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Green Transformation as a Critical Factor in Steel Industry Strategy Formulation

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Abstract

Aim: The author aimed to identify and present how the European steel industry practically responds to the regulatory changes termed the Green Deal. The article thoroughly discusses and compares the strategic responses of three market leaders – ArcelorMittal, Thyssenkrupp, and Voestalpine – to the regulatory environment shaped by mechanisms such as the EU ETS and CBAM.

Methodology: The study adopted a qualitative research strategy, utilising a multiple case study approach. The empirical basis consisted of desk research, encompassing corporate documents, industry publications, and statistical data. The collected material underwent thematic analysis to identify and compare the key dimensions of the announced strategies.

Results: The analysis revealed an apparent convergence that conceals a deep strategic divergence. While all the examined companies identified the hydrogen-based DRI-EAF technology as the target production model, their declared implementation logics and risk management pathways differed significantly – from technological diversification (ArcelorMittal) to radical transformation (Thyssenkrupp) and an evolutionary, phased approach (Voestalpine). A fundamental gap was also identified between corporate declarations and market realities, illustrated by the projects' dependence on timely public support and stable economic conditions.

Implications and recommendations: The conclusions point to a strategic gap in current plans, specifically the underestimation of operational risk arising from the incompatibility between continuous steel production and the variable generation of green energy and hydrogen. The strategic recommendation is for companies to consider vertical diversification towards proprietary hydrogen production and storage, which may secure supply and reduce exposure to market fluctuations.

Originality/value: The paper fills a research gap identified in the literature, moving from a general, sectoral perception of the transition to a granular, comparative analysis of announced corporate strategies. Its value lies in providing a benchmark for evaluating different models of strategic adaptation under conditions of unprecedented regulatory and technological pressure.

Keywords: decarbonisation, European steel industry, corporate strategies, case study, green transformation

1. Introduction

The European steel sector stands on the verge of an unprecedented transformation driven by the European Union's ambitious climate policy. Its historical dependence on coal and the high energy intensity of its production processes make it one of the main emitters of greenhouse gases, and thus a natural target for EU regulations. This is not a marginal issue as steelmaking is responsible for around 7% of global CO_2 emissions and approximately 5% within the EU, which makes decarbonisation of the sector both a climate and an industrial-policy priority (IEA, 2020). This pressure materialises in the form of two key instruments: the tightening European Union Emissions Trading System (EU ETS), which raises the direct cost of CO_2 emissions, and the newly introduced Carbon Border Adjustment Mechanism (CBAM), which aims to protect EU producers from competition from regions with lower environmental standards. These new legal frameworks create a complex business landscape. On the one hand, they generate immense challenges related to the need for multi-billion-euro investments in new technologies and the risk of losing competitiveness in the global market. This competitiveness dimension is essential because the EU accounts for only a minority share of global crude steel output while countries such as China produce “over half” of global crude steel (960,8 Mt out of 1849,4 Mt in 2025), shaping price pressure and the pace of technology deployment under a different regulatory logic (World Steel Association, 2026). Consequently, carbon leakage risks and cost benchmarks versus non-EU producers become central to assessing whether ‘green steel’ can scale beyond niche, premium-demand segments (ERCST, 2024). On the other hand, they open the door to new opportunities, such as the creation of a premium market for ’green steel’ and the achievement of a global technological edge. In this dynamic reality, survival and development depend on the capacity for strategic adaptation. This compels leading enterprises to fundamentally re-evaluate their business models and seek innovative decarbonisation pathways that will allow them to meet regulatory requirements without sacrificing their market position. The purpose of this article was to identify and present how the European steel industry practically responds to the regulatory changes termed the Green Deal. To achieve this, the article thoroughly discusses and compares the strategic responses of three steel market leaders—ArcelorMittal, Thyssenkrupp, and Voestalpine—to the regulatory environment shaped by mechanisms such as the EU ETS and CBAM. The analysis focuses on how these companies interpret the same regulatory signals and translate them into different decarbonisation priorities, technology choices, and investment sequencing, while managing key implementation constraints such as energy and hydrogen availability and the resulting competitiveness pressure in global markets. The study was based on a qualitative multiple case design using desk research of publicly available corporate and regulatory materials, treated as strategic declarations rather than verified implementation outcomes.

2. Literature Review

One of the key determinants of change is the European Green Deal, which aims for climate neutrality by 2050 (Rada Unii Europejskiej i Rada Europejska, 2025). In the literature, the Green Deal is typically framed not only as an environmental agenda, but also as an industrial transition programme that reshapes investment conditions, competitive dynamics, and the strategic time horizon of energy-intensive sectors such as steel (Guevara Opinska et al., 2021). It provides a fundamental impetus for implementing changes in current carbon steel production processes, being achieved through two main instruments.

