POLITICS & SOCIETY

POLICY PAPER

Climate-neutral steel

Enabling industrial transformation in Germany

Simon Schreck, Georg Kobiela, Simon Wolf

GERMANWATCH

Brief summary

The steel sector is responsible for approximately 30% of industrial greenhouse gas emissions in Germany – and, by extension, for 7% of national emissions. This makes the steel industry one of the most emission-intensive subsectors of the economy. The rapid and systematic decarbonisation of the steel industry is thus essential for achieving Germany's climate targets.

At the same time, the future of steel production is closely intertwined with the future of the German economy: The steel industry is responsible for 80,000 jobs domestically, and many other sectors depend on its products. One thing is clear: To preserve German and European competitiveness, policymakers must act rapidly to establish market and regulatory conditions that encourage investment in climate-neutral steel manufacturing.

The policy paper answers the following questions:

- Which technologies enable low-emission steel production?
- Which policy measures can support the transformation of the steel industry in Germany and the EU?
- How can German companies remain internationally competitive during the transition to climate neutrality?
- How can industrial transformation within Germany contribute to the rise of a climate-neutral steel sector internationally?

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Content

1 The importance of steel for climate policy

The steel industry is an important pillar of the German economy and a crucial source of domestic prosperity. Germany produces some 40 million tonnes of crude steel each year, making it the largest producer in Europe, and eighth largest worldwide. The steel industry directly employs some 80,000 people domestically and also provides important inputs to other areas of the economy, including the automotive and renewable energy sectors. Given its central economic importance, the steel industry will necessarily play an important role in the broader transition to climate neutrality and a circular economy.[1]

The steel industry is one of the most emission-intensive subsectors. In Germany, it is responsible for a just over 7% of national greenhouse gas emissions, emitting 55 million tonnes of CO_{2eq} in 2021. It is also responsible for 30% of industrial emissions. Globally, the steel industry produces more greenhouse gases than the world's third largest emitter, India.[2] The rapid and systematic decarbonisation of the steel industry is therefore essential for achieving the climate pledges made by Germany and the international community at large. At the same time, a successful transformation in Germany would position the German government and steel industry as an important source of expertise for the development of climate-neutral steel manufacturing in other countries.

Of particular relevance for the transformation in Germany is the age-related need for reinvestment in more than half of the primary production capacities for crude steel by 2030.[3] To be sure, the steel production capacities that should be located in Germany over the long-term remain unclear at present (given the goals of protecting the climate and ensuring economic resilience). However, steps must be taken now to ensure that future reinvestment is strategically channelled into key low-carbon technologies. The conditions that impact the relative attractiveness of steel production in a given geographic location are currently in flux, considering energy price trends in different regions of the world, geopolitical interests in a polarising world, and different frameworks for the necessary technology transition in China, the US, and the EU. This makes the need for rapid policy action to expedite the transformation of the steel sector in Germany and the EU all the more pressing. Therefore, the European Green Deal should be harnessed to maintain the attractiveness of Germany and Europe as jurisdictions for steel production and to preserve the innovative advantage currently enjoyed by European firms. In this way, the European Green Deal can be leveraged to establish new models for value creation. This, in turn, would furnish a basis for encouraging the transformation of the steel sector on a global scale.

[1] WV Stahl, Fakten zur Stahlindustrie in Deutschland 2022, 2022 (accessed: 28.04.2023).
[2] Globally the steel industry was responsible for 2.6 Gt $CO_{2eq\ of}$ direct emissions in 2019 (IEA, Iron and Steel Technology Roadmap, 2020, accessed: 28 April 2023). In the same year, India emitted 2.63 Gt CO_{2eq}. (Friedlingstein, P. et al, Global Carbon Budget, 2022, accessed: 28 April 2023).
[3] Agora Energiewende, Global Steel Transformation Tracker, 2023 (accessed: 28 April 2023).

