed agricultural use, which should reduce the pressure for the conversion of new land.

Furthermore, improved monitoring and governance of agricultural supply chains and forests may play an important role in reducing deforestation. Improving the tracking of livestock products will help establish deforestation-free value chains for cattle and other products. These solutions could build on ongoing initiatives, especially for livestock (e.g. the SISBOV certification system). It will also be important to reinforce the implementation of Brazil's forest code and the protection of conservation areas via strengthened command and control policies, including monitoring and the presence of authorities, the seizure of assets and equipment used in illegal exploitation, and the imposition of fines.

These transformations will rely on increased financial support and access to credit for farmers, particularly smallholders. To this end, the diversification of finance sources, particularly by attracting more private investment, is important. Furthermore, the provision of support must be accompanied by strengthened sustainability conditions, for example, agricultural loans should be granted in line with the Low-Carbon Agriculture plan that was implemented in 2021, a national policy to reduce the negative environmental impacts of agriculture. In a step in the right direction, the Brazilian Central Bank introduced new climate and socio-environmental criteria for rural credit in 2021.

COLOMBIA

Given that the AFOLU sector contributed 59% of gross CO_2eq emissions in 2018, according to the Colombian Biannual Update Report (BUR), it is clear that the sector will play a key role in attaining the goal of zero net emissions by 2050. Between 1990 and 2018, deforestation represented 33% of total emissions while enteric fermentation accounted for 14%. The Colombian Long-Term Strategy (LTS) indicates the need to prevent and rapidly reduce deforestation and ecosystem degradation, as well as the need to increase CO_2 absorption through ecosystem restoration, enhancing agroforestry and silvopastoral systems, and increasing commercial forestry. Increasing agricultural productivity via sustainable practices is necessary to guarantee adequate food provision for an increasing population, and for reducing an unsustainable increase in demand for land at the expense of forests and other carbon sinks. Livestock activities are particularly important in this respect as they significantly contribute to both gross emissions and deleterious land use change.

Rapid action is necessary to ensure long term decarbonization, and the updated nationally determined contribution (NDC) targets a 51% reduction in emissions by 2030. Meeting this target implies reducing deforestation from an average of over 200,000 ha/year to 37,500 ha/year, with an acceleration in this decrease at the start of this process and an increasing restoration effort. It also implies the transformation of 5 million hectares of traditional livestock production, about 20% of the total livestock area, into silvopastoral systems. Although there are no clear-cut goals in terms of increasing crop productivity, it is expected that a 70% increase in average productivity is required to supply the domestic demand in 2050 without encroaching into forest areas.

For deforestation control and conservation, the government issued the Comprehensive Strategy for Deforestation Control and Forest Management, which has recently been adjusted to maintain control over major deforesters, while collaboration and trust building efforts are being made with local communities to prevent deforestation. Building on these measures, the NDC sets a target of reducing deforestation to 50,000 ha/year for 2030 – which is likely to be insufficient in terms of supporting the NDC's emission reduction target. Regarding the transformation of livestock activities, there is an ongoing project to mainstream sustainable cattle ranching, which has provided the base for Resolution 126 of 2022 from the Ministry of Agriculture, officially issuing the Guidelines for Sustainable Bovine Cattle Ranching as the main tool for focusing governmental activity in this area. The guidelines emphasize the importance of a substantial adoption of silvopasture. The NDC sets a target on converting 3.5 million hectares of traditional pastures to sustainable livestock production, including silvopasture, by 2030 – which is short of the 5 million hectares considered as necessary according to recent estimates. Lastly, a set of sub-sectoral programmes focus on crop production (for sugar cane molasses, cocoa, rice, coffee, and commercial forests), some of which are quite ambitious, but there is a need for a comprehensive plan for a sustainable increase in agricultural productivity that is appropriately aligned with the goal of net zero emissions for 2050.