The first is the Emissions Trading System, which imposes a price on CO_2 emissions through a market mechanism. The literature extensively documents its evolution, from initial problems with an oversupply of allowances to the current fourth phase, characterised by a rising signal price and the gradual phasing out of free allocations, directly increasing cost pressure on producers (Stede et al., 2021). Recent analyses emphasise that the real strength of the EU ETS signal depends on how quickly free allocation declines relative to benchmark updates and investment cycles in capital-intensive plants, which makes the timing of policy changes strategically material for incumbents (Böhringer et al., 2024).

The second, newer instrument is the Carbon Border Adjustment Mechanism (CBAM), designed as a tool to counteract the phenomenon of "carbon leakage", namely the relocation of production to countries with less restrictive climate policies (Gajdzik et al., 2023). CBAM aims to level the competitive playing field by subjecting imported products to a charge equivalent to the emission costs borne by producers within the EU. Although its long-term effects are still debated, there is a consensus that it represents a crucial element in protecting European industry during the transition period. At the same time, the literature highlights key uncertainties: administrative complexity, interactions with the gradual phase-out of free allocation, and potential downstream effects along value chains (including pass-through of costs and competitiveness impacts for steel-using industries) (OECD, 2025a).

From a technological point of view, three main, though not mutually exclusive, directions for the decarbonization of the steel sector have been distinguished (Agora Industry & Wuppertal Institute, 2023; Rissman et al., 2020):

- **The Hydrogen Paradigm:** The most revolutionary pathway, viewed as the long-term solution, involves the use of green hydrogen in the Direct Reduced Iron (DRI) process, followed by melting the input in Electric Arc Furnaces (EAF). This method allows for the near-total elimination of CO_2 emissions from the production process. However, the primary subject of research and concern remains the provision of vast quantities of renewable electricity and green hydrogen at competitive prices (Vogl et al., 2021). Recent system-level studies stress that feasibility is constrained not by the steel process alone, but by the surrounding energy system (renewables build-out, grids, storage, and hydrogen logistics), which may create significant regional asymmetries in the viability and pace of H_2-DRI deployment (Muslemaniet al., 2021).
- **The Evolutionary Paradigm (CCUS):** This path relies on modernising existing blast furnace infrastructure by implementing Carbon Capture, Utilisation, and Storage (CCUS) technology (Rui et al., 2025). This is a transitional solution that can significantly lower emissions in the shorter term, yet it raises controversies related to costs, the safety of CO_2 storage, and long-term dependence on fossil fuels (Nath et al., 2024). The debate is also shaped by the perceived risk of 'lock-in': CCUS may prolong the lifetime of coal-based assets, while its scalability depends on transport and storage networks that are unevenly developed across Europe (Reuters, 2024).
- **The Circular Paradigm:** This focuses on maximising the recycling and utilisation of steel scrap in the EAF process. It is the most energy-efficient route, but its potential is naturally limited by the global supply and quality of available scrap (Compañero et al., 2021). Accordingly, the literature often treats scrap availability and quality as a structural constraint that differentiates firm strategies (e.g. by product portfolio and required metallurgical purity), rather than as a universally scalable solution.

However, a specific paradigm does not imply a clear path to transformation. Each steel mill has its unique processes. Although the final product is standardised and must fall within certain ranges, each mill achieves this in a different way. There are also various types of steel on the European market, and each grade requires a different approach to transformation. Perceiving the sector as a homogeneous entity is therefore a limiting factor.

Existing research on steel decarbonisation tends to focus on the sectoral level, neglecting the strategic heterogeneity of individual companies. Consequently, a gap has been identified in the literature concerning the lack of empirical comparative analyses that confront the actual strategies of market leaders. This paper fills that gap by practically examining how key players are implementing the transformation, allowing for an assessment of the convergences and divergences in their strategic choices.

3. Methodology

The study was conducted based on a qualitative research strategy, utilising the multiple case study method. The analysis included three deliberately selected, leading steel producers in the EU: ArcelorMittal, Thyssenkrupp, and Voestalpine. Their selection was justified by their dominant market position and the public nature of their transformation strategies. Following the logic of multiple-case designs, the cases were chosen as ‘information-rich’ and suitable for analytical comparison (replication logic), rather than to achieve statistical representativeness. The applied descriptive and comparative method aimed not only to present individual strategies but also to identify gaps in the current, often simplified perception of the steel industry transformation. Accordingly, the unit of analysis was the announced corporate decarbonisation strategy (i.e. declared pathways, investment sequencing, and risk framing), and not the verified implementation outcomes.

