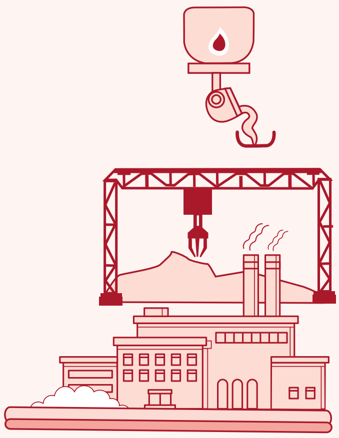
Innovative International Cooperation for Climate

Reconciling urgent action and transformational change



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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