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The Limits of Incrementalism in the Green Transformation of the Iron and Steel Industry

Beáta Buró University of Miskolc, e-mail: burobea@hotmail.com

SUMMARY

Incrementalism is a dominant decision-making paradigm, characterised by stepwise adjustments rather than structural transformation, and is often viewed as a pragmatic and politically feasible approach. Yet sustainability scholarship increasingly highlights its inadequacy in addressing the scale and urgency of today's environmental challenges. Following this critique, the paper investigates the limitations of incrementalism within the context of industrial decarbonisation, focusing on the steel sector. Rather than analysing political institutions or behaviour, the study examines macro-level decarbonisation pathways and EU policy instruments using incrementalism as a conceptual perspective to interpret how policies shape the pace and direction of change. Through a review of emerging pathways for green steel production, the analysis demonstrates that marginal improvements within the incumbent process are insufficient to achieve deep emissions reductions. The industry's transition demonstrates that sustainability goals cannot be achieved through incremental adjustments alone; they require systemic technological, infrastructural, and institutional change. Incremental approaches adjust expectations, but fail to deliver structural transformation, revealing how the myth of incrementalism obscures the transformative shifts necessary. Consequently, more ambitious and transformative policy interventions are required for a viable green transformation in the industry.

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1. INTRODUCTION

Steel is a vital material in modern life, and the steel industry is an important sector within the global economy. However, the iron and steel sector has the largest CO_2 emissions among the heavy industries and is the second-largest consumer of energy. The industry is a hard-to-abate sector because the production is highly energy-intensive and relies on fossil fuels; current technologies make it difficult to achieve significant emissions reductions (IRENA, 2024; Kumar et al., 2024). Greenhouse gas emissions are a major environmental concern; complying with climate goals and sustainability targets will require the industry to undergo substantial transformation. The total apparent steel consumption is projected to rise in the future by approximately 40% in 2050 compared with today's level. This anticipated growth reinforces the sector's already significant carbon footprint and raises important questions about whether incremental measures are sufficient to meaningfully shift such a carbon-intensive trajectory. Given the scale of emissions, long investment cycles of existing production assets, the need to deploy low-carbon production routes and supporting infrastructure, incremental adjustments risk delaying the adoption of alternative production routes.

2. Objective of the Study and Research Methodology

2.1. Objectives

The broader research project examines the green transition (understood here as the decarbonisation of iron and steel production) of the Hungarian steel industry. As Hungary is an EU Member State, national transition prospects must be understood within the wider EU27 context. At the same time, the steel sector operates within globally integrated markets, production technologies and industrial systems; therefore, global data are used to contextualise EU-level developments. This global-EU linkage is essential for understanding the structural conditions under which EU member states pursue decarbonisation pathways. Accordingly, this article focuses on the EU-level policy mechanisms as the primary institutional framework shaping the decarbonisation of the steel industry.

While incrementalism has traditionally been viewed as a practical and politically reasonable approach (Lindblom, 1959; Purdy, 2024), sustainability scholarship increasingly points to its shortcomings. The analysis illustrates the structural mismatch between the required technological transformation and the EU's incremental policy preferences. Accordingly, the study aims to:

- Provide an overview of incrementalism and sustainability
- Provide a general overview of the iron and steel industry
- Review pathways for green transition in the industry
- Conclude on the theoretical limits of incrementalism and practical implications for the EU steel industry

2.2. Methodological Approach

The study combines a conceptual analysis and a qualitative case analysis of steel-sector decarbonisation pathways. The conceptual component consists of a critical review of incrementalism, analysing its theoretical foundations and limitations within the sustainability transition scholarship. The empirical component employs a desk-based qualitative analysis to evaluate the extent to which green-steel pathways can contribute to deep decarbonisation.

The qualitative case analysis focuses on the EU27 steel sector decarbonisation pathways, interpreted within the global technological and industrial context that shapes steel-making options. The study examines three broader categories of pathways: circular economy, CO_2 reduction possibilities and direct carbon avoidance. Each pathway is assessed for expected CO_2-reduction potential, technology maturity, infrastructure requirements and capital intensity.

The various EU policies were evaluated to determine whether they support incremental or structural transformations. The criteria are summarized in Table 1.

Table 1

Criteria for evaluating policy mechanisms

Incrementalism / Optimisation	Structural Transformation
Efficiency improvements	Shift to new production routes
Marginal abatement measures	Deep emissions reductions aligned with climate trajectories
Lifetime extension of incumbent assets	Phase-out of carbon intensive assets
No major new infrastructure required	Requires substantial new infrastructure
Politically feasible, low risk, aligned with incumbent interest	High capital intensity, long investment cycles, transformative investment
Reinforces existing socio-technical regime	Creates new institutional and market arrangements

Source: Constructed by the author

The desk-based research component used the following publicly available datasets:

- World Steel Association (WSA) – production statistics, technology shares
- EU ETS Data Viewer – installation-level emissions
- Green Steel Tracker – project-level information of green-steel projects
- European Commission policy documents - Fit for 55, Hydrogen Strategy, CBAM
- Corporate disclosures – project announcements

These sources provide the empirical basis for evaluating technological pathways and policy alignments.

1. Literature Review of Incrementalism and Sustainability

Charles Lindblom's article ''The Science of Muddling Through'' published in Public Administration Review in 1959 provided an alternative approach to decision-making, suggesting that decisions proceed step-by-step and by small degrees from the current situation, rather than through radical changes (Allison & Saint-Martin, 2011; Lindblom, 1959, 1979). Incrementalism refers to the implementation of small, incremental modifications which jointly lead to significant transformations rather than through drastic or cautiously planned big steps (Purdy, 2024).

Incrementalism has been widely debated by public administration, political science, and strategic management literature (Allison & Saint-Martin, 2011; Lindblom, 1979). While the idea of incrementalism has been mainly applied to political processes, it has been examined across various fields in healthcare, civil rights, education, foreign policy, and climate change (Purdy, 2024).

Sustainability policy often defaults to incremental changes; therefore, sustainability literature studies examine how incrementalism shapes environmental governance and prospects for systematic change. Across the studies, various frameworks in transition studies examine the conflict between incremental change and structural transformation required for sustainability.

Sustainability governance provides a conceptual foundation for transition management by integrating regulatory and planning tools. Sustainability governance tends to proceed through incremental adjustments because policy change is shaped by political disagreements, slow institutions and competing priorities. However, deep decarbonisation requires long-term, strategic political commitment rather than incremental policy adjustments (Meadowcroft, 2009).