The empirical foundation was desk research (analysis of existing data), covering publicly available corporate documents (investor presentations, annual reports), articles in industry press, statistical data from Eurostat databases, and other academic papers on the sector and the specified companies. This approach involves document analysis, where public records are treated as data requiring critical interpretation (e.g. attention to purpose, audience, and potential bias). The collected material was subjected to thematic analysis, the purpose of which was to identify and compare the key dimensions of the announced strategies. The thematic procedure involved iterative coding and grouping of evidence into comparable strategic dimensions (e.g. target technology route, transitional solutions, financing/public support dependency, and supply-side constraints such as electricity/hydrogen availability), enabling cross-case synthesis. To enhance analytical rigor despite reliance on corporate disclosures, the study applied basic triangulation by cross-checking company claims with independent industry/regulatory sources where available and maintaining a transparent ‘chain of evidence’ and cited documents. Nevertheless, a key limitation remained that corporate materials were strategic narratives, therefore the findings should be interpreted as a comparative assessment of declared strategic intent under regulatory pressure, rather than a measurement of realised decarbonisation performance.

4. Results

4.1. The European Steel Market

The European steel industry, crucial to the EU economy in terms of generated value added €152 billion in 2023 and employment (303 thousand jobs) (Eurofer, 2024), is at a turning point. Its competitiveness is constrained by a combination of adverse macroeconomic factors and growing regulatory pressure from the EU ETS system. In these demanding conditions, the necessity of implementing the green transformation becomes a critical strategic challenge. Market data for 2023 accurately illustrate this situation. Crude steel production in the EU (126.2 million tons) (Eurostat, n.d.) represented only 6.8% of global production, highlighting the scale of international competition. This competitive asymmetry is reinforced by the global structure of output: in 2023 1,904.1 Mt of crude steel were produced, of which China contributed 1,028.9 Mt (about 54%), shaping global price dynamics under a different regulatory logic than the EU (World Steel Association, 2024). The EU market, with a consumption at 125.6 million tons, remained reliant on imports (28.9 million tons) (Eurofer, 2024), which poses a significant risk in the context of rising CO_2 costs in Europe. The OECD (2025b) stated that this import exposure is directly linked to carbon-leakage concerns – if EU producers face higher carbon and energy costs than non-EU suppliers, market share can shift toward external producers unless trade-defence instruments and CBAM implementation are effective. Although the sector demonstrates a strong commitment to recycling, consuming 75.2 million tons of scrap, its position as a net exporter of this raw material (15 million tons) (Eurofer, 2024; Eurostat, n.d.) indicated further opportunities for closing the material loop within the Community. At the same time, international analyses stressed that persistent global excess capacity—often amplified by state support in key producer economies—continues to exert downward pressure on margins, making capital-intensive decarbonisation projects more sensitive to market downturns and policy uncertainty (OECD, 2025b).

4.2. ArcelorMittal

ArcelorMittal has long remained one of the most important global players in the market. In recent years it has maintained the second position globally, surpassed only by the China Baowu Group (Tiwari, 2024). The company's operations are primarily attributed to Luxembourg, but it conducts business on six continents: North America, South America, Africa, Europe, Asia, and Australia, maintaining its position as the market leader in Europe for years. One of the largest steel mills of this brand is located in Bremen, Germany (ArcelorMittal, n.d.a). In response to the need for transformation, the organization proposed the XCarb® towards net zero steel project in 2021 (ArcelorMittal, n.d.b), with the goal to achieve carbon neutrality by 2050. The plan reflects a dual-track logic that is widely discussed in the decarbonisation literature, maintaining optionality by developing more than one pathway under high uncertainty. The plan assumed an ambitious transformation based on two main technological pillars: the DRI pathway and the Smart Carbon pathway. The innovative DRI pathway proposed the use of 'green' hydrogen as a reductant in the steel production process, which was intended to lead to near-zero CO_2 emissions. In this process, hydrogen (H_2) acts as a reductant, replacing coal and coke; the reaction with iron oxides (ore) results in water (H_2O) instead of carbon dioxide CO_2, which is the essence of this technology. The Smart Carbon idea focuses on the existing steel mills with blast furnaces, where emissions were to be reduced through Carbon Capture and Utilisation and Storage (CCUS), and the replacement of coal with biomass and waste (ArcelorMittal, 2021). ArcelorMittal explicitly presents this route as a way to retrofit BF-BOF assets by combining circular carbon inputs with carbon capture and use/storage, thereby reducing reliance on a single end-state technology. Since the evidence base is largely corporate communication, these pathways should be interpreted as strategic intent rather than a verified as-is state.