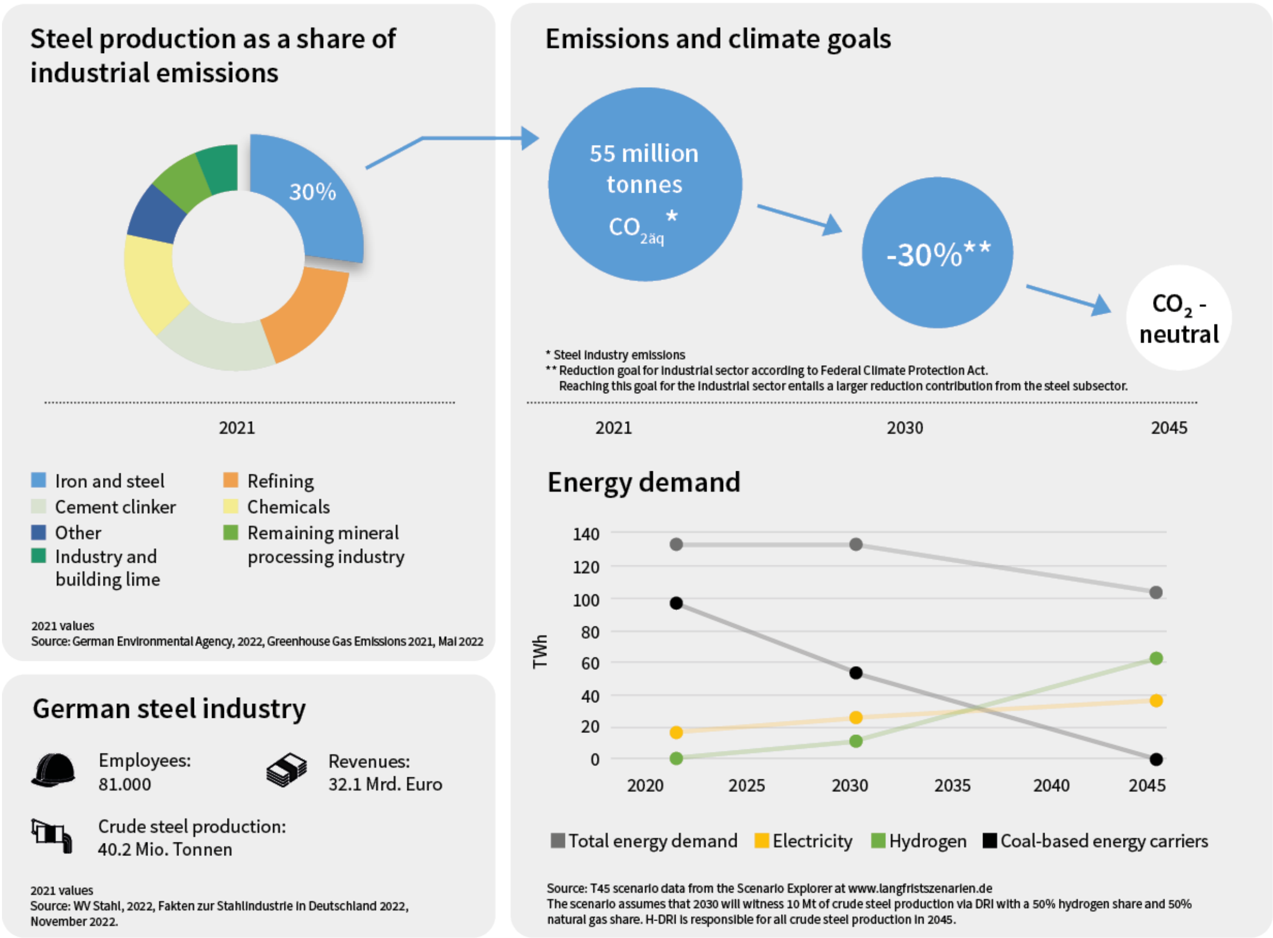

Fig. 1: Economic and climate data on the steel industry

2 Paths to climate-neutral steel

The predominant method of crude steel production is the blast furnace, which relies on coal as an energy source and reducing agent to convert iron ore into iron. On the blast furnace route, some 1.9 tonnes of CO_{2eq} are emitted for every tonne of crude steel manufactured.[4] Since these high emissions are process-dependent, entirely new production technologies are needed to avoid or reduce them. Various alternative technologies are already available today or will be available in a few years.