INDIA

The AFOLU sector accounted for 17% of India's GHG emissions in 2016, the primary sources being CH_4 and N_2O emissions from livestock, fertilizer applications, and rice cultivation. With almost 70% of India's population dependent on agricultural income and the sector characterized by small and marginal farmers, the transformation of agricultural systems must reduce non-CO_2 GHG emissions while ensuring improved livelihoods for the country's farmers. Additionally, India's AFOLU sector is must rapidly become more resilient.

Some of the key transitions within the land-use sector need to come from changes to rice cultivation practices (e.g. alternate aeration of continuously flooded paddy fields), improvements to livestock feed, and anaerobic digestors for manure management. These manure management policies would have the double benefits of gas capture, reducing methane emissions, as well as making organic fertilizers available for soil application. Furthermore, reducing nitrogen fertilizer use by improving the nutrient uptake efficiency of plants (e.g. through inhibitors, neem-coated urea fertilizers and nano- fertilizers) will reduce N_2O emissions, and other negative environmental impacts of excessive fertiliser application.

India's NDC aims to increase the LULUCF sector carbon sink by 2.5 to 3 billion tonnes of CO_2 equivalent through the expansion of additional forest and tree cover by 2030. Increasing on-farm tree cover could also play an important role for providing additional revenues to farmers and reducing risks as they diversify their production, and supporting biodiverse and resilient agricultural ecosystems.

The structure of the Indian agricultural sector, which comprises many smallholdings and marginal livestock farms, presents a challenge to the implementation of the above transformations. The Government of India is nonetheless endeavouring to stimulate these changes by undertaking extensive studies and mapping strategies towards doubling farmer income. The National Mission for Sustainable Agriculture (NMSA) is aimed at enhancing agricultural productivity especially in rainfed areas focusing on integrated farming, water use efficiency, soil health management and synergizing resource conservation. In 2014 the Government of India launched a national agroforestry policy with targets for farmer income, mitigation, and resilience. In addition, a biogas programme has been implemented to enhance manure management for harvesting energy and reducing emissions. Dairy co-operatives in India are active stakeholders in this programme who investigate the appropriate types of animal feeds and provision.

INDONESIA

The loss of peatlands and forests in Indonesia constitutes the country's main source of GHG emissions and biodiversity loss. Emissions from LULUCF accounted for 26% of national emissions in 2020, with high interannual variability due to the peaks and troughs in emissions from peat fires. Significant reductions in LULUCF emissions will be central for achieving the country's long-term strategy. Agricultural expansion is the main driver causing the decline in natural ecosystems, which means that to reduce deforestation and the loss and degradation of peatland, a transformation of land use and agriculture is necessary. To reduce the pressure for land conversion, important national-level actions have been identified, including boosting crop productivity via yield increases and cropping intensity, and optimizing the use of unproductive and marginal land for agricultural expansion. The former will require improvements to water and nutrient management (precision fertilizer, biofertilizer), crop rotation and diversification, as well as accelerating the restoration of water catchment areas to ensure a sustainable water supply; while the latter will require improvements to soil fertility and overall national, regional, and local land use planning. Improving the soil fertility of marginal lands is critical, and this will require innovative technologies to be made available to farmers, and public support to accelerate the adoption of new technologies and practices. In parallel to the restoration of degraded ecosystems for agricultural use, it is important that there is an acceleration in the restoration and rehabilitation of degraded forests, peatlands and mangroves.

In a context where 42% of the population is rural, of which many live in poverty, it is vital that climate and biodiversity objectives are aligned with rural livelihoods. Therefore, enabling local communities to use forests sustainably is a central tenet of Indonesia's land use transition strategy. Social forestry is a key policy aiming to achieve this goal, facilitating local communities to practice polyculture in forest ecosystems and to utilize non-timber forest products. As part of this policy, the government provides support to these communities in different forms (access to finance, extension services, technologies, markets), giving advice on how to carry out these activities without harming ecosystems. This also includes promoting the expansion of paludiculture – a type of farming carried out on peatland that does not degrade the peat. This requires issues around land tenures to be addressed, such as improving the lack of clarity in the land registry around ownership of certain land, and expanding government training and rural investment programmes to give farmers the necessary knowledge and initial investments to adopt more sustainable practices. Currently, 12 million hectares of forests are allocated to social forestry.