This situation changed in June 2025, when ArcelorMittal announced its withdrawal from continuing the investment in Germany. The company then informed the German government that it was unable to proceed with the investment in the construction of the DRI plant and Electric Arc Furnaces. The reasons cited were the inability to meet the deadline for starting construction (June 2025), which was a condition for receiving public subsidies totaling €1.3 billion, as well as generally unfavorable market conditions and high energy costs (Clean Energy Wire, n.d.). This decision is documented both in independent reporting and in ArcelorMittal's own statement, which directly linked the project's feasibility to Germany's "high and unpredictable" electricity costs and to the subsidy contract requirement to begin construction by June 2025 (Reuters, 2025a). This was a particularly important investment for the European market, as the indicated factory was the largest in Europe, also being a major source of supply for European customers. The withdrawal from this flagship investment revealed a fundamental discrepancy between ambitious climate declarations and the difficult economic realities currently faced by the European steel industry.

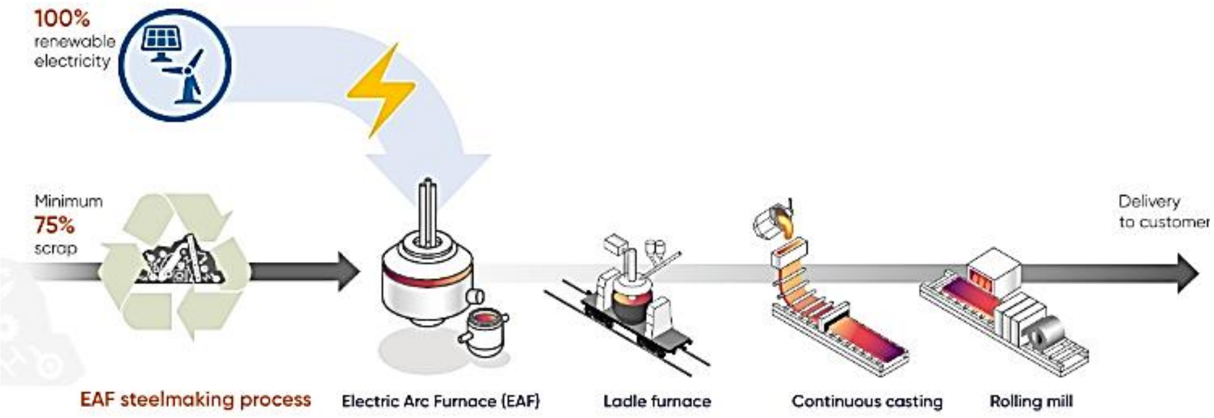

Fig. 1. XCarb® (flat products) acquisition process after the planned transformation

Source: (ArcelorMittal, n.d.b).

From a competitiveness perspective, the case illustrates a core ‘carbon-leakage’ dilemma: if EU decarbonisation pathways remain structurally more expensive than conventional production in regions operating under weaker carbon constraints, companies may rationally defer or relocate investment even when public support is available.

4.3. Thyssenkrupp

Thyssenkrupp, with its operational center in Duisburg, described by the company as Europe's largest single steelmaking site, is a key player in the European steel market (SMS Group, n.d.). As a leading producer of high-quality flat steel, the group plays a fundamental role in the supply chains for strategic industries. Thyssenkrupp’s decarbonisation strategy is based on a two-pillar architecture that combines radical, long-term technological transformation with pragmatic market solutions available during the transition period. The core of this strategy and its target solution is the flagship project tkH2Steel (Thyssenkrupp Steel, n.d.a), which assumes a fundamental change in the production paradigm.

This plan involves a complete shift away from traditional, high-emission blast furnace technology toward the construction of a Direct Reduced Iron plant, powered in the long term by green hydrogen. According to the company, the concept is based on a hydrogen-compatible direct reduction plant integrated with two electrically powered melting units at the Duisburg site. In contrast to a traditional blast furnace that produces liquid hot metal, a DRI plant produces sponge iron in a solid state. This process will be integrated with new electric melting units (Thyssenkrupp Steel, n.d.a), which are tasked with melting the solid input into crude steel, while maintaining its high quality and metallurgical purity. This is expected to lead to near-climate-neutral steel production. The company has set the project completion date for 2045. The implementation of this capital-intensive project is supported by public funding: Reuters reported total federal and state support of around €2 billion, while the overall investment is described as around €3 billion, with the site expected to start operating at the end of 2026 (Reuters, 2023).

