White paper

Manganese fostering sustainable and decarbonized steel value chain

A handbook for the industry

eramet
COMMITTED TO SUSTAINABLE METALS

Executive summary

- This white paper serves as a reference guide to **highlight the critical role of manganese and its alloys in building a sustainable, decarbonized steel value chain**. It explains why manganese is indispensable in steelmaking, how low CO_2, high-CSR manganese alloys can accelerate the transition to greener steel, the challenges the industry faces, and actionable recommendations for collective progress. Drawing on insights from across the value chain, from mining to alloy production, steelmaking, end-use applications, and market analysis, it provides a comprehensive overview of manganese's contribution to a more sustainable steel industry.

- **Manganese is a fundamental component in steel production**. In 2024, approximately 20 million tonnes of manganese alloys were consumed worldwide. These alloys significantly enhance steel's mechanical properties, such as hardness, strength, and toughness. Steel, in turn, remains a cornerstone material for sectors including automotive, railways, renewable energy, and many others.

Up to 78%

Of steel's carbon footprint

Low CO_2 cars, wind turbines and rails require steel with minimal carbon content. **One effective way to make steel greener is by using low CO_2 manganese alloys**. Indeed, the CO_2 emissions associated with manganese alloys can account for 2% to 78% of steel's total carbon footprint, making it a critical area for decarbonization.

- Assuming that low CO_2 manganese alloys are defined by a threshold of 1.9 tonnes of CO_2eq per tonne of alloy for Scope 1 and 2, which is twice as low as the industry average, **9% of global production in 2023 consisted of low-CO_2 manganese alloys**.

- **Manganese alloy producers can decarbonize through a multi-faceted approach**. For Scope 1, possible solutions include replacing fossil-based reductants with biocarbon, installing carbon capture and storage (CCS) or carbon capture, utilization and storage (CCUS) systems, or improving process efficiency. For Scope 2, producers will need to transition from fossil fuel-based electricity to fossil-free sources.

- To produce manganese alloys, manganese ore is required. **To meet societal expectations and ensure responsible business conduct, a sustainable source of manganese ore is essential. Standards such as IRMA can be part of the solution**. There is no better proof than an on-site audit by a third party to objectively assess human rights, social, and environmental impacts. **Traceability tools can also help customers make better purchasing decisions**. For example, Digital Product Passports (DPPs) act like identity cards for products, providing key Corporate Social Responsibility (CSR) information to guide informed choices.

Executive summary

- This white paper aims to shed light on the sustainability challenges faced by the manganese value chain. It focuses on environmental and social issues that must be addressed to build a more responsible and low CO_2 industry. The following recommendations are intended to support progress toward a more sustainable value chain:

  →**Ensuring the deployment of the International Manganese Institute (IMnI) carbon accounting standard** will clarify offerings for customers and markets.
  →**Educating stakeholders on the role of manganese and highlighting producers' current efforts** is essential to valorize the existing low CO_2 manganese alloy offer.
  →**Co-developing a decarbonization pathway with all manganese producers for the industry** appears to be the logical next step.
  →**Setting minimum criteria for responsibly sourced materials across the industry** would help ensure they represent a significant share of purchases.
  →**Finally, public support for the green transition should be strengthened** to maintain competitiveness and help companies reduce the risk associated with CSR-related projects.

- Eramet's ambition is to transform the industry, raising CSR standards and lowering CO_2 emissions, to make the manganese sector a strong contributor to the transition. To succeed, strong customer demand for low-impact products, robust standards, country-level regulations, and a future where costs and value are shared across the entire value chain are required.

