

Mapping the transition of the EU steel industry to carbon neutrality

2026

HIGHLIGHTS

- ▶ Near-zero emission steel production in the EU is driven by hydrogen-based direct reduction (H₂-DRI-EAF) and scrap-based electric arc furnace (EAF) steelmaking.
- ▶ Decarbonising steel production in the EU will more than double demand for fossil-free electricity from 2023 to 2030, particularly to produce low-carbon hydrogen. To realise a competitive transition, an abundant and affordable supply of renewable and low-carbon hydrogen is needed.
- ▶ The realisation of all near-zero emission steel projects already announced will cut CO₂ emissions by more than half from 2023 to 2030. An important prerequisite for the realisation of these projects is the existence of a business case.
- ▶ Challenges for steel companies include technological scale-up, securing resources, investment costs for which de-risking is needed, the availability of affordable and clean energy, developing a market for low-emission steel, re-skilling the workforce and barriers to phasing out emissions-intensive plants.

THE CHALLENGE

Introduction

Steel is a crucial material for the global economy, and for the technologies and infrastructure required to achieve climate neutrality. It is 100% recyclable and therefore fundamental to the circular economy. Steel is recognised as a permanent material [1].

In 2024, the EU was the world's third largest steel producer after China and India, with 130 Mt of steel a year, accounting for 7% of global output [2], [3]. The EU steel industry provides around 0.3 million direct jobs and supports 2.2 million indirect and induced jobs, which account for approximately 1% of all people employed in the EU. More than 500 steel production sites across 22 Member States create EUR

177 billion of Gross Value Added per year [3]. The steel industry is one of the most emissions-intensive sectors in the EU.

Responsible for 5% of total emissions and over a quarter of industrial emissions, its transformation is essential to achieving climate goals [4]. This involves a series of interconnected challenges, including scaling up breakthrough steelmaking technologies as well as its optimisation to achieve quality steel output, securing resources, ensuring investments, developing markets for low-carbon steel, re-skilling of the workforce and phasing out emissions-intensive plants.

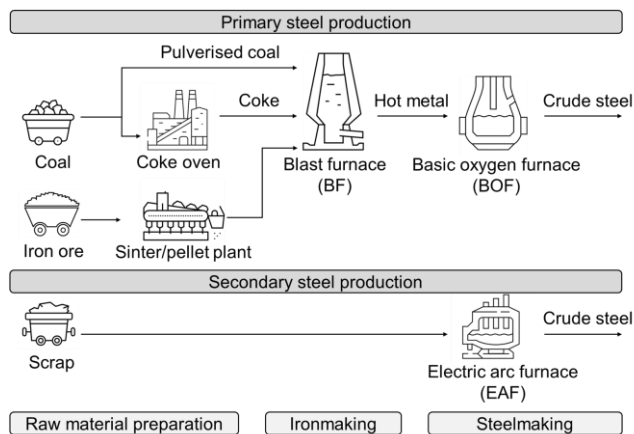
This factsheet offers an overview of the current status of the EU steel industry and discusses

emerging technologies being explored by the sector to decarbonise its processes, along with their abatement costs and maturity status. It also compiles information on pilot projects and evaluates how these align with EU policy objectives and the industry's decarbonisation trajectories.

Production processes

In the EU, steel is predominantly made in two ways: the primary and the secondary routes (Figure 1).

Figure 1 - Steel production routes



Source: JRC, 2026

In the primary route, iron ore is first processed into pellets or sinter by heating the ore to above 1 000 °C. A combination of sinter and pellets is then fed into a blast furnace (BF) alongside hot air, coke, pulverised coal, lime, and occasionally natural gas as an auxiliary fuel. During the iron-making process in the BF, oxygen is removed from the iron ore, converting it into liquid iron with a carbon content of ca. 4-5%. The liquid iron is then transferred into a basic oxygen furnace (BOF), where oxygen is blown into the melt, thereby oxidising the excess carbon, which forms carbon monoxide (CO) and carbon dioxide (CO₂). This reduces the carbon content of the liquid steel to around 0.03-1%. The waste gases produced in the primary blast furnace-basic oxygen furnace (BF-BOF) can be recovered as fuel to generate heat and electricity, partially offsetting emissions [5].

In the secondary route, steel scrap is melted in an electric arc furnace (EAF) to produce liquid steel. The electrodes that heat up the scrap are powered by electricity, therefore linking this process directly with the carbon intensity of the electricity source used.