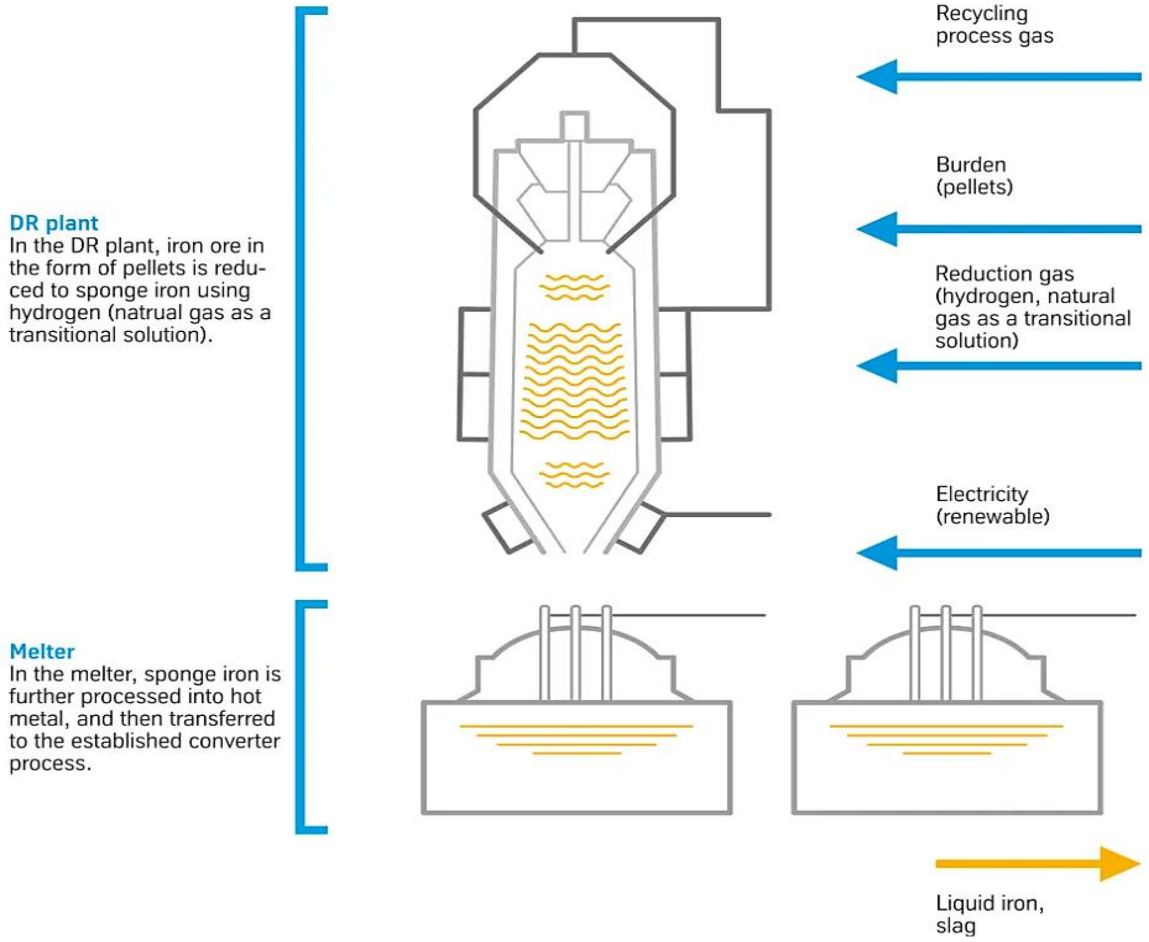

Fig. 2. The tkH2Steel steel production concept using a Direct Reduction Installation (DRI) and electric melting units

Source: (Thyssenkrupp Steel, n.d.a).

During the transition period preceding the full implementation of hydrogen technology, Thyssenkrupp introduced a portfolio of products with a reduced carbon footprint under the brand bluemint® (Thyssenkrupp Steel, n.d.b). These products allow for immediate emission reduction within existing processes and respond to the growing market demand for more sustainable materials (Yermolenko, 2025). The first pathway, bluemint® pure, utilises a mass balance methodology (Thyssenkrupp Steel, n.d.b). In the company communication, bluemint® pure is presented as enabling "up to 70%" lower allocated CO_2 intensity, with independent assurance. The second pathway, bluemint® recycled, fits into the circular economy paradigm and involves using 100% steel scrap as input material, resulting in a 64% emission reduction compared to the traditional integrated route (Thyssenkrupp Steel, n.d.a). This "up to 64%" reduction is also stated in Thyssenkrupp's bluemint® product description and certification materials.