This white paper brings together the voices of multiple industry stakeholders, reflecting a genuine collective momentum:

CRU SSAB IMnI

RAILSPONSIBLE grupo maringá Ferroglobe TILKAL

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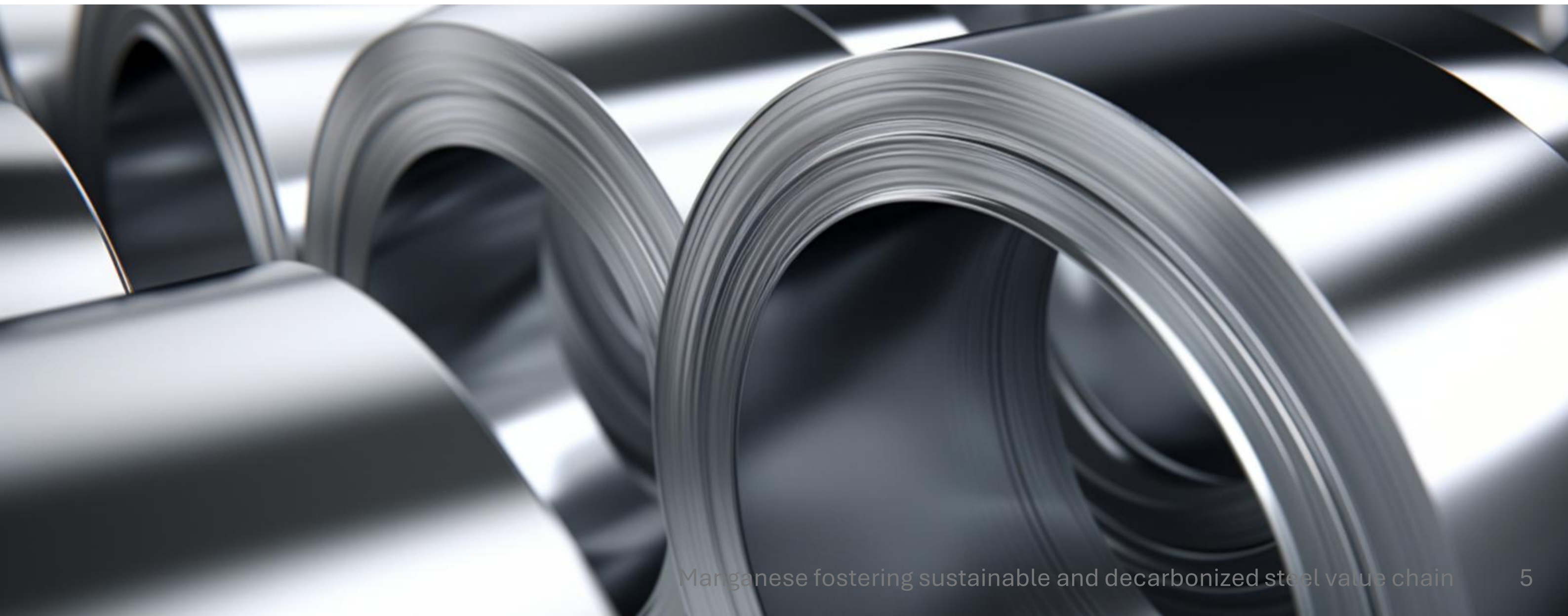
Manganese is essential for steel production

Many people might say that steel is merely an alloy of iron and carbon, with varying amounts of other chemical elements. However, this definition falls short. Steel is actually an alloy of iron, carbon, and manganese, along with varying amounts of other elements. **Without manganese, steel would not exist in its current form**. Whether it is carbon steel or stainless steel, for flat products or long products, for commercial applications or specialized uses, manganese is an indispensable element in the chemical composition of steel.

Manganese enhances the mechanical properties of steel, including hardness, yield and tensile strength, and toughness, qualities that are crucial for the rigorous demands of construction and manufacturing. Manganese also improves steel's hardenability, allowing it to be effectively hardened through heat treatment. Furthermore, manganese is vital for improving the hot workability of steel. It reduces the risk of hot shortness by inhibiting the formation of iron sulfides, which can cause brittleness and cracking when steel is exposed to high temperatures.

Last but not least, **manganese boosts the wear resistance of steel**, increasing its durability in applications that involve continuous friction and abrasion. It also acts as a **deoxidizer**, reacting with dissolved oxygen in liquid steel to form MnO oxides that are far less harmful to the steel's cleanliness and overall quality. This positions manganese as a critical element in the production of construction materials, automotive parts, railway tracks, and machinery components, ensuring superior performance and reliability across industries.

