comment

A climate club to decarbonize the global steel industry

Decarbonizing global steel production requires a fundamental transformation. A sectoral climate club, which goes beyond tariffs and involves deep transnational cooperation, can facilitate this transformation by addressing technical, economic and political uncertainties.

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Steel is an essential ingredient of modern economies. It is used in consumer products and embedded in infrastructures that underpin global societies. Its production is currently highly energy- and emissions-intensive. In 2019, direct CO_2 emissions from steelmaking accounted for 7% of global CO_2 emissions (10% if indirect emissions from electricity consumption are included)[1]. To achieve decarbonization, the sector requires deep transformation as current technologies provide only limited mitigation potential[2]. Moreover, steel is an internationally traded commodity. Consequently, any ambitious decarbonization policy will have international ramifications. Hence, the steel industry has become a focal point of political considerations for developing a 'climate club'. For instance, the European Union and United States agreed to launch negotiations for "arrangements to restore market-oriented conditions and address carbon intensity" for the aluminium and steel industry, inviting "like-minded economies to participate"[3]. Moreover, the German government seeks to initiate a climate club leveraging the German G7 presidency in 2022[4], highlighting steel as a pilot sector[5].

Such a sectoral focus is appropriate. Decarbonizing steel requires a fundamental transformation at the level of a sectoral system consisting of various actors, technologies and infrastructures, economic structures, institutions and ideas. Collectively, these produce sector-specific transformation challenges[6,7]. As 'institutional fit' has been identified as a key determinant of the efficacy of global governance[8], sectoral climate clubs addressing those challenges seem particularly pertinent. A sectoral club would also allow for a transnational governance arrangement, involving multinational corporations alongside national and subnational governments. Here, we highlight some of the particular challenges for transforming the steel industry and derive key design elements for a steel decarbonization club.

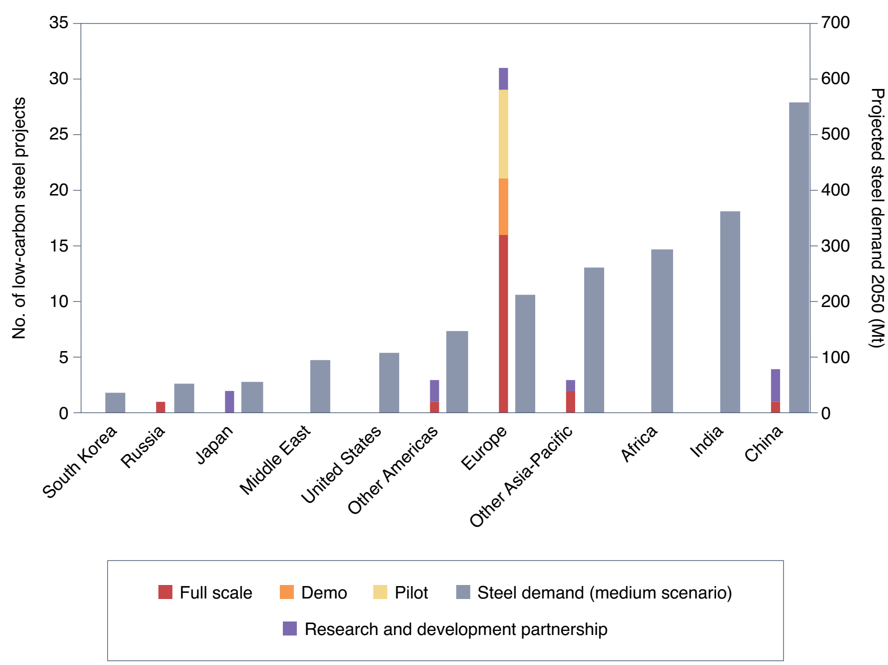

Fig. 1 | The global steel decarbonization technology gap. The vast majority of green steel projects and initiatives are located in the Global North, but the bulk of future demand for green steel will come from emerging and developing economies. Source: own illustration based on data from ref. [21] (green steel projects) and ref. [9] (demand projections).