Electric steel route

So-called secondary steel production is based on the recycling of steel scrap. This production method is already in use today, irrespective of climate policy concerns. Steel scrap is melted down in an electric arc furnace. This process can be almost completely carbon-neutral given reliance on green electricity. However, despite a high recycling rate of 80–90% globally, steel scrap availability is limited. In the future, only a portion of steel demand will be met via this route (36–38% globally; 50% in Germany).[5, 6] Reliance on steel scrap will be limited first and foremost due to strong increases in global demand, particularly in China and India. However, the need for high-quality steel in various applications also constrains steel-scrap utilisation; such quality requirements can only be met with secondary steel given much higher energy inputs.

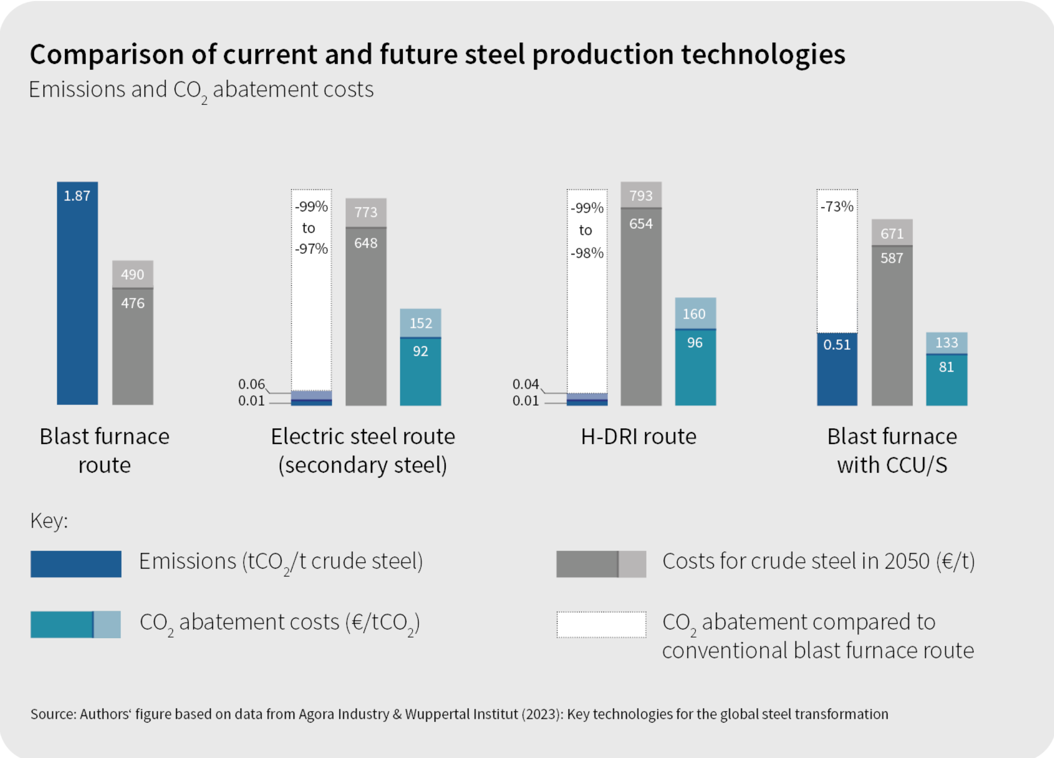

Fig. 2: Overview of low-carbon technologies and their climate performance metrics

[4] Agora Industry & Wuppertal Institut, Key technologies for the global steel transformation, in press.
[5] IEA, Iron and Steel Technology Roadmap, 2020 (accessed: 28 April 2023).
[6] Langfristszenarien 2022, available at www.langfristszenarien.de (accessed: 28 April 2023).