Manganese is used in steel mainly in the form of alloys (ferromanganese or silicomanganese) with a manganese content ranging from 68% to 82%, or in the form of manganese metal (pure manganese).



In 2024, 90% of manganese was consumed by the steel industry. The remaining 10% was used in the chemical industry (batteries, electronics, agriculture, pigments, fine chemicals...).

In 2024, around 20 million tonnes of manganese alloys were consumed to produce 1.9 billion tonnes of steel. The steel then continues its journey down the value chain to supply the construction, machinery, automotive, consumer goods, transportation, and energy industries.

To produce manganese alloys, manganese ore is needed. To provide the general public with a sense of scale:

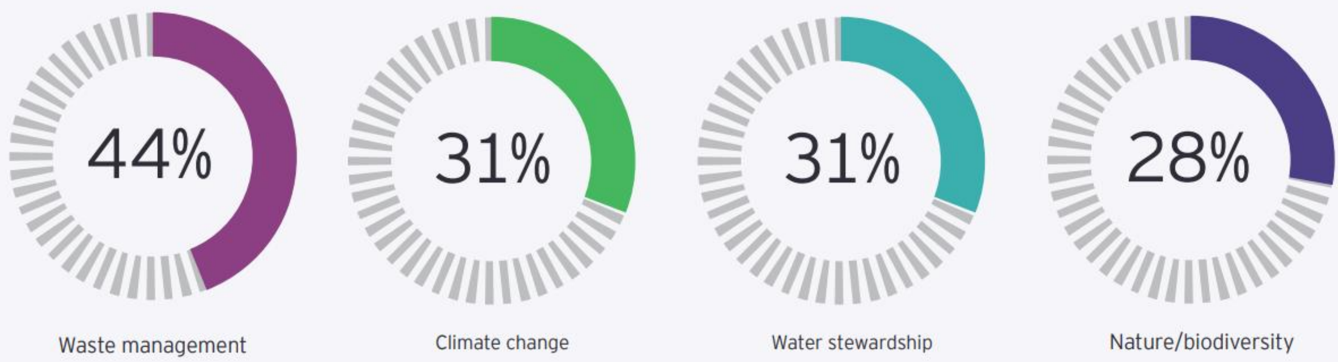
- 10 kg of ferromanganese are required to produce 1 tonne of steel with 0.76% Mn.
- 2 tonnes of manganese ore are required to produce 1 tonne of manganese alloys.

The mining industry is more scrutinized than ever, being the first step of a sustainable value chain. **By relying on manganese, one of Earth's mineral resources, the steel industry can make a significant stride toward a more sustainable and responsible value chain.**

“Without manganese, steel simply would not exist in the form we know today.”

Bruno Henriques, Steelmaking Expert

ESG factors facing the most scrutiny from investors in 2025 for mining and metals companies