Sustainable energy transition research highlights that choices are deeply political, influenced by incumbent interests that work to defend the existing socio-technical regime and often constrain more transformative pathways (Smith et al., 2005; Geels & Schot, 2007; Stirling, 2014). Brand further strengthens this argument by showing that incrementalism is a political choice, while green economy approaches frame sustainability as a technical and economic optimisation problem (Brand, 2012).

Scoones also raises the point that while green transition implies technology and market shifts, it is also fundamentally political. This transformation differs from changes we witnessed in the past, driven by economic, social, technological and cultural developments or geopolitical events. The green transformation aims to change the existing economic model towards sustainability (Scoones et al., 2015). Past changes were open-ended or driven by market or technological dynamics alone, whereas sustainability transitions have directionality. They are normatively orientated towards specific environmental outcomes, such as deep decarbonisation (Stirling, 2009).

Sustainable transition cannot be achieved by incremental improvements of the existing regime. These changes are not just technological transitions, but systematic "socio-technical transitions", as they involve reconfiguring technology, infrastructure, markets, policy frameworks and cultural understanding (Geels, 2002, 2011; Rotmans et al., 2001; Markard et al., 2012). Societies face multiple possible routes, reflecting the existence of multi-pathways for the kind of change required for sustainability (Scoones et al., 2015). Choices among these pathways are inherently political, and ignoring the directionality of sustainability transition leads to a form of incrementalism that reinforces incumbent socio-technical regimes (Stirling, 2009).

The literature also notes that more ambitious climate policies or targets can trigger political or social resistance. Such backlash can shape the politics of climate policy and the pace of transformation. To maintain support for transformative change, the emphasis is on fairness, transparent communication and inclusive governance (Patterson et al., 2026; Patterson, 2023; Scoones, 2016).

This process is embedded within broader multi-level interactions among technology, policy and politics, economic and market dynamics, and culture or discursive factors, which together shape shifts towards more sustainable production and consumption (Geels, 2002, 2011; Smith et al., 2005; Markard et al., 2012).

Transition studies frequently use the concept of "niche"; niche innovations gain momentum and can eventually compete with incumbent system. However, the growth of "green" niches requires support to reshape economic framework conditions (Geels et al., 2004; Smith, 2006; Markard et al., 2012).

Within the multi-level perspective, interaction occurs between regimes, which represent the dominant configuration; the landscape, which reflects broader societal system; and niches which include the non-conforming configurations (Avelino & Rotmans, 2009; Geels & Schot, 2007). These interactions are reinforced by technological, behavioural and institutional lock-ins that stabilise the dominant regime (Loorbach & Rotmans, 2010).

Consequently, established socio-technical systems undergo incremental rather than radical changes (Loorbach et al., 2017; Markard et al., 2012), and such incremental changes will not suffice to cope with the prevailing sustainability challenges; transformative change requires reconfiguration, not optimisation (Geels, 2002; Markard et al., 2012; Petrović, 2023).

Transformative change involves the deliberate phase-out of incumbent carbon-intensive technologies and creation of a new socio-technical configuration aligned with climate goals, because incremental changes cannot deliver the pace, scale and directionality required for deep decarbonisation. Furthermore, institutional change aligned with financial and political incentives is necessary to create a window of opportunity for such transformation (Westley et al., 2011).

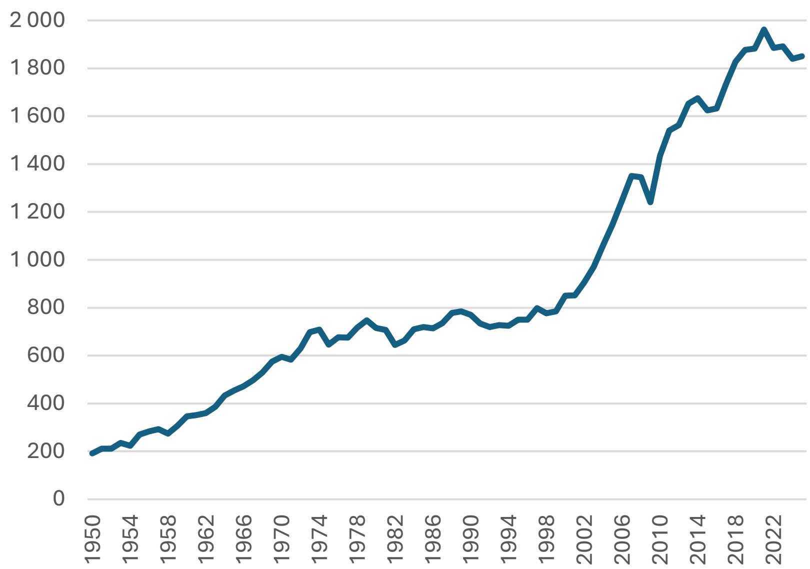
In contrast to political and socio-technical perspectives, the heavy-industry decarbonisation literature primarily adopts technology-centred and techno-economic approaches. A wide range of studies map mitigation pathways and assess the feasibility of low-carbon technologies using techno-economic assessments, life-cycle analysis, supply-chain optimisation and levelized cost modelling (e.g.: Devlin et al., 2023; Fischedick et al., 2014; Hasanbeigi et al., 2013; Mayer et al., 2019). Although Bataille and colleagues (2020) discuss policy instruments relevant to industrial transformation, this engagement with politics is largely limited to identifying policy instruments that enable technology deployment rather than analysing political dynamics shaping the pace and direction of change.

Based on the literature review, sustainability transition cannot be resolved through technology, markets or marginal optimisation alone; sustainability is fundamentally a political exercise. While existing governance tends to deliver incremental change, the scale of sustainability challenge requires structural transformation rather than incremental adjustment. This understanding provides a useful foundation for analysing the steel industry.

Accordingly, this article uses incrementalism as a conceptual perspective to analyse how EU industrial decarbonisation policies shape the pace and direction of change in the steel-sector. Rather than providing an analysis of political institutions and behaviour, the study focuses on macro-level pathways and EU policy instruments, investigating how incremental policy design and implementation contribute to regime stability. In doing so, the paper argues that policymakers must confront the urgency and difficulty of transformative change in the steel industry, rather than relying on incremental adjustments that delay decisions and undermine climate objectives.

2. Steel Sector overview and Environmental Challenges

Steel is one of the most important materials in the world. More than a hundred years ago, in 1900, the world crude steel production was only 37 million tons, now the annual production of crude steel reached 1,850 Mt in 2025 (WSA, 2025a). The total crude steel production growth since 1950's is shown in Figure 1.