The world has seen a surge of net-zero announcements and investment decisions in low-emission steel production recently. Since December 2020, five of the top six global steel producers (Baowu Steel, ArcelorMittal, HBIS Group, Nippon Steel and POSCO) have adopted some sort of net-zero emission target, covering 17% of total global steel production. The steel industry is evidently embarking on transformation. The main challenge now is to spread zero-emission steel technologies across the globe, responding to where the bulk of future steel demand will come from. So far, industrialized countries, in particular in Europe, are leading the transformation (Fig. 1). Advancing the decarbonization of the steel industry globally requires addressing technological, economic and political uncertainties that translate into higher financial risk and capital costs, slowing the transformation.

Several low-carbon steel technologies exist at varying degrees of technological readiness. To date, most announced green steel projects focus on direct reduced iron (DRI) technology based on green hydrogen, and on secondary steel-making using green electricity. Meanwhile, carbon capture and storage or utilization technologies have not caught on. Other technologies exist at lower levels of technological readiness. But viability will depend on infrastructures and specifically on sufficient renewable energy and green hydrogen supply.

Moreover, substantial economic uncertainty remains. Massive investments are required: given the age structure of the existing steel plants, over 50% of the global industry's core assets will have to be replaced with new technology by 2030[9,10]. Deployment of novel low-emission technology will lock steel-makers into uncertain, most probably higher operating expenditures, which require a substantial market premium to recover costs. To achieve this premium, a credible certification scheme for green steel and politically supported lead markets are needed. Especially in the coming decade, the size of the demand and willingness to pay for green steel is still uncertain, impeding investment decisions.

Decarbonized steel production neither lowers production cost nor increases product quality, thus providing no incentives for related investments. Instead, innovation leaders are motivated by the opportunity to capture incipient green steel markets and avoid stranded assets in anticipation of more stringent climate policy. In this regard, political uncertainty hampers the transformation of the steel industry. This is now exacerbated by the Russian invasion of Ukraine. Spiking natural gas prices may impede a key near-term avenue towards decarbonization for the steel industry: many green steel projects employ hybrid natural gas sourced syngas (H_2 and CO) DRI technology that can be shifted towards green hydrogen as it becomes available. The first step of this decarbonization strategy has now become much more expensive. In response to the same energy supply shock, many governments, particularly in Europe, consider accelerating renewable energy production and energy efficiency efforts[11]. The combination of high natural gas prices and accelerating green hydrogen adoption may bring full green hydrogen DRI production to market at scale sooner than anticipated.

Alternatively, green steel investments could be redirected towards places that can produce under more favourable conditions, especially in regions where iron ore supply meets vast low-cost renewable energy potential, capacity for industrial production and corresponding export infrastructures. In addition to domestic production (for example, in Sweden), Europe could import green iron from countries like Australia, Brazil or South Africa, and use it in existing steel plants to produce steel with substantially lower embedded CO_2 emissions while maintaining key parts of the value chain in Europe[12]. A steel sector club could support the build-up of such new value chains, establish green primary iron as a traded global commodity, and facilitate intensive collaboration between innovation leaders in Europe and their counterparts abroad.

More generally, a steel sector decarbonization club could address political uncertainties by setting credible long-term goals supported by strong government commitment and adequate policies. Member countries should define national transformation pathways leading to carbon neutrality by 2050 globally, and substantially earlier in developed countries. To avoid stranded assets, this implies a moratorium on (re-)investments in conventional unabated steel-making facilities from 2025. A club could also decrease political uncertainty by a strong commitment to ramp up renewable energy and green hydrogen production[11].

A club can address technological uncertainty by helping to coordinate global technology development. Public–private partnerships between governments and company members of a transnational steel club could be one avenue for sharing investment risks and managing access to intellectual property rights of successful technologies. This could take inspiration from previous transnational partnerships to develop drugs and vaccines[13]. At the national level, the UK Carbon Trust's Offshore Wind Accelerator or the French Instituts pour la Transition Energétique provide innovative examples. The club may also synergize with existing industry-led initiatives, such as the recently launched Global Low-Carbon Metallurgical Innovation Alliance[14].