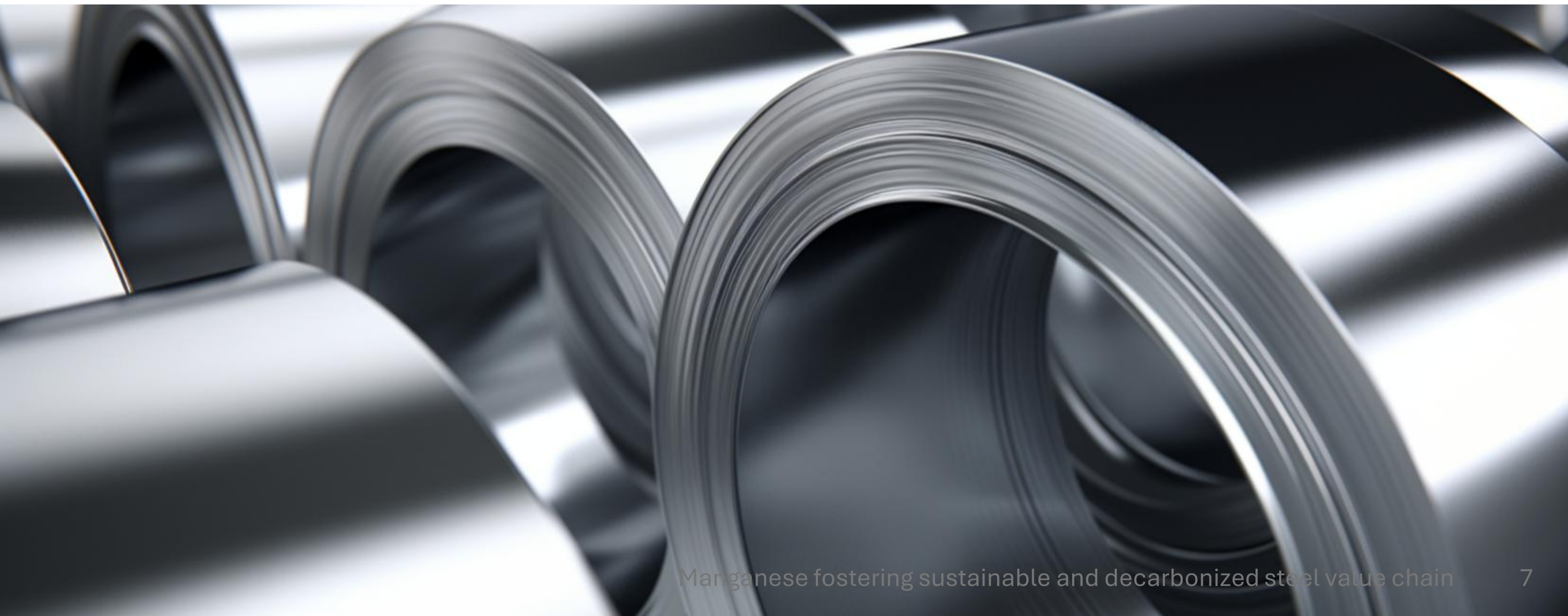


Note: Respondents could choose more than one option.
Source: EY Business Risks and Opportunities Study 2025.

*Since **ESG (Environmental, Social, and Governance) is the major risk for mining companies**, it represents, de-facto, a **major supply-chain risk for steel customers.***

World steel output is expected to reach the 2 billion tonnes mark within the next 10 years. At the same time, the amount of manganese contained in batteries is expected to keep rising, especially in the automotive industry.

As a result, **demand for manganese should continue growing in the long term** to provide the required properties for steel, batteries, and other applications, putting more pressure on Earth's mineral resources. In addition, the long-term trend is toward steels with even higher strength and hardness performance. These steels require a higher amount of manganese alloys per tonne.