Source: Constructed by the author using data from WSA

Figure 1: World crude steel production, Mt

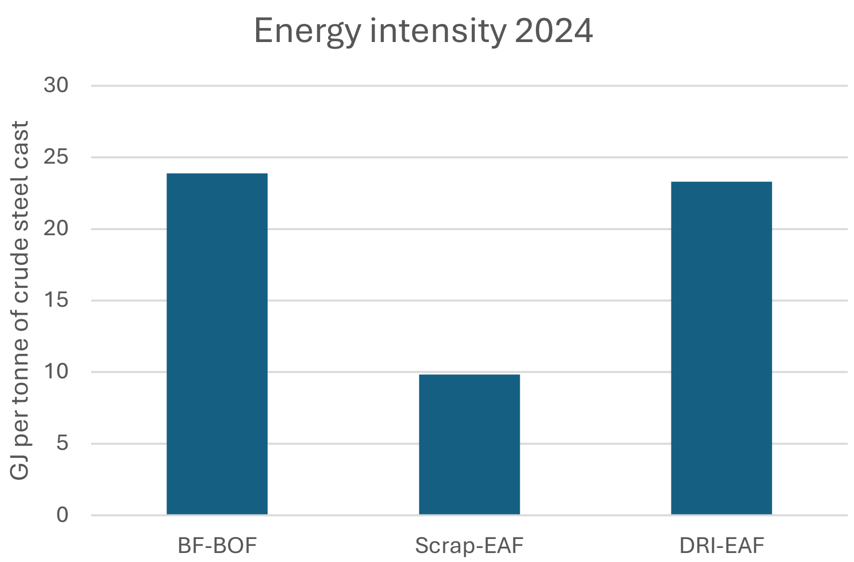
The steel industry is known for being cyclical and reflective of overall market conditions and for being sensitive to trends in cyclical industries, such as the automotive, construction, appliance, machinery, equipment and transportation industries (Frost & Sullivan, 2018). The level of per capita consumption of steel is treated as an important index of socioeconomic development, which gives the steel industry strong institutional and political influence.

The industry is characterized by a small number of large, established firms that dominate an industry with large-scale production facilities, heavy machinery, and significant capital investment. Therefore, the sector is deeply locked into socio-technical regime with dependence on fossil fuels, long-life capital stock, and strong reliance on infrastructure (OECD, 2024; Vogl, 2023).

Steel is one of the most highly recycled materials in use today; steel scrap is reused in Electric Arc Furnaces (EAF), but most of the steel is still produced via the integrated route, Blast Furnace and Basic Oxygen Furnace (BF-BOF). Globally the crude steel produced by BF-BOF process is over 70%.

During the BF-BOF process, iron ore is reduced in the blast furnace to hot metal with coal, coke and gas, which is subsequently refined to crude steel in the basic oxygen furnace. It is a hard-to-abate sector because the energy-intensive nature of the process and fossil fuels make it difficult to achieve significant emissions reductions with current technologies (IRENA, 2024; Kumar et al., 2024).

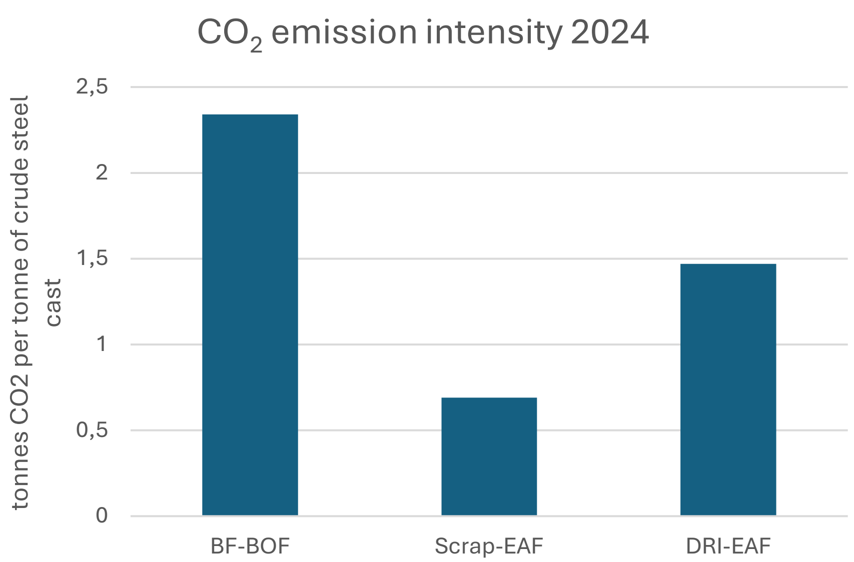
The BF-BOF process is the largest industrial consumer of coal, which provides around 75% of its energy demand, making it second in terms of energy consumption (IEA, 2020). The energy intensity of the industry is summarized in Figure 2.



Source: Constructed by the author from WSA data (WSA, 2025b)

Figure 2: 2021-2024 global energy intensity

The iron and steel sector has the largest CO_2 emissions among the heavy industries. The CO_2 emission intensity of the main process routes is summarised in Figure 3.



Source: Constructed by the author from WSA data (WSA, 2025b)

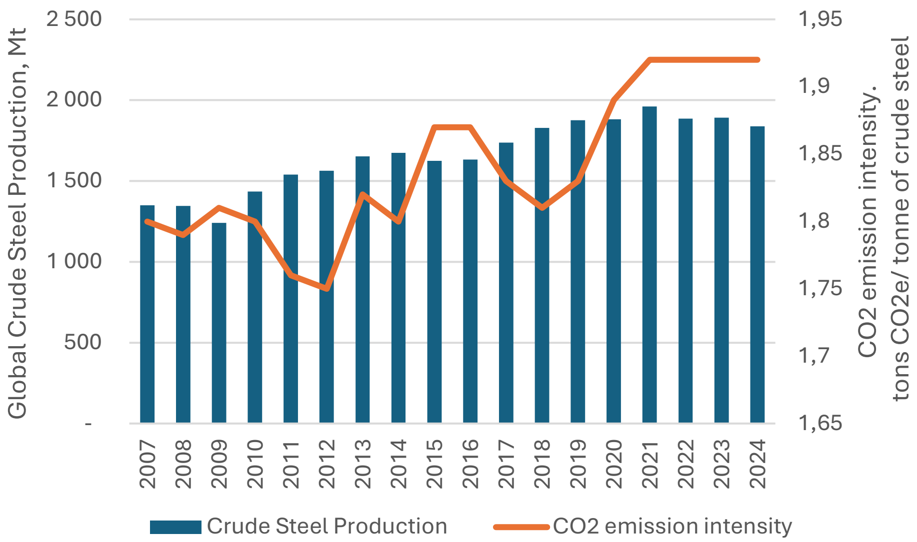
Figure 3: 2021-2024 global CO_2 emission intensity

The largest direct emissions originate from integrated BF-BOF plants, the global average CO_2 emission intensity was around 2.34 t of CO_2 per tons of steel in 2024 (Steelonthenet, 2012; WSA, 2025b).