Recent reporting also illustrates the strategic risk dimension highlighted in the literature, i.e. the economic viability of hydrogen-based transformation depends on the availability and price stability of green hydrogen, which company leadership has publicly described as uncertain relative to earlier assumptions (Reuters, 2025b).

4.4. Voestalpine

The Austrian technology group Voestalpine occupies a unique position in the European market, focusing on the production of technologically advanced steel products with high value-added. As a global leader in segments such as railway systems and high-strength sheets for the automotive industry, the company positions itself not as a mass producer but as a supplier of specialised material solutions. The group's steel production activities are concentrated in two integrated plants in Austria, namely Linz and Donawitz (Voestalpine, n.d.a). This product and geographical specificity is directly reflected in the adopted decarbonisation strategy, greentec steel, which distinguishes itself from competitors by its pragmatic, evolutionary, and carefully phased character. Moreover, this strategy implicitly assumes that sufficient volumes of competitively priced green electricity will be available, an external dependency that the company itself highlights as a key prerequisite.

Voestalpine's transformation plan has been precisely divided into three main steps (Voestalpine, n.d.b):

- Phase One, already implemented, involved optimising the existing, conventional blast furnace route. While these actions did not constitute a technological breakthrough, they allowed for an initial, incremental CO_2 emission reduction of approximately 10%, creating a foundation for further, more capital-intensive changes. This “~10%” reduction is also described in Voestalpine’s communication on CO_2-reduced premium steel as the effect of process and input optimisation within the integrated route.
- Phase Two, currently in the implementation stage, constitutes the core of the company's strategy and involves investing in two new Electric Arc Furnaces, which are intended to ultimately reduce emissions by approximately 30%. EAF technology, in contrast to the blast furnace process, is not based on the chemical reduction of iron ore but on melting steel input (mainly scrap) using an electric arc generated between graphite electrodes. This enables steel production with significantly lower direct emissions, provided the furnace is powered by electricity from renewable sources. From an analytical perspective, the key concept here is "hybrid technology", where the new furnaces will be powered by a mixture of scrap, market-purchased low-emission input (HBI), and hot metal from the still-operating blast furnace. The use of hot metal in the input mix allows for the precise control of the chemical composition and maintenance of the highest quality steel, which is crucial for the company's specialised product portfolio. This is a conscious risk--minimisation strategy, enabling significant decarbonisation without full and immediate dependence on the uncertain supply and price of green hydrogen. Similar to Thyssenkrupp, this investment, valued at €1.5 billion, is co-financed by public funds (Voestalpine, 2025). Voestalpine specifies that one EAF in Linz and one in Donawitz are planned to go into operation at the start of 2027, enabling a CO_2 reduction of around 30% by 2029 versus the 2019 baseline (with stated annual savings of almost 4 million tons of CO_2).
- Phase Three sets the long-term vision of achieving climate neutrality by 2050. It assumes a full transition to hydrogen-based steel production, which will require the construction of proprietary Direct Reduced Iron plants. This final step is, however, clearly contingent on the future maturity and scale of the European hydrogen economy. Notably, Voestalpine frames this as a post-2030 step and links feasibility to the build-out of hydrogen availability and infrastructure, which positions hydrogen-DRI as a conditional end-state rather than an immediately bankable pathway.

The presented transformation plan thus assumes a three-stage approach to achieving climate neutrality; following initial optimisation, hybrid technology based on EAFs will play a key role in the perspective up to 2029, while the final transition to hydrogen-based production is planned for the period after 2030 (Voestalpine, n.d.b). From a competitiveness standpoint, this sequencing can be interpreted as a deliberate hedging strategy: it delivers material near-term abatement while deferring the most uncertain, input-dependent investments until the economics of green electricity and hydrogen become clearer. As the evidence relies mainly on corporate disclosures, the strategy should be read as declared intent and risk framing rather than verified implementation performance.