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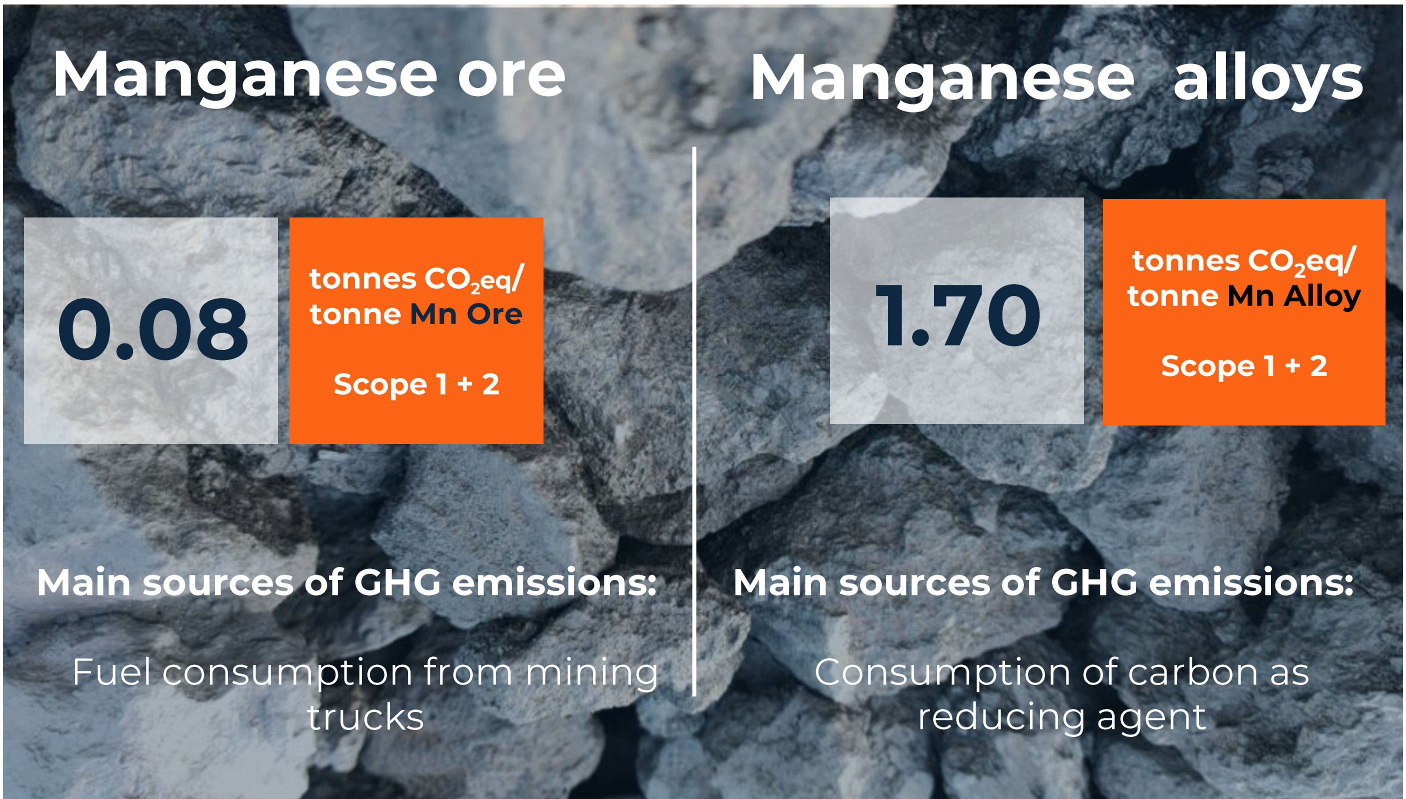
Structure of manganese-related CO_2 emissions

Manganese ore and manganese alloys: order of magnitude

The CO_2eq intensity in terms of Scope 1 and 2 for manganese ore and manganese alloy production is drastically different. Below are some figures to illustrate this difference.



Source: based on Eramet's data. Calculation made in compliance with the GHG protocol and the IMnI guidelines.

Figure 3. Manganese ore and alloys emissions

While decarbonization should be addressed across the board, these figures help us understand how to prioritize our actions. That's why this document will emphasize solutions available to manganese alloy producers.

Manganese alloys production process

The pyrometallurgical technologies used to produce manganese alloys are significant sources of greenhouse gas emissions. At the core of these processes lies the use of carbon as a reducing agent, a practice that dates back thousands of years in metallurgy.

The fundamental principle involves heating manganese oxides to very high temperatures and using carbon to remove the oxygen atoms bonded to the metal.

This process, known as reduction, enables the extraction of manganese in its metallic form. It inevitably generates carbon dioxide (CO_2) as a direct by-product of the chemical reaction, "hard-to-abate" emissions:
$MnO_{x>1} + C \rightarrow Mn + CO/CO_2$.

In electric arc furnaces, this reaction also requires large amounts of electrical energy to reach the melting and activation temperatures needed for reduction.

When this electricity is sourced from fossil fuels, it leads to additional indirect emissions, further increasing the product's carbon footprint. It is therefore not surprising that industrial sites with access to low-carbon electricity, such as those located in France, Norway, Brazil, or Gabon, are among the producers with the lowest carbon footprint.