Secondary steel production is limited by scrap quality and availability, and the resulting steel may be of lower quality due to impurities in the scrap, which can

affect performance in high-grade applications. Steel produced in a BF-BOF using coal is the dominant production route in the EU, accounting for roughly 55% of steel production, with steel produced via EAF accounting for 45% in 2024 [3].

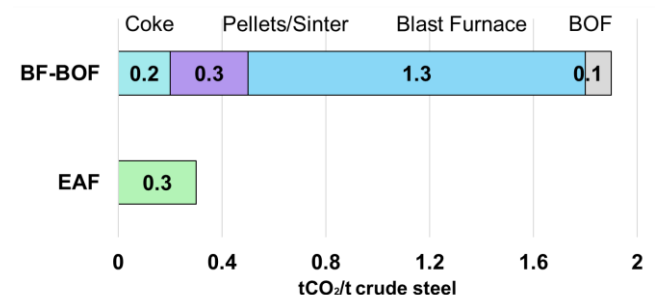
The EU's blast furnace fleet is ageing, at 50 years old on average, with 25% in operation for over 60 years. Almost half of EU blast furnaces are set to retire before 2035 [6]. European steel production plants face important investment decisions over the next five years: they need to decide whether to shut down plants, reinvest in existing assets, or invest in near-zero and zero-emission production processes.

Current CO₂ emissions

The CO₂ emission intensity of crude steel varies heavily, depending on the production route (Figure 2). The actual emissions vary considerably, depending on the plant design and location [5].

In 2022, the average CO₂ emission intensity of EU steel produced via the BF-BOF route was estimated at 1.81 tCO₂e per tonne of steel, compared to 0.24 tCO₂e for the EAF route [7]. The BF-BOF route has a higher emissions intensity than the EAF route, primarily due to the use of fossil fuels in the blast furnace. BFs are responsible for almost 60% of all CO₂ emissions from steel production [4].

Figure 2 - Sources of CO₂ emissions for different steel production routes. Illustrative CO₂ emission values from [7]



Source: JRC, 2026

Steel's impact on CO₂ emissions extends beyond production processes. The ratio between the net CO₂ emission reduction potential due to steel use in other sectors and the emissions from steel production per year from 2030 onward is estimated to be 6 to 1 [8].

Policy targets and context

There are no specific CO₂ emission reduction targets for the iron and steel sector in the EU. However, the industry must be decarbonised to achieve the overall EU targets of at least 55% reduction by 2030, 90%

reduction by 2040 (as proposed in the [2040 Climate Target](#)), and net-zero by 2050.

Free emissions allowances for the steel sector under the EU Emissions Trading Scheme will be ending completely in 2034 (still under discussion) as the [Carbon Border Adjustment Mechanism](#) (CBAM) is phased in from 2026. This timeline may accelerate plans to achieve climate-neutral steel if the enabling conditions, such as internationally competitive availability of low-carbon energy and input materials, have been realised.

The [Steel and Metals Action Plan](#) (SMAP), published in March 2025, is a non-binding policy instrument that aims to strengthen the EU's competitiveness in steel and metals production while accelerating the sector's climate neutrality trajectory. The SMAP emphasises key levers such as process electrification, switching to low-carbon hydrogen, and circularity, primarily through instruments already in place or under development.

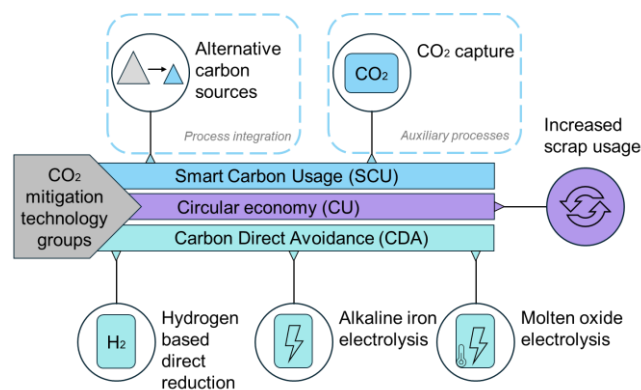
The [Clean Steel Partnership](#) aims to develop breakthrough steelmaking technologies at a high readiness level (TRL 8, i.e., system complete and qualified [9]) to reduce the CO₂ emissions from EU steel production by 80-95% compared to 1990 levels by 2050, ultimately leading to climate neutrality.

THE WAY FORWARD

Decarbonisation trajectories¹.