5. Discussion

The analysis of the strategies adopted by the three leading European steel producers, i.e. ArcelorMittal, Thyssenkrupp, and Voestalpine, reveals a picture of apparent convergence that conceals a deep divergence in implementation approaches and risk management. Whilst all the examined entities have identified the same target technological paradigm, their pathways to achieving this goal, particularly the reactions to current market conditions, differ significantly. This finding is consistent with the literature that treats steel decarbonisation as a portfolio decision under uncertainty rather than a single ‘best’ route, where company-level constraints (asset legacy, product portfolio, and access to inputs) shape strategic sequencing.

The most important common denominator for all the three groups is the acceptance of Direct Reduced Iron (DRI) technology utilising hydrogen, integrated with Electric Arc Furnaces, as the target model for climate-neutral production. This convergence of vision indicates the emergence of a dominant technological paradigm within the sector, which is a direct response to the regulatory pressure from the European Union. However, while the technological horizon is shared, the paths leading towards it are clearly diversified, as illustrated by the table below.

Table 1. Comparison of key decarbonisation strategy features

Company	Main strategy feature	Approach to risk
ArcelorMittal	Dual-track strategy (DRI pathway and Smart Carbon with CCUS pathway)	Diversification of technological risk through parallel development of two different options
Thyssenkrupp	Radical, concentrated transformation (flagship tkH2Steel project)	High operational and investment risk, but potentially the fastest route to the goal
Voestalpine	Evolutionary, phased transformation (EAF first, then DRI)	Minimisation of risk by deferring the most uncertain investments and maximising flexibility

Source: author's own elaboration.

Each company has adopted a transformation model that reflects its specific characteristics. ArcelorMittal, as a global giant, diversifies its technological portfolio. Thyssenkrupp is making a radical, concentrated shift in its key production centre. Voestalpine, as a producer of high-value-added products, focuses on evolution and risk minimisation, which allows for the maintenance of operational stability during the transition period. It is also worth noting that Thyssenkrupp, through its bluemint® brand, is the most active in commercialising transitional products, striving to build a market for steel with a reduced carbon footprint immediately. This may suggest that transitional products are not only an emissions tool, but also a market-creation mechanism that can partially finance and de-risk long--cycle investments.

However the key conclusion was derived from the comparison of these three cases concerns the fundamental gap between ambitious declarations and market realities. ArcelorMittal and its withdrawal from the investment in Germany serve as a warning signal. It demonstrates that even granted public support does not guarantee project success if unfavorable market conditions prevent the fulfillment of formal conditions for receiving that support, such as starting construction by the required deadline. This is a significant contrast to the progress made by Thyssenkrupp and Voestalpine, whose projects, also reliant on subsidies, commenced realisation during a more favourable period. From the discussion perspective, this highlights that decarbonisation pathways are highly sensitive to short-term shocks (energy prices, demand cycles) even when long-term policy direction is clear, which can widen the implementation gap between strategy and execution.

This demonstrates that the green transformation is not a linear process but a series of difficult investment decisions. The success of these undertakings is critically dependent on external factors. In this context another gap emerges in the strategic thinking about transformation, related to the simplified perception of hydrogen.

Current strategies, while focusing on the implementation of DRI technology, often overlook a fundamental operational challenge – steel production is a continuous process requiring stable and uninterrupted energy supply, whereas the production of green hydrogen from renewable sources (solar, wind) is inherently variable and inflexible. This incompatibility between the inelastic demand of a steel mill and the flexible supply of green energy creates a strategic risk of dependence on price fluctuations in the energy and hydrogen markets. Therefore, the discussion implies that technology choice alone is insufficient as system integration and supply security become strategic variables alongside process decarbonisation.

Thus it appears that a long-term, sustainable decarbonisation strategy should extend beyond merely changing the input technology. The strategic recommendation is to indicate the necessity of considering vertical diversification towards proprietary hydrogen production and storage. Investments in electrolysers, potentially co-financed by public funds intended for the development of the hydrogen economy, would allow steel companies not only to secure a key raw material and become independent of market volatility but also to create a new source of revenue by selling surplus hydrogen during periods of lower steel production. Such an approach would transform the steel mill from a passive consumer into an active participant and stabiliser of the local energy system. At the same time, companies may also reduce exposure through long-term renewable PPAs, grid-connection upgrades, and staged hybrid configurations (scrap/HBI/hot metal mixes), which align operational continuity with the decarbonisation progress without assuming immediate hydrogen abundance.