Additionally, research shows that demand side action to reduce food loss in national agrifood supply chains, and to limit the increase in meat consumption as the Indonesian population gets richer, will be important to contain agricultural expansion in Indonesia.

SENEGAL

In Senegal, five transformations will be central to a transition of agriculture, forests and land use:

- First, improving access to land and promoting the restoration of degraded ecosystems through improved land-use planning (including mapping of ecosystems and the changes they are undergoing in terms of salinisation, soil erosion, etc.), sustainable land management, and the promotion of agroforestry and agro-ecological practices in agricultural systems. Such transformations will require trainings for farmers and land managers based on local restoration practices, the management of local forests and public support to the development of agricultural entrepreneurship among young people and women.
- Second, the development of the integration of value chains in the agricultural, livestock and fisheries sectors is key to support the livelihoods of farmers. This requires interventions by various players in administrative authorities, local authorities and producer organisations as well as in technical support services. Furthermore, the development of integrated production centres for agriculture, livestock and fisheries (including improving access to inputs and water accessibility and use, and to animal health services). These centres should also promote integrated crop-livestock production systems.
- Third, gradual and sustainable intensification of farming systems, by promoting agroecology and resilient, low-carbon technologies is important, given low current land- and labour productivity. This transformation will build on low-carbon mechanisation, the control of water resources, the integration of zero carbon energy production into agriculture (biogas, solar, etc.). The integrated, low-carbon and resilient development of sub-sectors (including beekeeping, animal fattening, etc.) via for instance the introduction of new breeds with high genetic potential will also be important. This increase in the productivity of agriculture must be accompanied with an improvement in the competitiveness of domestic agri-food processing units, to ensure that it feeds a process of national industrialisation.
- Fourth, improved access to, and rational management of, resources for more resilient agriculture through improved governance of land and the promotion of management tools and information systems will prepare agricultural production for a changing climate. This includes action on the mobilisation of surface water and groundwater, improved management of wastewater, and energy. Ensuring hydro-agricultural rehabilitation and development via anti-salt and water retention dykes, and retention basins is also key in this trans-

formation. Strengthening of inter-zone water transfers will further help to mitigate impacts of regional weather events.

- Fifth, reducing agricultural production losses (pre- and post-harvest) will have benefits to the full range of objectives identified. Important strategies to do so including choosing resistant crop varieties; improving production, harvesting and conservation practices that minimises waste, for instance by to ensure that grains are harvested at the right stage of maturity; and facilitating farmers access to appropriate storage and conservation units and equipment.

COMMON TRANSFORMATIONS

The analyses of Brazil, Colombia, India, Indonesia and Senegal show that different strategies will be appropriate in different countries. Nevertheless, these studies also highlight some common transformations which must be implemented to achieve a resilient and biodiverse land use system that can reduce emissions while also supporting food security and rural livelihoods. These common elements include increasing crop and livestock productivity with agroecological and/or otherwise sustainable practices; improved governance of the use and ownership of land; the restoration of degraded land for agriculture or forests; increasing multipurpose land use; and improving the governance and efficiency of agricultural supply chains. **Table 1** provides further details on these transformations.