There are three main technology groups for CO₂ reduction in the steel sector. These are Circular Economy (CE), Smart Carbon Usage (SCU) and Carbon Direct Avoidance (CDA). These technology groups, shown in Figure 3, aim to reduce the use of carbon compared to current steel production technologies or to avoid carbon emissions entirely [10]. This factsheet explores six trajectories to a close-to-zero emissions EU steel industry in 2050 (Figure 4). Each trajectory incorporates all the technology groups identified above, but with different degrees of emphasis.

Figure 3 - Key CO₂ mitigation technology groups for the European steel industry



Source: JRC, 2026

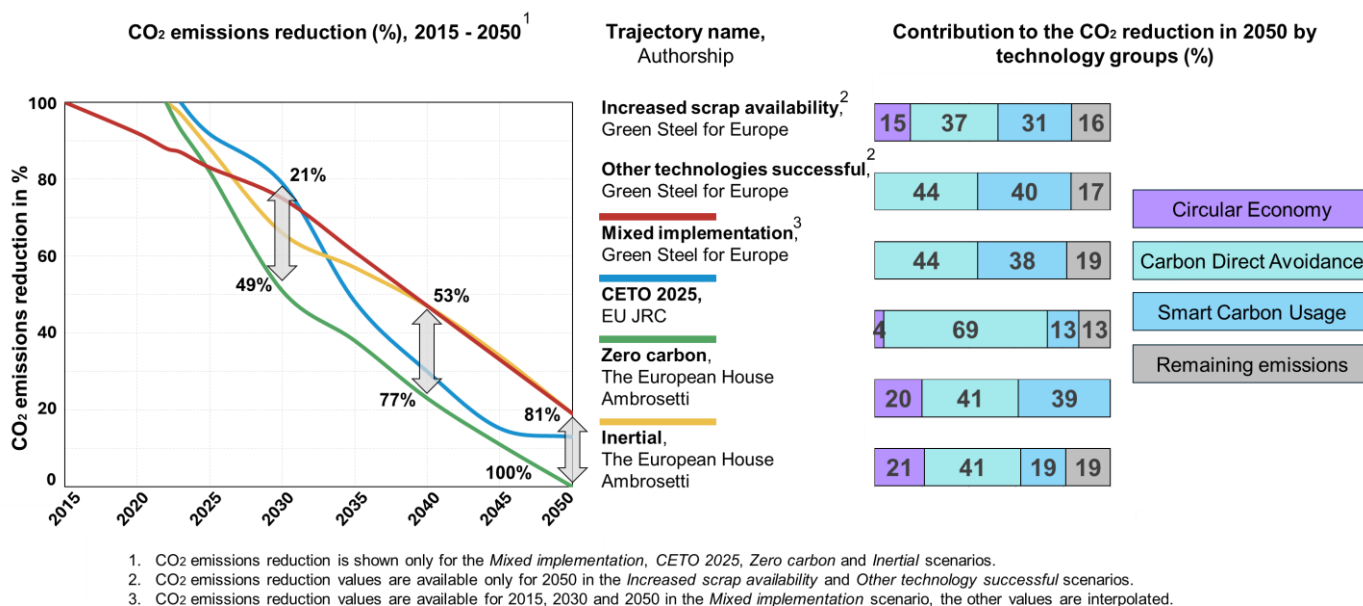
In all trajectories, the Carbon Direct Avoidance technology group, which includes the usage of hydrogen and/or electricity to replace carbon as the main reduction agent for the iron ore reduction stage, contributes the largest share of the CO₂ emissions reduction (37-69%) in 2050. Access to low-cost and clean energy is key when implementing CDA technologies, since close to net-zero emissions reductions are only possible if CO₂-free electricity and hydrogen are available.

In the *Increased scrap availability*, *Zero carbon* and *Inertial* trajectories, the CE technology group, and materials efficiency and steel recycling in particular, provides more than 15% of the CO₂ emissions reduction in 2050. Steel production from scrap in the EAF route requires only 10-15% of the energy needed for primary steel production and is less capital-intensive. Increasing the share of scrap input in total EU production would require improvements in control over the quality of steel scrap. The most important step is to reduce the contamination of steel scrap by undesired 'tramp elements', especially copper. Steel scrap plays an enhanced role for the EU steel industry, as it contributes to environmental goals by reducing the use of virgin raw materials, energy and CO₂ emissions. The [European Steel Action Plan](#) calls for the recognition of steel scrap as a strategic secondary raw material.