H-DRI route

Hydrogen based direct reduction (H-DRI) is an innovative low-carbon primary steel production technology that transforms iron ore into sponge iron (AKA pig iron). Sponge iron as an intermediate product is comparatively easy to transport – whether domestically or internationally – in the form of pig iron pellets. Given reliance on green hydrogen (that is, hydrogen generated by electrolysis using renewables) as well as the further processing of the sponge iron into crude steel in an electric arc furnace, emissions per tonne of crude steel produced can be reduced to as low as 0.01 tonnes of CO_{2eq}.[7] As the simple substitution of coal with green hydrogen in a blast furnace is only possible to a limited extent, it is necessary to build entirely new production facilities for direct reduction. Furthermore, green hydrogen production and electric arc furnace operation require a plentiful supply of renewable electricity. As sufficient green hydrogen is unlikely to be available at the beginning of the transformation, natural gas or blue hydrogen will play an important role as an interim solution prior to reliance on the fully climate-neutral H-DRI route. Forecasts indicate the H-DRI route will produce specific supplementary costs of +40–60% compared to the blast furnace route in the year 2050.[8]

CCU/S route

Unlike the previously mentioned options, Carbon Capture and Use or Storage (CCU/S) technologies do not directly avoid process emissions. Instead, associated carbon emissions are captured for further use or storage. These technologies will generate specific supplementary costs of +20–40% compared to the blast furnace route. Since it is generally not possible to capture 100% of emitted greenhouse gas emissions, CCU/S is associated with residual carbon emissions of at least 0.5 tonnes per tonne of crude steel produced.[9] Complete decarbonisation is therefore not possible via this technology path. In addition, carbon capture requires considerable energy inputs.

Comparing technologies

When the above technological options are compared (see figure 2),[10] the H-DRI route emerges as the only available option at present for primary steel production that is rigorously climate-neutral. Economically, it has similar carbon abatement costs as the CCU/S route. However, CCU/S technologies in the steel sector would enable the continued operation of coal-based blast furnaces, prolonging a business model based on fossil fuels.[11]

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[7] Agora Industry & Wuppertal Institut, Key technologies for the global steel transformation, in press.

[8] Agora Industry & Wuppertal Institut, Key technologies for the global steel transformation, in press.

[9] Agora Industry & Wuppertal Institut, Key technologies for the global steel transformation, in press.

[10] The data in figure 2 were kindly provided in advance by Agora Industry & Wuppertal Institute and will be published in summer 2023 in a study titled "Key technologies for the global steel transformation". For each value, a max/min bandwidth is shown, which reflects deployment of different specific technologies in each technological subsector.

[11] Given the goal of a climate-neutral steel industry in which secondary steel production plays a major role, innovative processes and technologies must be introduced in the domain of steel finishing to reduce energy and material inputs and increase recyclability, in addition to the technological transformation of primary steelmaking. However, a detailed consideration of these measures goes beyond the scope of this brief paper.

3 Germany has initiated transformation

All of Germany's major steel companies are seeking to achieve a 30–50% reduction in emissions by 2030 and climate neutrality by 2045 or 2050. In the run up to 2030, the individual companies are pursuing various strategies and have made divergent levels of progress. At German production sites, however, there is a clear focus on hydrogen-based steel production (H-DRI route).[12]

Three of the four major steel producers in Germany have ongoing or planned projects to replace their coal-based blast furnaces with H-DRI plants. One example in this regard is the large-scale SALCOS project, which will produce green steel using the H-DRI route starting in 2025; Salzgitter AG is leading the project consortium. Salzgitter AG intends to switch its production completely to the H-DRI route by 2033. In March 2023, Thyssenkrupp awarded a contract for a first H-DRI plant with a capacity of 2.5 million tonnes of direct-reduced iron. The plant is scheduled to enter operation in 2026. Thyssenkrupp is also involved in a CCU project (which does not enable complete climate neutrality) as part of the Carbon2Chem joint research project. ArcelorMittal, for its part, has already gained extensive experience with natural gas-fuelled DRI steel production. The company plans to convert all of its four German sites to H-DRI. In addition, there are currently numerous research, demonstration and pilot projects for climate-neutral steel production. However, for the most part the above companies have not yet made clear investment decisions for a rigorous conversion of production sites to climate-neutral technologies.

[12] LeadIT, Green Steel Tracker, 2022 (accessed: 28 April 2023).

4 Challenges and necessary policy measures

A number of challenges and obstacles must be overcome for the transformation of the steel sector to occur at the necessary pace. These can be broken down into three areas: Infrastructure, Financing, and Markets (see figure 3).