To address economic uncertainty, a club should coordinate and integrate a suite of measures in a coherent package. This includes establishing a credible labelling or certification scheme for low-emission steel, combined with an independent auditing and compliance mechanism. Most of the academic literature so far has focused more on 'sticks' — coordination of carbon pricing and carbon border adjustments — to address free-riding and carbon leakage concerns, which are seen as the main rationales for a climate club[15–18]. While necessary, these face political headwinds. Initially, government members could also support the demand side in a coordinated fashion with the creation of less contentious 'carrot' lead markets through public procurement and dynamic but limited subsidies enabled through carbon contracts for difference[19]. The club could leverage these efforts with private sector demand for green steel by including large steel buyers. This approach is already being taken by the Clean Energy Ministerial's Industrial Deep Decarbonization Initiative[20].

Although 'carrots' can lead the process, such a climate club should aim to eventually coordinate its 'sticks' via similar carbon pricing stringency combined with similar common external tariffs or border carbon adjustments on carbon-intensive imports from non-members to attract participation. While this approach may play a role for a steel club in the long term, an exclusive focus on trade restrictions would leave plenty of potential for global governance underexploited. In particular, it is not suitable to facilitate the global spread of green technologies.

Building a climate club around sectoral transformation challenges could help build alliances and advance the discussion towards greater international collaboration for decarbonization. Decarbonizing global steel requires massive investments from the industry. To enable this transition, governments need to secure stable frameworks and the supporting infrastructure for vast amounts of clean electricity and hydrogen. A steel decarbonization club could facilitate coordination, providing governments with information and political backing for setting up sectoral transition plans integrated with infrastructure plans and incentivizing investment. By making and implementing such plans in parallel, the major obstacle of unfair competition could be tackled by the club. It also serves to increase industry confidence in governments' commitment regarding infrastructure investment and framework conditions. Further, a sector-focused climate club can provide leverage for cooperative low-carbon research and innovation, labelling and certification, as well as accumulating demand necessary to initiate markets.

A global climate club for steel could use the momentum generated by the US–EU trade agreement. However, a transatlantic agreement is insufficient to achieve global decarbonization. In the coming decades, the bulk of new steel demand will originate from emerging and developing economies.

A well-designed sectoral club involving those countries early on could provide a much-needed foundation for global cooperation and serve as a role model for other GHG-intensive and trade-exposed sectors, and may ultimately result in an overarching cross-sectoral club arrangement. ❐

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Published online: 23 May 2022
https://doi.org/10.1038/s41558-022-01383-9

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Acknowledgements

We acknowledge support from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement no. 101003866 (NDC ASPECTS).

Author contributions

L.H., S.L., H.v.A., C.B. and S.O. conceptualized the article. C.B. provided data for Fig. 1. L.H. wrote the initial draft and coordinated the reviewing and editing process. All authors contributed to reviewing and editing the manuscript.

Competing interests

The authors declare no competing interests.

The small scales of the ocean may hold the key to surprises

Sharp fronts and eddies that are ubiquitous in the world ocean, as well as features such as shelf seas and under-ice-shelf cavities, are not captured in climate projections. Such small-scale processes can play a key role in how the large-scale ocean and cryosphere evolve under climate change, posing a challenge to climate models.

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There is much debate about what scales of motion need to be represented explicitly ('resolved') in models in order to produce robust climate projections. By contrast to atmospheric jet streams, mid-latitude weather systems and squall lines, the oceanic equivalents (boundary currents such as the Gulf Stream, mesoscale eddies and submesoscale eddies) are roughly ten times smaller in scale. The ocean also has boundaries (coastlines) and sub-surface orography (bathymetry) that constrain the circulation pathways, and shallower shelf regions where tides become more important. Determining the scales that need to be explicitly resolved in the ocean is challenging as small-scale processes can have a substantial impact on high-impact, low-likelihood events.

Critical regions

The IPCC *Sixth Assessment Report* (AR6)[1] has made new assessments of future changes in the ocean. The agreement between multiple lines of evidence led to increasing confidence in large-scale changes such as warming of the global ocean and sea-level rise due to thermal expansion. However, there is less confidence in future projections linked to the large-scale circulation associated with the Atlantic Meridional Overturning Circulation (AMOC) and the Southern Ocean[2], sometimes described as the oceanic conveyor belt. The North Atlantic and Southern Ocean are both associated with high mesoscale activity