¹ This factsheet avoids using the term 'pathways' to prevent confusion with the sector-specific decarbonisation pathways published by the European Commission in November 2025. Those sector-specific pathways

are intended as a voluntary tool to support companies set their individual decarbonisation targets in line with the European Climate Law. See [EC, making finance flows consistent with climate goals – Climate Action, 2025](#)

Figure 4 - Overview of the decarbonisation trajectories (Increased scrap availability [11], Other technologies successful [11], Mixed implementation [11], CETO 2025 [12], Zero carbon [13] and Inertial [13]) for the steel industry: CO₂ emissions reduction in % from 2015 to 2050; steel production technology groups contribution to the CO₂ reduction in 2050



Source: JRC, 2026

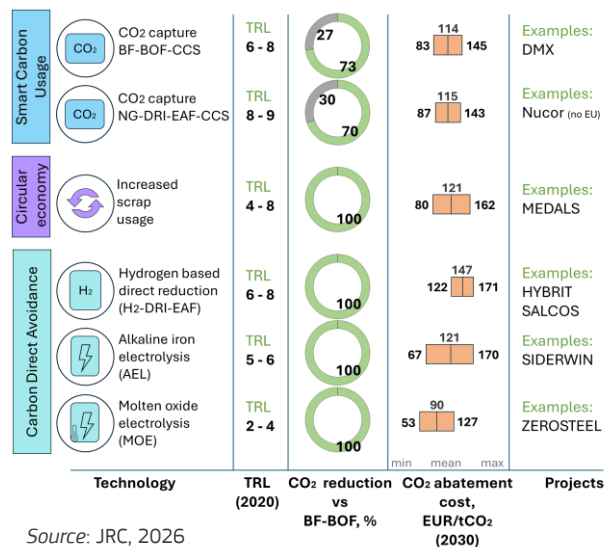
Future scrap availability will depend not only on scrap production and scrap trade balances, but also on progress in circular economy efforts, such as scrap sorting and processing [11].

The Zero carbon, Mixed implementation and Other technologies successful trajectories have the highest share of the SCU technology group (38-40%). The steel industry transition trajectories analysed estimate a potential CO₂ reduction in the range of 21-49% in 2030, 53-77% in 2040 and 81-100% in 2050. All trajectories except for the Zero carbon trajectory show remaining emissions of 13-19% in 2050. To compensate for these, 'negative emissions' would be required in other parts of the economy.

Decarbonisation technologies

Various technologies to decarbonise the iron and steel sector are either already available or in development (Figure 5). The technologies and the way they are designed, built, maintained, operated and decommissioned are considered Best Available Techniques (BAT), only if these techniques are the most environmentally effective and economically and technically viable for the prevention and control of emissions².

Figure 5 - Technology readiness level (TRL), level of the CO₂ emissions reduction and CO₂ abatement costs of selected steel production technologies. Examples of low-CO₂ steel production projects



Existing BFs can be retrofitted with a chemical absorption amine-based CO₂ capture unit that is connected to major CO₂ point sources: the onsite power plant that runs on the steel plant's flue gases, the coking plants and the blast furnace hot stoves. This offers emissions reductions of around 73% of onsite CO₂ emissions. CCS applied to the BF-BOF has a technology readiness level (TRL) of 6-8 [14], and an estimated CO₂ abatement cost of EUR 83-145/t CO₂ [15].

² Directive (EU) 2024/1785, Article 3

The CDA group of technologies has the potential to reduce CO₂ emissions from the steel production process by 100%, provided the electricity is CO₂-free. The H₂-DRI-EAF technology has a TRL of 6-8, and an average CO₂ abatement cost of EUR 122-171/t CO₂ [15]. The wide range for the CO₂ abatement costs of the H₂-DRI-EAF technology is due to uncertainty about the future cost of hydrogen, which relates to the level and pace of electrolyser technology deployment, as well as demand for fossil-free electricity for its production. The state-of-the-art DRI plants are 100% hydrogen-ready.

At the same time, DRI plants can operate with natural gas, which makes NG-DRI-EAF a bridging technology until sufficient quantities of hydrogen are available. The natural gas-based DRI process can also be combined with post-combustion CO₂ capture since the DRI furnace emits a highly concentrated stream of CO₂. From a technology readiness perspective, this is already being deployed commercially, albeit with limited CO₂ capture potential (TRL 8-9).