Infrastructure refers broadly to the availability of renewable electricity and hydrogen (or, as a temporary bridge, natural gas) in sufficient quantities, including associated transmission and distribution grids, and the technical capacity to construct H-DRI plants. In the area of **Financing**, targeted policy measures are necessary to finance the significant capital and operating expenditures required for climate-neutral steel production. In this connection, necessary policy measures include special subsidy programmes, carbon contracts for difference (CCfDs), and the further development of the EU Taxonomy. In the area of **Markets**, the sale of climate-neutral steel will depend on jurisdictions adopting clear standards and associated certification regimes in order to act as green lead markets for the technology. It will also require a rising carbon price and effective border adjustment mechanism to prevent carbon leakage.

Some of these policy measures are already being intensively deliberated by policymakers, business leaders, and civil society representatives, and are thus largely on the table as options. What is needed now is rapid action to adopt and implement associated policies. To be sure, some design elements are particularly important for ensuring the rapid, complete, and socially equitable transformation of the steel industry.

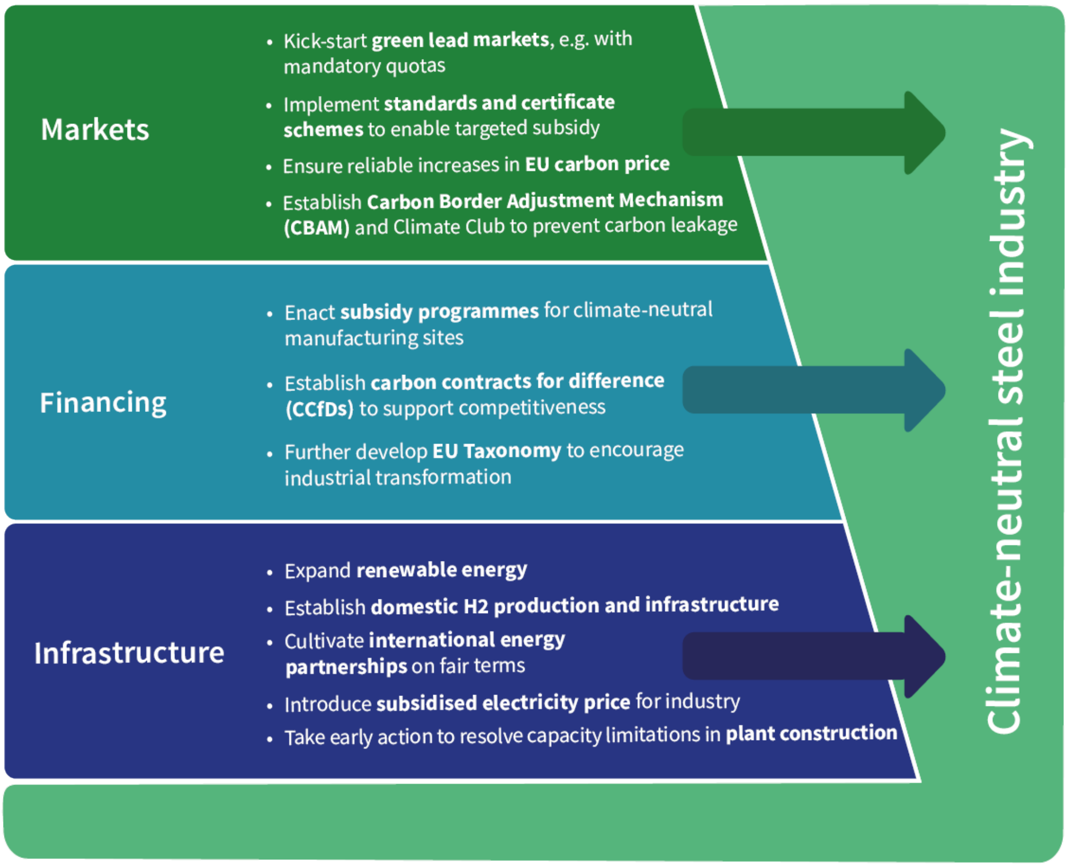

Fig. 3: Challenges and policy measures on the way to a climate-neutral steel industry

4.1 Ensuring necessary energy and infrastructure development

National and European green hydrogen production and associated transmission infrastructure must be developed as quickly as possible. For this to occur, however, policymakers must devote attention to streamlining existing permit approval processes, as well as to bolstering the administrative capacities of planning authorities and the courts. International energy partnerships will also play a key role in supplying the steel industry with sufficient quantities of green hydrogen. These partnerships should be designed to support economic development and transformation in partnering countries in a socially responsible manner.