It is estimated that 2-3 tons CO_2 per tons of steel is emitted if the direct reduction process is coal based, or 0.7-1.2 tons CO_2 per tons of steel if the process is gas-based (Morfeldt et al., 2015; Steelonthenet, 2012). The global average of CO_2 emission intensity for direct reduced iron with EAFs was around 1.47 t of CO_2 per tons of steel in 2024.

The remaining emissions in the iron and steel industry come mainly from power generation (indirect) to run Electric Arc Furnaces (EAF), and from rolling mills, which are for downstream processing of steel products. For the scrap-based EAF process the global average of CO_2 emission intensity was around 0.69 t of CO_2 per tons of steel.

Most of the countries and companies have committed to reducing CO_2 emissions, but while the sector-specific CO_2 emissions showed some decrease after the Paris Agreement in 2015, specific emissions figures have shown an increase since 2018-19 driven by the dominance of carbon-intensive BF-BOF route. Figure 4 shows the crude steel production and changes in CO_2 emission intensity over the years, highlighting the current gap between ambition and actual progress.



Source: Constructed by the author from WSA data, (WSA, 2025b)

Figure 4: Global crude steel production and CO_2 emission intensity 2007-2024

2.1. Future Steel Demand

In general, steel demand is sensitive to macroeconomic fluctuations in the global economy which are impacted by many factors ranging from trade and geopolitical tensions to global and regional monetary policy to specific disruptive events such as pandemics and natural disasters.

The total apparent steel consumption has almost doubled in the last 20 years. The total steel demand was approximately 1,773 Mt in 2025 (WSA, 2025c). It is expected that steel demand will continue to rise in the future with increased demand in end-user sectors. Various sources project the demand to be above 2,000 Mtpy and in some scenarios reaching 2,500 Mtpy by 2050, which is approximately 40% increase compared to today's level (Hasanbeigi et al., 2013; Hornby & Brooks, 2021; IEA, 2020; Material Economics, 2019; van Ruijven et al., 2016).

Figure 5 summarizes the steel production from 2012-2024 and the forecast for 2050. As discussed before, most of the production is still mainly coming from integrated technology route (BF-BOF) that creates the largest CO_2 emissions, thus without any changes the emissions would increase around 4.8 billion tons of CO_2 in 2050 with the increased production to meet demand. The CO_2 commitment level by the Paris agreement is also shown in Figure 5.

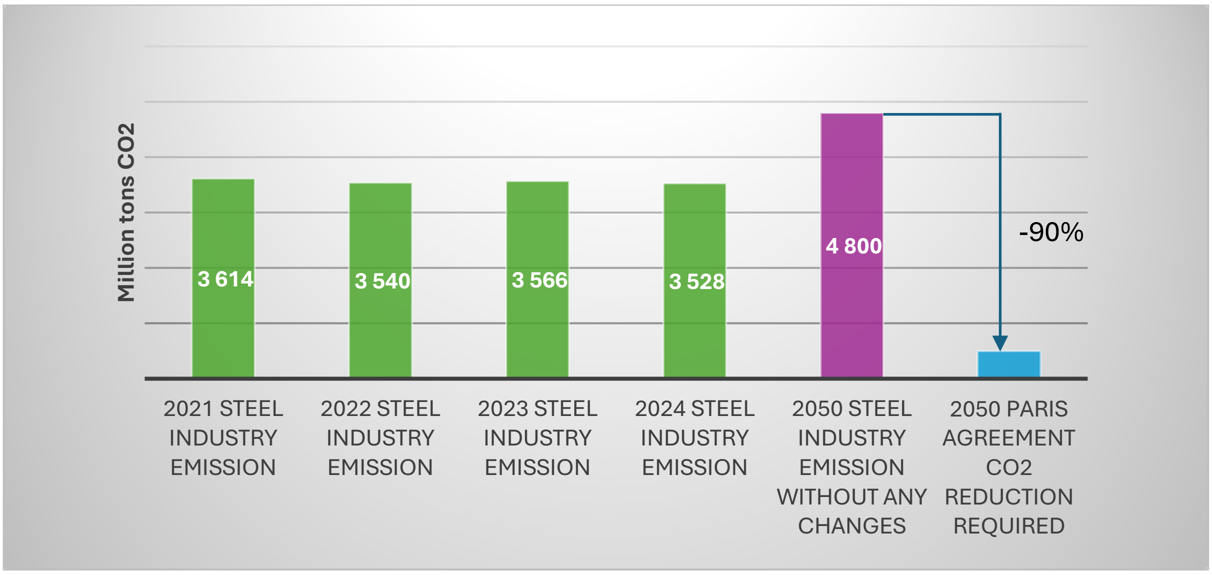
The scale of the challenge is substantial; the industry faces a CO_2 reduction requirement by approximately 90% (OECD, 2022). Consequently, the industry needs to undergo major transformation in order to reduce emissions.

2.2. Technologies - Decarbonization Strategies

There are many possible technological pathways for structural transformation currently under consideration by the industry, such as:

- Circular economy
- CO_2 reduction
- Direct Carbon avoidance

Each decarbonisation pathway is assessed by expected CO2-reduction potential, technology maturity, infrastructure requirements and capital intensity.



Source: Author's own compilation based on data from WSA, additional external sources (Hornby & Brooks, 2021), and the author's own 2050 calculation

Figure 5: CO_2 emission intensities and committed CO_2 level by Paris Agreement in 2050

2.2.1. Circular Economy

While some decarbonisation approaches focus on reducing primary steel demand and replacing by a higher degree of scrap-based production, material efficiency strategies, on the other hand, aim to reduce the need for additional steel production in the first place (Bataille, 2020; Kim et al., 2022; MPP, 2022).

Circular economy represents the integration of economic activities with environmental well-being (Murray et al., 2017); a move from linear business models, where products are manufactured from raw materials and then discarded at the end of their useful lives, to circular business models where intelligent design leads to products or their parts being repaired, reused, returned and recycled (WEF, 2014).