The EAF technology is well-suited to handling direct reduced iron (or its compacted and shippable form, hot briquetted iron) and steel scrap in any ratio, although the quality of the final product is sensitive to the quality of both the DRI and scrap inputs. Adjusting scrap and DRI ratios based on the availability and cost of these materials, as well as the required quality of the steel output, provides flexibility in operating the DRI-EAF process [15].

The average CO₂ abatement costs in 2030 range from EUR 90/tCO₂ (MOE) to EUR 147/tCO₂ (H₂-DRI-EAF). A CO₂ price above EUR 147/tCO₂ in 2030 would make the presented breakthrough technologies (Figure 5) more competitive than the current primary steel production via BF-BOF.

Molten Oxide Electrolysis (MOE) and alkaline iron electrolysis (AEL) technologies are potential game-changers for the global steel transformation, combining high CO₂ reductions (>90%) with lower CO₂ abatement costs compared to H₂-based technologies (H₂-DRI-EAF). However, since these technologies are still in the early stage of development (expected to reach market readiness by the end of the next decade and into the 2040s), there is uncertainty associated with the capital investments required to deploy them and with the total operating costs needed to run these processes at industrial scale.

Scrap-based EAF production (the main technology of the CE group) is an established, mature technology whose costs vary according to the prices of electricity and scrap, while the price of scrap, in turn, depends on the steel quality required for end-use applications. The costs of scrap-EAF steel production would be 35-68% higher than production via the BF-BOF [15]. The higher costs of the scrap-EAF are largely due to the need for high-purity steel scrap, as well as the use of biogenic carbon as a source of carbon for slag-foaming purposes in the EAF.

Establishing a business case and de-risking investments are essential to overcoming the “valley of death” (the term is used to describe the situation in which a technology fails to reach the market because of an inability to advance from the technology’s demonstration phase through the commercialisation phase [16]).

STATE OF DEVELOPMENT

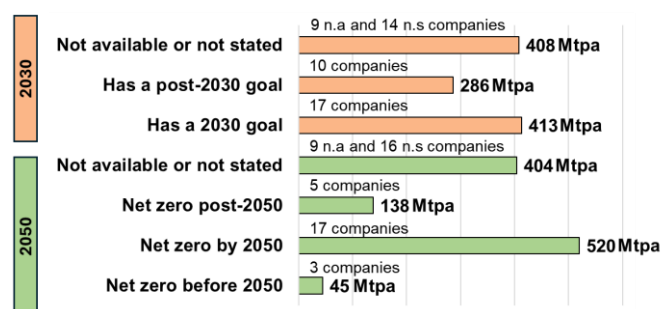
Industrial decarbonisation targets

The number of near-zero emissions projects announced by steel producers in the EU27 has been increasing since 2020, but only some are progressing as scheduled. 77% of them focus on the CDA technologies group, i.e., H₂-DRI-EAF and scrap-based EAF [17]. The realisation of these projects would result in 33 Mt of green hot briquetted iron/direct reduced iron (HBI/DRI) and 42 Mt of green primary steel annually by 2030 [18].

Global Energy Monitor (GEM) and the Leadership Group for Industry Transition (LeadIT) analysed the state [19] and are tracking the progress [20] of net-zero commitments by the top 50 steel-producing companies (representing 60% of global steel production and 1.9 Gt of steel in 2024) [21] (Figure 6). The global number two, ArcelorMittal, produced 53% of its crude steel in Europe in 2024. Thyssenkrupp is second in the EU and 42nd in the world. Both are included in the emissions targets analysis presented in Figure 6.

Seventeen steel producers have set a 2030 emissions reduction goal, and 10 have established milestones between 2030 and 2040, covering a production capacity of 286 Mt per year (Mtpa).

Figure 6 - Emissions target of the world's top 50 steel producers and their production in Mt per annum (Mtpa). Data adopted from [17] and [20]



Source: JRC, 2026

Only three companies (producing 45 Mtpa) plan to reach net-zero before 2050, and 17 (producing 520 Mtpa) have committed to being net-zero by 2050. Of the EU's steel producers, ThyssenKrupp and SSAB have pledged carbon neutrality by 2045 (SSAB is not included in Figure 6), and ArcelorMittal by 2050.

While there has been progress in the steel industry's commitment to emissions reduction targets, 23 of the top 50 producers globally still lack concrete intermediate milestones, making it challenging to achieve the goal of net-zero by 2050.

Demonstrators

46% of EU-funded demonstrator projects³ intend to decarbonise the steel industry through the implementation of CE technologies, including energy efficiency and digitalisation. 49% of the projects focus on CDA and 5% on SCU [22] (Figure 3).