Especially during the initial years of the transformation process, as green hydrogen is in limited supply, the steel industry must be prioritised as field of application for this virtually emissions-free energy carrier, as this is where the highest CO_2 reduction potential exists amongst industrial sectors.[13] In this connection, policymakers should promote the use of hydrogen whenever possible in identified priority areas. During a limited time period, priority should also be given to the use of natural gas, which can be an important bridge fuel for the transition to H-DRI.[14] Planned sites and capacities will need to be H_2-ready, thus ensuring quick and easy conversion to hydrogen.[15] Future conversion to hydrogen-based operation should be taken into consideration from the very beginning of the plant design process, and conversion should proceed based on scheduled milestones.

Subsidised power prices for industry are necessary in order to ensure that power remains affordable for climate-neutral manufacturing sites. A special power tariff for industry will additionally support the renewables-based energy system overall. This industrial power tariff should have clear price caps in order to guarantee reliable prices for industrial firms. At the same time, dynamic pricing should be introduced to incentivise flexible consumption.

[13] WV Stahl, Fakten zur Stahlindustrie in Deutschland 2022, 2022 (last accessed: 28 April 2023).
[14] While European natural gas prices soared following the Russian invasion of Ukraine, higher natural gas prices mean a smaller cost gap between natural gas and hydrogen-fueled DRI plants, which makes direct entry into H-DRI more attractive, given sufficient hydrogen availability.
[15] Over the medium and long term, the supply of green hydrogen must be economical as well as feasible in terms of energy balances in order to prevent “compulsory” reliance on natural gas from resulting or being construed.

4.2 Financing the transformation

Subsidy programmes and carbon contracts for difference

Investment grants from European and national funding programmes that support the establishment of climate-neutral H-DRI production facilities should be promised to industry as soon as possible. The operation of these plants also needs to be secured through carbon contracts for difference (CCfDs).[16] CCfDs will encourage the rapid development of H-DRI while also ensuring their competitiveness, especially in the initial years. The political process to introduce CCfDs is underway and needs to be completed as soon as possible. CCfDs should include dynamic adjustments of subsidy levels in order to prevent subsidies from becoming too high or too low. Excess revenues earned by firms when selling green products are forfeited to the government; at the same time, when firm revenues fall too low, the government makes up for shortfalls. All of these features are foreseen in the draft version of the CCfD Directive presented by the German Ministry of Economics in December 2022.[17] For its part, industry should make a binding pledge to decarbonise as quickly as possible in line with Germany's climate targets while also committing to preserve manufacturing sites and jobs. In our view, the CCfD draft directive should more firmly stipulate the need for such a commitment.

EU Taxonomy

In order to promote the investment necessary to bring about climate neutrality in the steel industry and other branches of the economy, rapid action must be taken to further develop the EU Taxonomy.[18] In addition, companies and policymakers should arrive at a consensus concerning the technologies and processes that will be used to achieve climate neutrality in the steel industry. This is essential for ensuring that sufficient funding will be available for transformation.

[16] Agora Industrie, FutureCamp, Wuppertal Institut & Ecologic Institut, Klimaschutzverträge für die Industrietransformation. Aktualisierte Analyse zur Stahlbranche, 2022 (last accessed on 28 April 2023).

[17] For more information, see the data provided by the Federal Ministry of Economics and Climate Protection (last accessed: 28 April 2023).

[18] For more information on the EU Taxonomy, see: Hoffmann, C., Die EU-Taxonomie – Fortschritte, Versäumnisse und aktueller Stand der Dinge, 2023 (last accessed: 28 April 2023).