Although the steel industry is already an integral part of the global circular economy, as steel is one of the most recycled materials in the world, this form of circularity is described by some authors as a weak, incremental interpretation of circular economy (Broadbent, 2016; Murray et al., 2017). Circular economy practices in the steel industry can reinforce existing socio-technical regime, because they are politically attractive and safe incremental sustainability strategies. However, they represent incremental innovation within the stable regime rather than a pathway to structural transformation (Geels et al., 2004).

2.2.2. CO2 reduction possibilities

Using steel scrap reduces the virgin material input requirement, waste and emissions for the industry (Korhonen et al., 2018). However, impurity accumulations and limited scrap availability prevent completely scrap-based steel production, meaning that iron produced from iron ore will still be required in the future (Radloff et al., 2023).

The blast furnace is quite an efficient process in terms of energy use and productivity, but the use of coke generates the largest amounts of CO_2 (Sohn, 2020). One of the key options identified as the fastest way to slow emissions growth without considerable cost is to improve the energy efficiency of current BF processes (Holappa, 2020).

To optimize efficiency, diverse options are being investigated; the major technologies are summarized below:

- New burden of iron–carbon agglomerates,
- HBI use in BF,
- Hydrogen usage in BF: by injecting waste plastics, natural gas partially or pure hydrogen,
- Top gas recycling (Feiterna et al., 2014)

However, to achieve further reductions, carbon capture and utilization (CCU) and/or carbon capture and storage (CCS) are required (de Silveira Cachola et al., 2023). CCS cannot be regarded as a long-term solution though to reduce CO_2 emissions; it can only be used as a temporary mitigation method. A better way is carbon capture combined with utilization (CCU), where CO_2 can be chemically converted into other products such as plastics, concrete or biofuel, or without conversion used in enhanced oil recovery (EOR) (Holappa, 2020; WSA, 2023).

Nonetheless, there are some growing concerns arising regarding CCUS technologies. The only CCS project for the steel industry is the Al Reyadah project in UAE, serving a gas-based DRI plant, but only captures 19-26% of the plant emissions. It is even more difficult to integrate CCS with a coal-based iron and steelmaking facility which has several sources of carbon emissions, therefore this technology seems less likely to be utilized in the sector (Amand et al., 2024; Nicholas, 2025).

The emissions reduction potential using traditional energy-efficiency measures shows that to reduce emissions is limited (Muslemani et al., 2021). This reinforces the earlier argument from the literature review that incremental adjustments are unlikely to be sufficient. These measures optimise the existing BF-BOF regime but remain incremental improvements within the incumbent system and therefore cannot deliver the scale of change required in the steel sector.

2.2.3. Direct Carbon Avoidance

To achieve the required change, direct avoidance of CO_2 emissions will be required in the future. These emerging production routes, such as replacement of carbon by renewable electricity and/or fossil-free reductants to directly avoid CO_2 emissions, and using hydrogen, represent transformational change because they replace rather than optimise the incumbent BF-BOF technology (EUROFER, 2019).

There are many new breakthrough technologies that exist, such as:

- direct electrolysis: Hydrogen Plasma Smelting Reduction (HPSR), electrowinning (ULCOS, SIDEWIN, Electra), Molten Oxide Electrolysis (MOE),
- novel flash ironmaking,

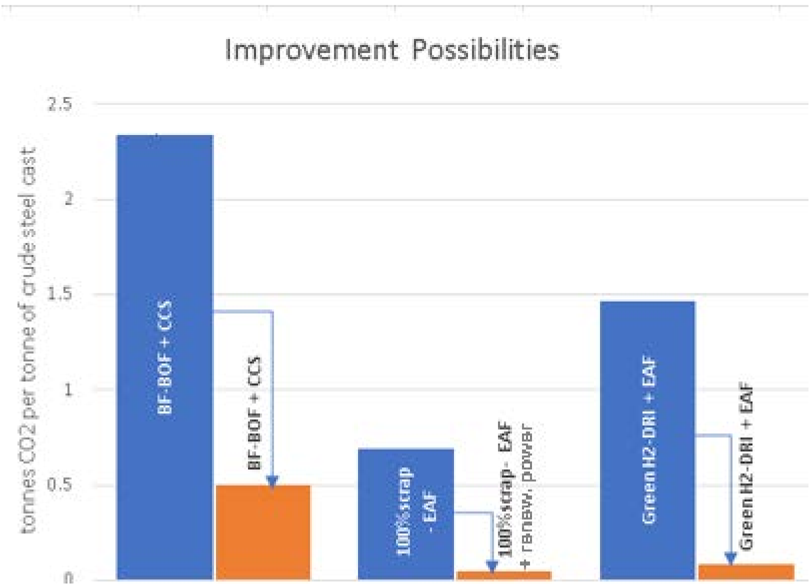
but many of these technologies remain at low technology readiness levels and have only been demonstrated at laboratory or pilot scale.

Smelting Reduction processes aim at overcoming the fundamental problems of the existing blast furnace route, however, most of these technologies only insignificantly reduce CO_2 emissions and they rely on the integration of CCS and CCUS technologies (Shahabuddin et al., 2023; Zhao et al., 2020).

The gas-based DRI process already has substantially lower greenhouse emissions and can operate economically. Hydrogen is already present in the process through the use of natural gas and increasing the ratio of it has been studied for many decades; replacing natural gas with green hydrogen (H-DRI) makes it technically possible to bring the iron and steel sector on a path to net zero emissions (MPP, 2022; World Economic Forum, 2022).

Hydrogen-based ironmaking being sensitivity to electricity price and availability, hence various studies investigating the potential for locating these facilities where low-cost renewable energy is available, preferably in locations with iron ore deposits, in order to develop green iron or steel as a value-added commodity (Bilici et al., 2024; Ellersdorfer et al., 2024; Lopez et al., 2023; Rhee et al., 2024; Trollip et al., 2022).

Various electric smelting furnaces concepts are also being explored, but commercial deployment is limited to EAF in ferrous industry, which can approach net-zero emissions with scrap and/or H_2-DRI when operated with renewable power. The estimated CO_2 reduction possibilities are summarized in Figure 6.



Source: Author's own compilation based on data from external sources (Material Economics, 2019; MPP, 2022; Amand et al., 2024)

Figure 6: Estimated CO_2 emissions for various technologies

The most promising technologies, however, require substantial investment in the associated renewable power generation, grid capacity and hydrogen infrastructure to supply green electricity and hydrogen at cost-competitive prices and sufficient volumes to meet the needs of the steel industry. At present, the required infrastructure is not readily available to completely avoid GHG emissions from the steel industry (Graupner et al., 2022).