Table 1: Common systemic transformations in agriculture and forestry

Key elements of systemic transformation	Conditions for success / implementation	Countries where this transformation is cited
Increasing crop and livestock productivity with agroecological and/or otherwise sustainable practices	• access to improved technology and farming practices, e.g. light machinery and new crop production practices • improved financial support to farmers for changing practices	Colombia Brazil Indonesia Senegal India
Improve governance of the use and ownership of land	• land registry reform • increase state presence in/near forests for surveillance	Colombia Brazil Indonesia Senegal
Restore degraded land for agriculture or forests	• improved financial support to farmers for changing practices	Brazil Indonesia Colombia India Senegal
Increase multipurpose land-use, such as agroforestry	• access to knowledge about new production methods • improved financial support to farmers for changing practices	India Colombia Brazil Indonesia Senegal
Improve agricultural supply chain governance to reduce food losses and illegal activities	• infrastructure investments and investments in on-farm storage facilities • coordination among supply chain actors around sustainability norms	Brazil Indonesia Senegal

DIRECTIONS FOR INTERNATIONAL COOPERATION TO ACCELERATE NATIONAL ACTION IN THE AFOLU SECTOR

Implementing the transformations discussed above requires a package of coherent national policies and national political leadership, and on international conditions, including in terms of finance, trade and knowledge-sharing.

Innovative, well-targeted international cooperation designed with a bottom-up and needs-based approach can ensure that these conditions are in place. Many international initiatives already exist, especially around forestry-related questions. However, existing cooperation is poorly orchestrated and does not respond to the needs identified by countries in its current forms, and therefore leaves an international governance gap (Vidal, et. al., 2022). Hence, strengthening the coordination of international cooperation on AFOLU, and better aligning it with country needs is necessary to support ambitious national agriculture and forestry transformations. To avoid complicating the governance of AFOLU, it is worth noting that possible solutions may be found by reforming existing initiatives and institutions, and not necessarily through the creation of new ones.

Table 2 details how each international cooperation area could support the four identified transformations.

Finance can be an important area of international cooperation to support accelerated national action on AFOLU. Of particular significance is the support given to farmers and foresters to change their management practices – which requires investment by land managers (see **Table 2**). International finance has a major role in complementing domestic finance in emerging and developing countries (Songwe, Stern and Bhattacharya, 2022) and many initiatives already exist for financing forestry conservation and agricultural development. However, the AFOLU sector faces the greatest funding gap of all sectors in terms of achieving its global mitigation potential, which highlights an issue around the magnitude of finance available to support sectoral transformations (IPCC, 2022(a)). Recent research indicates that the AFOLU sector received 28.5 billion USD in 2019-2020, including 11.9 billion USD for agriculture and 11.7 USD billion for forestry (CPI, 2023a). The finance provided remain siloed within different objectives (food security, mitigation, adaptation, resilience, biodiversity, and agricultural development) (CPI, 2023a; FAO, UNDP, UNEP, 2021; CIDSE, 2020). This points to a need to reorganize the international financial architecture to better streamline these different objectives, and to organize financing around systemic sectoral transformations in the AFOLU sector. Furthermore, given the economic structure of agriculture and forestry, with many smallholders, there is a challenge to ensure that finance actually reaches these actors (as opposed to downstream actors in agrifood value chains) (Global Alliance for the Future of Food, 2023; Buto, 2021). Finance available to smallholders come predominantly from public sources (CPI, 2023b). Hence, questions around the sources (public versus private) and types of finance (for instance concessional loans versus grants) are central to ensure that international cooperation on finance meets the needs of countries.

Trade also has an important role in helping to reduce deforestation, the loss of other natural ecosystems, and to support sustainable agriculture transformations, including by setting internationally agreed standards on sustainability and deforestation-free products (see **Table 2**). Trade regulations and trade agreements increasingly consider environmental and development objectives (OECD, 2023). Environmental questions are also increasingly addressed via unilateral trade regulations and by setting standards, such as the EU's Deforestation Regulation (EUDR), functioning as an import ban on six commodities and their associated products from recently deforested land. However, such trade regulations