4.3 Markets for green steel

Green lead markets

Lead markets for green steel in Germany, the EU and abroad represent an important component of the solution. Markets for certified green steel will allow at least part of the additional cost of producing such steel to be passed along to customers. However, the development of such markets will take time. To encourage the growth of markets for green steel, public procurement should be harnessed as a demand-creation vehicle, by making green steel mandatory for public infrastructure and real estate development projects. Policymakers should also establish quotas that require real estate developers and industrial manufacturers to use a certain percentage of green steel as an input material. In addition, efforts should be made to develop alliances with industrial actors in key subsectors – specifically, with subsectors in which the use of green steel has a strong impact in terms of market demand, yet only entails a small increase to end prices. Promising candidates in this regard include the automotive and wind energy sectors. To be sure, whenever mandatory standards or quotas are used to stimulate demand in product markets, care should be taken not to put domestic manufacturers at a disadvantage. Furthermore, when developing support instruments, policymakers should consider in advance opportunities for eventually achieving a well-functioning market that requires minimal intervention.

Green standards and certification schemes

Many of the policy measures described in this document are fundamentally dependent on the introduction of recognised standards and certification schemes for green hydrogen, green steel, and products that rely on green hydrogen or green steel as inputs. Legal frameworks and mechanisms for the establishment of these standards and certification schemes need to be adopted rapidly, both in Europe and internationally. In this regard, it is important for secondary steel to become more attractive than primary steel. In addition, incentives need to be established within the secondary steel industry to encourage reliance on renewable energy, green hydrogen, and emissions avoidance. While the standards and certification schemes must be aligned with the current availability of green commodities, at the same time, they must always be a reliable seal of quality, denoting ambitious transformation plans and their implementation. Amongst other things, it is important to consider real emissions throughout the value chain, so that steel produced with green hydrogen, for instance, receives a better certification than steel based on blue hydrogen. Emission offsets should not reduce total emissions for certification purposes.

Carbon prices, CBAM, Climate Club

To make green steel competitive in Europe over the medium to long term without government subsidies, it will be important to ensure a rapid reduction in free allocations in the European Emissions Trading (ETS) and reliable increases in the ETS price. Furthermore, the adoption of a Carbon Border Adjustment Mechanism (CBAM) will be crucial for preventing carbon leakage to non-European countries and for ensuring that green steel manufactured in Europe remains competitive with emissions-intensive steel from other parts of the world. The EU agreement reached in mid-April 2023 to reform and expand the ETS and introduce the CBAM is therefore a decisive step in the right direction. The task now is to ensure swift and consistent implementation of this agreement by EU member states.[19]

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[19] Gläser, A. and Caspar, O., Der CO_2-Grenzausgleich kommt, 2023 (last accessed: 28 April 2023).

However, it is important to be aware that over the long term, the market for green steel should not rely on direct subsidies (such as CCfDs) or market-shielding measures (such as the CBAM). Such policies must be viewed as temporary instruments for accelerating the transformation of the steel industry within Germany, the EU, and internationally. This spotlights the importance of ensuring that interventions remain bureaucratically straight-forward and efficient.

The Climate Club proposed as part of German G7 presidency may help to level the playing field internationally over the medium to long term, and thus minimise the risk of carbon leakage. The Climate Club's specific structure will be unveiled at the upcoming COP28 in Dubai.

5 German steel manufacturing in the face of global competition: renewables pull

The adoption of the H-DRI route for primary steel production modifies the calculus for selecting favourable production sites. On the one hand, hydrogen (or, in the interim, natural gas) is used as an energy carrier and reduction agent, rather than coal. On the other hand, DRI pig iron pellets (sponge iron) are easily transportable as an intermediate product. Accordingly, regions that boast a plentiful supply of low-cost renewable energy may be particularly attractive for the siting of H-DRI plants. This 'renewables pull effect' may mean the partial relocation of steel production to more suitable regions. This relocation of production capacities may be sensible from an macroeconomic perspective, in addition to its benefits for decarbonisation.[20, 21]

However, there are also good reasons to keep a significant share of sponge iron production in Germany or the EU. The preservation of domestic steel manufacturing capacities would not only help to protect jobs and economic prosperity. It would also bolster supply chain security while enhancing the resilience and independence of the European single market. Moving forward, the maintenance of domestic manufacturing will be all the more easier given significant further expansion of renewables in combination with greater energy efficiency across all sectors, as this would weaken any renewables pull effect emanating from abroad. In addition, the question arises as to whether certain subsectors, such as automotive manufacturing or wind power industries, would be willing to pay a premium for steel produced close to home.