The incumbent BF-BOF route remains constrained too, as it can only deliver incremental efficiency improvements. The marginal efficiency improvements are insufficient to achieve deep emissions reductions, mirroring the literature's conclusion that sustainability challenges demand structural transformation rather than marginal optimization.

Meeting climate targets requires substantial emissions reductions within the next decade, yet BF reinvestment cycles and long-lead infrastructure projects risk locking in carbon-intensive production until even the 2040s. As the largest industrial emitter, the steel industry is essential for achieving climate goals, particularly given the sector's role in supplying raw materials for renewable energy systems and the expected increase in steel demand.

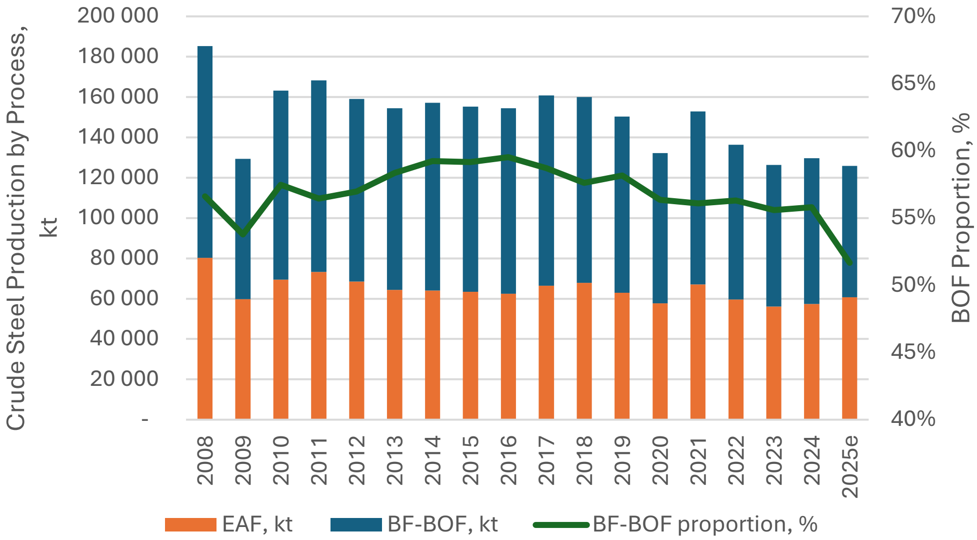
The transition away from incumbent regime depends not only on technological feasibility but also on the wider policy and political context that shapes industry decision making. The pace of progress will depend on the extent to which policy and company decisions can bring forward investments in low-emissions steelmaking (Lopez et al., 2023; MPP, 2022).

3. EU27 - Iron and Steel Sector

The EU has committed to a 55% reduction in the net greenhouse gas emissions level by 2030 (relative to 1990) and to achieve net zero emissions by 2050, in line with the Paris Climate agreement, the European Green Deal, and the Fit for 55 packages (European Commission, 2023, 2025; European Council, 2024).

Although European Union steel production has continued to decline from its peak over the past decade and in 2025 only produced 126 Mt., the industry plays a crucial role in driving economic growth, employment, and innovation.

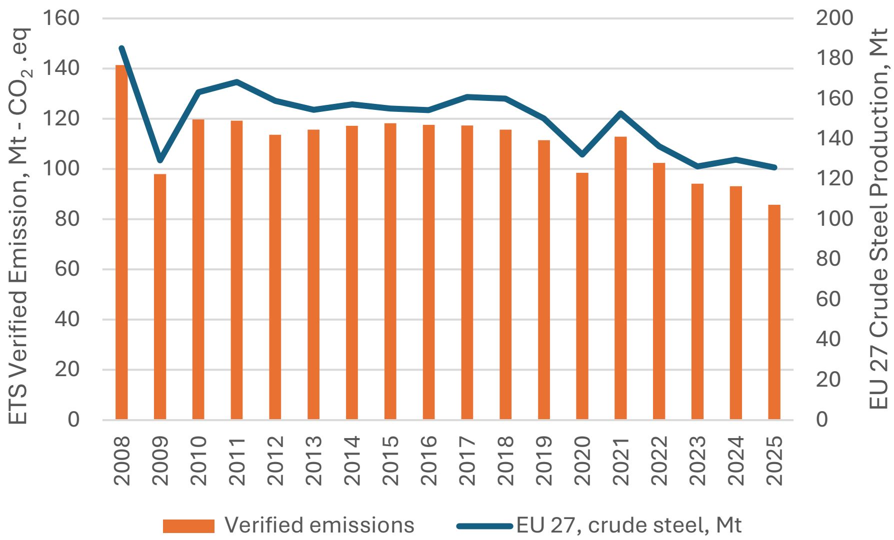
Europe traditionally has many coal-based blast furnaces; the share of the BF-BOF route is already lower than the global average, but it is still above 50% (Figure 7) (IEA, 2020). Most of the blast furnaces are approaching the end of their operating life, meaning that companies must decide between reinvestment in carbon-intensive assets or investing in low-carbon technologies. Considering long asset life, investment decisions will shape technology composition into the 2050s, therefore they are crucial for the decarbonization of the industry (MPP, 2022; Lopez et al., 2023; Choksey et al., 2025).



Source: Author’s own compilation based on data from WSA

Figure 7: European Union Crude Steel Production by Process and BF-BOF Route Proportion

Despite the European Union being a global leader in decarbonisation efforts, CO_2 emissions reductions in the iron and steel industry have so far resulted mainly from lower production volumes rather than deployment of low-carbon technologies, as shown in Figure 8.



Source: Author’s own compilation based on EU Emissions Trading System (ETS) Data Viewer, 2025

Figure 8: European Union Production of Pig Iron and Steel Historical Emissions

To achieve net-zero, the industry will require deployment of multiple available and emerging technologies. The main issue is not the lack of technological solutions, but the high cost associated with these solutions, affecting market share, trade and labour politics (Fan & Friedmann, 2021).

EU’s steel companies have publicly committed to transformation, with integrated steel producers seeking to shift towards greener technologies such as hydrogen-based DRI and electric arc furnaces, maximizing scrap usage and secure partnerships with green iron producers and suppliers of green electricity to meet climate targets of the industry. None of the steel companies are currently considering commercial-scale CCUS with BF-BOF projects (Choksey et al., 2025).