Projects such as [STEGRA](#) and [HYBRIT](#) centre on the construction of H₂-compatible DRI plants alongside EAFs (H₂-DRI-EAF) to replace BF-BOF facilities. HYBRIT's pilot plant has alkaline electrolysers with a nominal production capacity of 910 Nm₃/h (4.5 MWh₂) [23]. [MEDALS](#) aims to increase the recycling rate of steel by improving scrap sorting and enhancing the separation of unwanted elements from valuable alloying elements. CCS technology is the focus of [DMX](#), the first pilot plant of which aims to implement a 1 MtCO₂/year CCS unit after 2025. AEL technology (reducing iron ore via electrolysis) was developed in the EU-funded [SIDERWIN](#) project. [ArcelorMittal](#) aims to produce 40–80 kt of steel per year at the first industrial-scale low-temperature iron electrolysis plant by 2027, increasing its capacity to 0.3–1 Mt by 2030, and reaching commercial readiness (TRL 9) by

2040. The start-up [Boston Metal](#) is working on the commercialisation of molten oxide electrolysis (MOE) technology. In the MOE process, iron ore is converted electrochemically to its elementary components, oxygen and iron, in an electrolysis cell without a carbon-based reducing agent. The EU [ZEROSTEEL](#) project is developing the MOE process as one of four novel processes which will integrate hydrogen and/or renewables into the steel production process.

Evaluation of progress and alignment with policy and industry targets

Around 650 Mt of scrap is consumed each year by steel production worldwide, resulting in the avoidance of 975 Mt of CO₂ emissions and the reduction of the use of iron ore, coal and limestone [24]. The availability of scrap might become a limiting factor in efforts to further increase EAF capacity.

The strategic importance of scrap has resulted in countries introducing measures to control its export. In 2022, about 72 export measures, affecting 3.3 Mt of steel scrap, were in force globally. Export taxes and licensing requirements were the most common measures, followed by export quotas [25]. In the EU, the upcoming [Circular Economy Act](#) and the proposed regulation on [circularity requirements for vehicle design and on management of end-of-life vehicles](#) will offer policy levers to bolster the supply and use of steel scrap.

The European Steel Association (EUROFER) has projected CO₂ emissions reductions of 81.5 Mt per year by 2030 (from 145 MtCO₂ in 2023 [4]), if the announced near-zero emissions steel projects are completed. The realisation of the announced near-zero emissions steel projects until 2030 will cost EUR 31 billion in capital expenditure (CAPEX). The operating expenditures (OPEX) are estimated to be EUR 54 billion, bringing the total bill to EUR 85 billion [26].

The EU steel industry currently consumes 75 TWh of electricity per year, of which 55 TWh is purchased from the grid, while the rest is generated by primary steelmaking (mainly BF-BOF) from its industrial residual gases [27]. To run the announced plants, 75 TWh of electricity would be required annually, along with about 2.12 Mt of hydrogen (corresponding to 90 TWh of electricity, if this hydrogen is produced

³ Mapping of demonstration plants in energy intensive industries (INCITE) layer on [EIGL website](#)

via water electrolysis). In total, this comes to around 165 TWh of fossil-free electricity [26].

CONCLUSIONS

In the EU, a high share of steel companies' announced decarbonisation projects, including EU-funded demonstrator projects, is based on a combination of H₂-DRI-EAF and scrap-based EAF. This is unlike the rest of the world, where CCUS is preferred [28]. Decarbonising EU steel production will involve a significant increase in demand for fossil-free electricity, particularly for the production of low-carbon hydrogen. Investments in fossil-free energy capacity, grid infrastructure, and low-carbon hydrogen production and storage should be incentivised to meet this growing electricity demand. A major challenge to increasing the share of scrap-based steel production will be availability. Ensuring open markets for steel scrap is key [29].

Assessing the investment needed to decarbonise European steel is contingent on the industry remaining globally competitive and profitable. Additionally, there needs to be sufficient quantities of low-carbon hydrogen and electricity, as well as scrap available at an internationally competitive price, as part of the business case. A coherent legislative framework is necessary to achieve the scale and speed of steel decarbonisation required to meet the EU's climate targets. This framework should strike a balance between transforming production processes (EU ETS and CBAM), ramping up transition enablers (support for renewable energy and infrastructure), and addressing consumption via demand-side/product policies to stimulate the uptake of clean steel [30]. The adoption of a definition for green steel and interoperability with other international standards would facilitate the creation of a green steel market.

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