Table 2: international cooperation to support systemic transformations in AFOLU

Key elements of systemic transformation	Finance needs	Trade regulations required	Issues where experience-sharing and knowledge building would be beneficial
Increasing crop and livestock productivity with agroecological and/or otherwise sustainable practices	• support for national financial actors to finance farmers and foresters, including smallholders, to help them change practices • improve access to finance for other agricultural actors, including agritech firms in developing countries, to support the emergence of a national industry	• collective processes to define sustainability criteria (including for deforestation free products) for agricultural products in bilateral, regional and multilateral trade agreements • ensure that multilateral and regional trade rules do not counteract sustainable agricultural practices by blocking the differentiation of products based on their environmental impact	• practices and policies for agroecological / sustainable intensification that align with environmental and socio-economic objectives, among countries that are eco-climatically and socio-economically similar • barriers to the implementation of these practices and policies • establishing and reinforcing international research cooperation on these topics
Improve governance of the use and ownership of land	• support for national capacity building for monitoring and controlling forest areas • support for the reform of land use registries and tenures	• banning products from recently deforested land in trade agreements to incentivise improved land governance	• how to build and reform land use registries • how to establish effective land protection
Restore degraded land for use in agriculture and for rewilding	• support for national financial actors to provide finance to farmers and foresters, including smallholders, to help them change practices	• ensure that multilateral and regional trade rules support the protection and restoration of ecosystems	• practices and policies for restoring and rewilding that align environmental and socio-economic objectives, among countries that are eco-climatically and socio-economically similar • barriers to the implementation of these practices and policies
Increase multipurpose land use	• support for national financial actors to provide finance to farmers and foresters, to help them change practices	• favour products from multipurpose land use via trade agreements, for instance by including such practices as sustainable in trade agreements and collectively developing international agroforestry and/or agroecological certifications	• practices and policies that encourage multipurpose land use and align environmental and socio-economic objectives, among eco-climatically and socio-economically similar countries • the barriers to the implementation of these practices and policies
Improve agricultural supply chains to reduce losses and illegal activities	• support for national financial institutions and direct support to storage facilities, transport infrastructure, and platforms for supply chain actors to coordinate	• differentiating agricultural and forestry products in trade agreements and trade regulations based on their links to illegal activities, including illegal deforestation	• supply chain organization among countries facing similar challenges • dietary reform
Cross-cutting international cooperation that would favour all transformations cited	• international financial initiatives to adopt a sectoral financing approach instead of siloing investments along different objectives of subsectors (agriculture and forestry)	• develop trade and sustainability partnerships that include greater cooperation on sectoral transformations, alongside trade provisions	• address the implementation barriers that hinder best-practice policies • reinforce links between knowledge-sharing fora and international cooperation mechanisms, including on trade and finance

are often not developed in collaboration with exporter countries. Furthermore, for these trade regulations to propel lasting change they must also address systemic transformations of the land use sector, which in the case of the EUDR means linking international cooperation to support investments in the transformation of agriculture to the trade regulation. In this vein, integrating both trade and sustainability into agreements intended to function as cooperative mechanisms that address trade in the context of sustainable development is a promising approach. The Agreement on Climate Change, Trade and Sustainability, first announced in 2019 and currently including New Zealand, Costa Rica, Fiji, Iceland, Norway and Switzerland, is an interesting example of such cooperation (Voituriez, 2023).

An effective exchange of information around successful policies and practices in agriculture and forestry that align the different environmental and socio-economic objectives of the sectoral transformation, including on the barriers to implement these policies and practices, can play an important role in accelerating the five identified transformations (see **Table 2**). Some existing initiatives for such knowledge-sharing already exist, including the six workshops organized on different agricultural topics under the Koronivia Joint Work Programme on Agriculture, under the UNFCCC's Subsidiary Body for Scientific and Technical Advice (SBSTA) and SBI (Subsidiary Body for Implementation), and the FACT Dialogues on forest, agriculture and commodity trade launched at COP26 in Glasgow and hosted by the COP26 secretariat, the Beef Round Tables, etc. Such knowledge-sharing forums are constructive, but to be truly effective the dialogues and knowledge-sharing must not only address questions around best practices, but also around how barriers to implement best practices can be overcome. Clear links to other areas of international cooperation (such as international trade and finance) are also positive, to ensure that conducive enabling environments to the implementation of identified best practices are established at the international level.

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