6. Conclusion

The transformation of the European steel industry is not a monolithic process but a mosaic of differentiated corporate strategies. While the technological goal is shared, the pathways to its realisation are heterogeneous and susceptible to market shocks. The final shape and pace of decarbonisation will thus be a result of not only internal corporate decisions but, above all, the capacity to create a stable and supportive ecosystem at the level of the entire European Union. This includes consistent public support frameworks, effective market protection, and the creation of intelligent mechanisms to integrate inflexible industrial production with variable renewable energy generation. The examined cases indicate three practical conclusions: (1) the ‘dominant end-state’ (H_2- DRI-EAF) does not eliminate the need for transitional and hybrid solutions, (2) investment sequencing is constrained by external input availability and subsidy design, (3) competitiveness risk can delay or reverse flagship projects even under declared climate commitments.

This study contributes by moving from a sector-level view to a company-level comparison of declared strategies, showing how the same regulatory signals can yield materially different strategic configurations. Importantly, the study does not omit implementation assessment by choice, instead the analytical focus is constrained by the current empirical accessibility of comparable implementation data. At the time of writing, a substantial share of the key initiatives (e.g. DRI modules, new EAF units, hydrogen supply arrangements) remains at the stage of announced or planned investments, i.e. strategic commitments and project assumptions rather than fully executed and commissioned assets. Although some measures are already implemented and publicly reported in individual cases, the availability, granularity, and comparability of implementation indicators are not consistent across companies. Consequently, robust verification using measurable implementation indicators (such as realised CAPEX execution, commissioning progress, or independently verified emissions-intensity outcomes) is not yet consistently feasible across cases, which limits the possibility of a like-for-like performance comparison. Future research should therefore triangulate corporate declarations with implementation evidence as projects mature and comparable datasets become available, enabling assessment of how strategic intent translates into realised decarbonisation trajectories.

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Zielona transformacja jako krytyczny czynnik dla formułowania strategii w branży hutniczej stali

Streszczenie

Cel: Celem artykułu jest rozpoznanie i przedstawienie, w jaki sposób europejskie hutnictwo w praktyce reaguje na zmiany regulacyjne określane mianem Zielonego Ładu. Praca szczegółowo omawia i porównuje strategiczne odpowiedzi trzech liderów rynku – ArcelorMittal, Thyssenkrupp i Voestalpine – na otoczenie regulacyjne kształtowane przez takie mechanizmy, jak EU ETS i CBAM.

Metodyka: W pracy zastosowano jakościową strategię badawczą, wykorzystując metodę wielokrotnego, porównawczego studium przypadku (*multiple case study*). Podstawę empiryczną stanowiła analiza danych zastanych (*desk research*), obejmująca dokumenty korporacyjne, publikacje branżowe i dane statystyczne. Zebrany materiał poddano analizie tematycznej w celu identyfikacji i porównania kluczowych wymiarów ogłoszonych strategii.

Wyniki: Analiza wykazała pozorną konwergencję, pod którą kryje się głęboka dywergencja strategiczna. Choć wszystkie badane firmy identyfikują technologię DRI-EAF opartą na wodorze jako docelowy model produkcyjny, ich deklarowane ścieżki wdrażania (planowane sekwencje inwestycyjne i zarządzania ryzykiem) znacząco się różnią: od dywersyfikacji technologicznej (ArcelorMittal), przez radykalną transformację (Thyssenkrupp), po ewolucyjne, etapowe podejście (Voestalpine). Zidentyfikowano również fundamentalną lukę między deklaracjami a realiami rynkowymi, zilustrowaną przez zależność projektów od terminowego wsparcia publicznego i stabilnych warunków ekonomicznych.

Implikacje i rekomendacje: Wnioski wskazują na strategiczną lukę w obecnych planach, polegającą na niedoszacowaniu ryzyka operacyjnego wynikającego z niekompatybilności ciągłej produkcji stali ze zmienną generacją zielonej energii i wodoru. Jako rekomendację strategiczną wskazano zasadność rozważenia przez firmy dywersyfikacji pionowej w kierunku własnej produkcji i magazynowania wodoru, co potencjalnie pozwoliłoby na zabezpieczenie dostaw i uniezależnienie się od wahań rynkowych.

Oryginalność/wartość: Praca wypełnia zidentyfikowaną w literaturze lukę badawczą, przechodząc od ogólnego, sektorowego postrzegania transformacji do granularnej, porównawczej analizy deklarowanych strategii korporacyjnych. Jej wartość polega na dostarczeniu benchmarku dla oceny różnych modeli adaptacji strategicznej w warunkach bezprecedensowej presji regulacyjnej i technologicznej.

Słowa kluczowe: dekarbonizacja, europejskie hutnictwo stali, strategie korporacyjne, studium przypadku, zielona transformacja