Table 2 summarizes major green iron and steel projects in the EU. However, the initial momentum appears to have slowed, with many projects delayed, postponed or even cancelled (in red), and some of the largest companies reconsidering their low-carbon transformation pathways.

ArcelorMittal's Steel4Future DRI projects in Bremen and Eisenhüttenstadt, Germany, have been cancelled due to increasing steel imports, weak European demand, high energy costs and the lack of competitively priced green hydrogen. The company also suspended its plans for a DRI plant in Dunkirk, France because the investment was unprofitable with the given prices of natural gas and green hydrogen. ArcelorMittal has likewise put on hold its plan for a DRI plant in Gijon, Spain for reasons such as energy cost, political and market uncertainty (Laity, 2025; Yermolenko, 2025a, 2025b).

Table 2

Major Green Iron and Steel Projects in the EU27

Project name	Planned commissioning	Technology to be used	Company	Location
Complementing conventional steelmaking				
Sestao (DRI from Gijon)	2025	BF-BOF to EAF	ArcelorMittal	Spain
Oxelösund mini-mill	2026	BF-BOF to EAF	SSAB	Sweden
Greentec steel – Linz	2027	BF-BOF to EAF	Voestalpine Group	Austria
Greentec steel – Donawitz	2027	BF-BOF to EAF	Voestalpine Group	Austria
Luleå mini-mill	2028	BF-BOF to EAF	SSAB	Sweden
Phasing out BF				
Stegra Boden (formerly H2GreenSteel)	2025	H-DRI	Stegra (formerly H2 Green Steel)	Sweden
Bremen DRI (Steel4Future)	2026- withdrawn	NG-DRI to H-DRI	ArcelorMittal	Germany
Eisenhüttenstadt DRI (Steel4Future)	2026- withdrawn	NG-DRI to H-DRI	ArcelorMittal	Germany
Gijon DRI and EAF	2026 – postponed	H-DRI & EAF	ArcelorMittal	Spain
Hydnum Steel (Ph.1)	2026	H-DRI	Hydnum Steel	Spain
H-DRI Dunkirk	Withdrawn Now planned	NG-DRI to H-DRI EAFs in Dunkirk	ArcelorMittal	France
The Blastr Green Steel Project	2027	H-DRI	Blastr Green Steel	Finland
tkH2Steel	2026- curtailed 2028	NG-DRI to H-DRI NG-DRI	ThyssenKupp	Germany
GravitHy	2028	H-DRI	GravitHy	France
ArcelorMittal Belgium DRI	2030	NG-DRI to H-DRI	ArcelorMittal	Belgium
SALCOS	2033 (delayed)	H-DRI	Salzgitter Group	Germany
Power4Steel (Pure Steel+ brand)	2045	NG-DRI to H-DRI + EAF	Stahl Holding Saar GmbH	Germany
Demo Plant				
HYBRIT	2026	H-DRI	LKAB, SSAB, Vattenfall	Sweden

Source: Author's own compilation based on data from Green Steel Tracker, 2026

ThyssenKrupp's tkH2Steel project has been curtailed to a natural gas-based process due to higher than expected hydrogen price and slow development of the hydrogen sector (Burgess, 2025). Salzgitter has also postponed the next stages of its SALCOS project for three years, again due to hydrogen market conditions and lack of promised regulatory changes by governments (Yermolenko, 2025b).

Even though BF-BOF conversion to EAF is technically proven and already occurring in the EU and other jurisdictions, the current landscape in the EU does not provide sufficient support to deploy or accelerate these transitions at the necessary scale. The EU is already a global leader in green innovation such as Hybrit and Stegra, demonstrating technical feasibility (LeadIT, 2026). However, firms cite similar constraints across projects. Policy and market uncertainty is linked to EU ETS and CBAM reforms; weak market demand for premium-priced green steel reflects the limited scope of public procurement; and high energy and hydrogen prices, combined with slow infrastructure development connected to gaps in renewable expansion, hydrogen strategies and permitting processes.

Taken together, these developments reveal a structural mismatch between the scale of technological transformation required for steel industry decarbonisation and the EU's predominantly incremental policy preferences.

4. EU Policies Supporting Low-Emitting Technologies

The EU relies on policy instruments designed to promote low-emitting technologies and exert pressure on the incumbent BF–BOF regime. This section presents the relevant policies and examines the potential issues with their effectiveness, helping to explain why these measures have not translated into lower specific emissions in the steel sector.

4.1. Carbon Pricing

Carbon pricing, such as the EU ETS, is one of the policy tools aimed at incentivising the shift towards lower-emitting technologies and support carbon reduction technologies, to create a viable business case for low-CO_2 steelmaking technologies.

The EU ETS works on the principle of a "cap and trade" system. It sets benchmark values of emitted carbon, above which the companies must pay a proportion of the additional pollution generated. (EU, n.d.) EU Allowances (EUAs) are a type of carbon allowance that permits companies covered by the EU ETS to emit a certain amount of CO_2 equivalent. The cap on the total number of available allowances guarantees their value. The price of EUAs should encourage emissions reductions and promote investment in innovative, low-carbon technologies.

While Europe is leading the way in regulatory reform, the steel industry enjoys free ETS allowances for most of its production volumes. Concerns about losing competitiveness on global markets, as well as carbon leakage, have been the main reasons behind carbon price exemptions observed for the steel sector (OECD, 2022).

Although rising carbon costs would impose significant pressure on incumbent processes, the continued use of free allocation dampens these incentives and slows structural change, reflecting a gradual, step-by-step compromise that embodies Lindblom's incrementalism argument and protects the competitiveness of the incumbent industry.

4.2. CBAM

As carbon prices increase, shipping steel products from non-EU countries could become attractive despite transport costs (Lehne & Sartor, 2020). Exporting emissions would undermine climate change initiatives and cause economic damage. Therefore, the EU became the first to introduce measures to address the issue with the Carbon Border Adjustment Mechanism (CBAM).

The CBAM equalises the price of carbon between domestic products and imports to ensure their equal treatment by applying a tariff on emissions embedded in goods produced outside the EU ETS. Since the ETS currently assigns free allowances to protect industrial competitiveness, these must be phased out as the CBAM is phased in to comply with World Trade Organization rules.

The CBAM phase-in plan gradually ends the free allocation of EU ETS allowances over a nine-year period, with CBAM applying only to the proportion of emissions not covered by free allocation during this transition (EC, 2025; Tiseo, 2024).