However, even if steel production capacities are partially relocated abroad as part of the transition to H-DRI, the central part of the value creation chain – that is, the further processing of the DRI pig iron pellets (sponge iron) in an electric arc furnace and in rolling mills – can in principle remain in Germany, and thus close to important sales markets, even if this involves efficiency losses compared with integrated routes. This would allow the preservation of most steel-sector jobs in Germany.

Therefore, the first step is to better understand what effects a partial relocation of production steps would actually have on integrated supply chains. Building on this, public discussion is needed concerning the policy actions that can and should be taken to reduce the incentives to offshore production. Specifically, it is necessary to clarify the manner with which the aforementioned policy instruments should be combined to foster the rise of green steel while also maintaining significant value creation activities within Europe. One important issue in this regard is the price that society is willing to pay to preserve domestic steel manufacturing.

However, the speed with which the selected policy measures can be implemented is no less important. If upcoming investment decisions in the German steel sector are made in the absence of a policy and regulatory environment that is conducive to green steel, there is a good chance that future investment in climate-neutral steel production will be made in regions with more attractive financial, regulatory, or energy market conditions. Accordingly, efforts should be made to construct the key H-DRI capacities required to replace blast furnaces at German integrated sites by the early 2030s. While this is an advisable goal for preserving the economic prospects of existing production sites, achieving it will require coherent policy measures at both the national and European levels. The economically more powerful Germany must not give the impression that it is looking after its own industrial interests, possibly at the expense of its European neighbours. For this reason, Germany should advocate for EU policy that supports transformation across all EU states. A higher EU

[20] Samadi, S., et al., Renewables Pull – Verlagerung industrieller Produktion aufgrund unterschiedlicher Kosten erneuerbarer Energien, Energiewirtschaftliche Tagesfragen, 71. Jg., 2021, Heft 7-8 (accessed: 28 April 2023).

[21] Verpoort, P. C. et alhttps://zenodo.org/record/7826081., Estimating the renewables pull in future global green value chains (v1.0.1), 2023 (accessed: 28 April 2023).

share of public funding for industrial transformation, as has been proposed by the EU Commission in its Net-Zero Industry Act, would be one helpful step in this regard. Yet another helpful step would be policy support for the rapid and coordinated ramp-up of a European hydrogen industry.

6 Transforming global steel production

While discussions surrounding the transformation of the German steel industry should naturally consider domestic economic interests, it is also important to give due attention to our collective welfare and climate protection in a global context. Indeed, German industrial policy should not merely be informed by narrowly conceived domestic considerations, but also by a desire to contribute to the rapid decarbonisation of global steel production. One objective in this regard should be to ensure that world regions with a growing demand for steel in the coming years and decades can satisfy this demand to the greatest possible extent with green steel.

This goal is not incompatible with domestic economic interests; rather, it can be complementary to them. By bearing the initially higher cost of green steel production and by contributing to associated technological development and learning curves, Germany and the EU have an opportunity to play a vanguard role in green steel adoption that accelerates the global transformation of the steel sector. This, in turn, will increase the likelihood that new steel investment will flow into green steel technologies, both within and outside Europe. In addition, Germany and the EU can be much more effective in contributing to international dialogue and associated processes on green steel if the transformation is tackled ambitiously and successfully implemented in Germany.

The development of green steel in Germany and the EU would also position Europe to provide targeted support for the construction of industrial capacities abroad, especially in countries with lower per capita GDP. This could take place within the context of strategic partnerships that secure access to low-cost raw materials. Alternatively, foreign DRI and hydrogen production could be integrated in a targeted fashion into German and European supply chains. Both would safeguard and strengthen value creation in Germany and Europe as a whole. On the other hand, the development of corresponding industrial structures could be supported irrespective of European or German strategic interests as part of Just Energy Transition Partnerships (JETPs), especially in countries with lower per capita GDP. For example, funds from the CBAM could be used for this purpose, sending a signal that German and European industrial strategy does not pursue protectionist aims.

Notes:

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