This considerably long transitional phase reflects a deliberate, step-by-step political compromise, consistent with Lindblom's incrementalism argument, and continues to protect incumbent technologies.

4.3. Green Public Procurement

Changing customer requirements and growing demand for low-carbon steel products can be observed already in various industries. Customers' willingness to recognise the value of green steel products and pay for decarbonization through "green premiums" can drive the shift to more sustainable production technologies. There is a need to strengthen "demand pull" for green steel from downstream industries and increase confidence that the premium can be passed to end consumers (Hoffmann et al., 2020; Åhman et al., 2023; Perez et al., 2025).

Green Public Procurement (GPP) is a process for public authorities to obtain products that have a lower environmental impact throughout their life cycle. However, existing GPP regulation rules are not unified and mainly voluntary at the present in the EU, so they do not provide enough to stimulate demand (EC, n.d.).

The EU is proposing minimum mandatory GPP criteria in sectoral regulation, but for effective changes well-coordinated policies, such as material-efficiency building codes, design & recyclability policies are needed at national and international levels (Bataille, 2020; Åhman et al., 2023; EC, n.d.).

4.4. Steel Scrap

Recycling steel generates significantly fewer emissions than primary production; therefore, steel scrap is a strategic source of low-carbon raw material with significant economic value. The EU is the biggest exporter of steel scrap, but with the transition to EAFs a steady supply of large amounts of high-quality scrap will be required (JRC, 2025; Lee et al., 2026).

Regulations are planned to 'onshore' the supply of scrap and incentivise domestic consumption, but non-EU buyers often offer better prices, causing high-quality scrap to leave the EU. Hence, there is an ongoing debate about restrictions, as conflicting interests between steel producer and the recycling industry have delayed any decision-making (Hansen, 2025; Pickens, 2023).

The quality of the steel scrap is also important, as products from the BF-BOF process route have traditionally higher quality, hence clearer classification and harmonised waste regulations are required to improve sorting and treatment (EUROFER, 2020; JRC, 2025). While the legislative framework is evolving, the shifts are only incremental and so far achieved modest results (Grabbe & Moffat, 2024).

4.5. Renewable Power

To deploy low-carbon technologies of the iron and steel industry, policies are required to support the development of renewable power generation capacity, such as wind, solar and biomass, as well as nuclear power (Toktarova et al., 2022; Superchi et al., 2023; Fuhrlaender et al., 2025).

It is a significant challenge to match variable electricity supply from renewable energy sources with the demand from electric arc furnaces and electrolysers. Renewable energy deployment is also limited by grid connection issues, permitting can take a long time causing delays in grid capacity required for both EAFs and H_2 electrolysers (Superchi et al., 2023; Toktarova et al., 2022).

Beyond availability, low energy cost is also essential for supporting the green transition. The EU is preparing the EU Electrification Plan and AccelerateEU packages as a response to energy-price volatility, presenting measures to improve system efficiency, replace fossil fuels and stimulate investment in clean energy (Bolotova et al., 2026; EC, 2026). However, due to repeated delays, deadlines are being missed, creating a situation where these initiatives are losing momentum.

4.6. Hydrogen Economy

Hydrogen infrastructure is an emerging alternative energy infrastructure that includes green H_2 production, storage, transportation and utilizing gases rich in hydrogen. (Johnson et al., 2025). Most hydrogen developments are in their early stages. Although the EU laid out a roadmap ensuring the scaling up of renewable hydrogen production, establishing the logistical infrastructure and storage facilities in 2020, lawmakers approved only around 100 hydrogen projects in April 2026, including electrolysers and pipelines. As a result, the infrastructure rollout remains slow and fragmented (IEA, 2023; OECD, 2025; Hydrogen Infrastructure, 2026).

Also, it should be noted that before hydrogen can be widely adopted, robust safety measures must be developed to ensure secure and reliable utilization (Sun et al., 2024).

Today's hydrogen production technologies operating at commercial scale do not yet deliver affordable green hydrogen. Nonetheless, hydrogen needs to be cost-competitive, sustainable and available at scale in order to be used widely in the steel industry (Shahabuddin et al., 2023; Sun et al., 2024). This challenge is linked back to the price and availability of renewable energy, reinforcing existing sectoral lock-ins that continue to slow transformative change.

5. Conclusions

The analysis shows that the existing BF-BOF regime remains the dominant configuration in the EU iron and steelmaking. Although climate and sustainability targets create momentum for change, specific policy instruments intended to exert pressure on the incumbent regime remain insufficient.

Circular economy and CO_2-reduction measures largely deliver incremental improvements within the existing system. By contrast, only niche pathways such as direct carbon-avoidance innovations have the potential to challenge the incumbent regime. However, the way policy instruments are implemented to support niches still reflects the broader pattern of policy incrementalism.

Carbon pricing, CBAM, green procurement, steel scrap developments, renewable and hydrogen infrastructure plans are designed to exert pressure on high-emission technology routes. However, across the EU policy landscape, a consistent pattern of political compromise is visible, such as free allocation under EU ETS, the nine-year CBAM phase-in, voluntary GPP rules, delayed scrap regulations and slow permitting processes for renewables and hydrogen infrastructure.

Together, these reflect political constraints that slow the pace of change. More ambitious sustainability measures can provoke resistance, shape the politics of climate policy and slow transformation. These political dynamics help explain why policy instruments may signal a shift in expectations, while their slow and incremental implementation, combined with exemptions and transitional arrangements, often reinforces lock-ins rather than destabilise the regime.

As a result, EU policy instruments reshape expectations without yet enabling structural transformation. This illustrates how the myth of incrementalism obscures the transformative change required for viable green decarbonisation pathways in the steel sector. This interpretation is conceptual, because the study examines policy instruments and sectoral pathways, not political behaviour. In conclusion, stronger and more transformative policy interventions, aligned with long-term strategic frameworks, are required to enable a meaningful shift away from the incumbent regime. This is especially urgent because current investment decisions carry long-term lock-in effects that will shape the emissions trajectories for decades to come.

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Generative AI Declaration Statement

If AI was used:

During the preparation of this manuscript, the author(s) used CoPilot for the purpose of identifying related sources for the literature review, refining the academic tone, and correcting grammar and punctuation. The author(s) subsequently reviewed and edited the content as necessary, maintained full human oversight of the process, and assume full responsibility for the accuracy and integrity of the published work.

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The data that support the findings of this study are available from the corresponding author (Beáta Buró, burobea@hotmail.com) upon reasonable request.

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