This same model applies to both steel production and the manufacturing of manganese alloys. As such, the reliance on carbon places these technologies at the heart of decarbonization challenges in the metallurgical industry.

Market overview: All manganese alloys are not equal

CRU Consulting has developed capabilities to model reliable and comparable plant-level Scope 1 and 2 emissions for manganese alloys. Its recent study found that the global average emissions intensity in 2023 was 3.9 tonnes CO_2eq per tonne of Mn alloy[1].

Low CO_2 manganese alloys are already available. For instance, if we define low CO_2 manganese alloys as those with an intensity factor equal to or below 1.9 tonnes CO_2eq per tonne of Mn alloy (Scope 1, 2), which is twice as low as the industry average, 9% of worldwide production in 2023 was low CO_2.

“ Understanding emissions of those products is crucial for producers and end users in a context of carbon policies like CBAM and a continued push for decarbonization in different regions worldwide. ”

Aurélien Henry, CRU Expert

Figure 4. Illustration explaining why manganese alloys Scope 2 is very different among the producers

Eramet already offers eraLow to steelmakers. EraLow products are guaranteed below 1.9 tonnes CO_2eq per tonne Mn alloy for Scope 1 and 2 emissions. These results are achieved thanks to the use of carbon-free electricity, combined with cutting-edge production processes.

Standard for accounting GHG emissions in manganese alloys production

Given the structural emission sources of manganese alloys, it is critical to adopt clear, sector-appropriate methodologies for accounting greenhouse gas emissions. Without such frameworks, comparisons between producers or assessments of progress in decarbonization remain inconsistent and potentially misleading.

To address this need, **the manganese industry has equipped itself with a robust and standardized methodology**: the “Product Carbon Footprint Guideline” developed by the International Manganese Institute (IMnI)[2].

This guidance establishes a harmonized approach for calculating the cradle-to-gate carbon footprint of manganese alloys such as high-carbon ferromanganese (HC FeMn), medium and low-carbon ferromanganese (MC/LC FeMn), and silicomanganese (SiMn).

The guideline builds upon internationally recognized Life Cycle Assessment (LCA) principles, as set out in ISO 14040 and ISO 14044, while tailoring them specifically to the characteristics of manganese metallurgy. It provides clear rules on system boundaries, emission sources (Scope 1, 2, and 3), data requirements, allocation methods for by-products, and treatment of electricity and reductants.

“Establishing a common carbon footprint calculation approach is an important step forward for the manganese alloys industry. It shows a clear commitment from manganese producers to transparency, CO_2 reduction, and working together toward a lower-impact future.”

Dr. Agnieszka Leopold, HSE & Regulatory Affairs Manager IMnI

To ensure the credibility of these calculations and foster trust among stakeholders, it is important that reported carbon footprint be reviewed by independent third parties.

Such verification enhances the transparency and reliability of greenhouse gas accounting, especially when communicated to external stakeholders.

Ferroglobe

“Having a common accounting framework is essential to enhance reliability and transparency on carbon footprint for the benefit of the whole value chain.”

Cristina Cadarso Escribano, Corporate Sustainability Manager

Low CO_2 manganese alloys play a key role in steel decarbonization

Steel industry: manganese alloys' role in cradle-to-gate carbon footprint

- Standard manganese alloys case

Manganese alloys account for 2% of the steel industry's carbon footprint, based on an average of 1,910 kg of CO_2eq per tonne of steel across Scopes 1, 2, and 3 upstream[(4)]. Considering **scrap-based EAF steel** (Electric Arc Furnace) at 680 kg of CO_2eq per tonne of steel across Scopes 1, 2, and 3 upstream[(4)], manganese alloys account for **6% of this carbon footprint**.

The steel industry is moving toward decarbonization and the development of green steel, also referred to as near-zero steel.

According to the ResponsibleSteel standard [(3)] and its sliding scale, near-zero steel should have a cradle-to-gate carbon footprint (including manganese alloys) of 50 to 400 kg CO_2eq per tonne of crude steel. Manganese alloys, therefore, represent **10% to 78% of these footprints**.

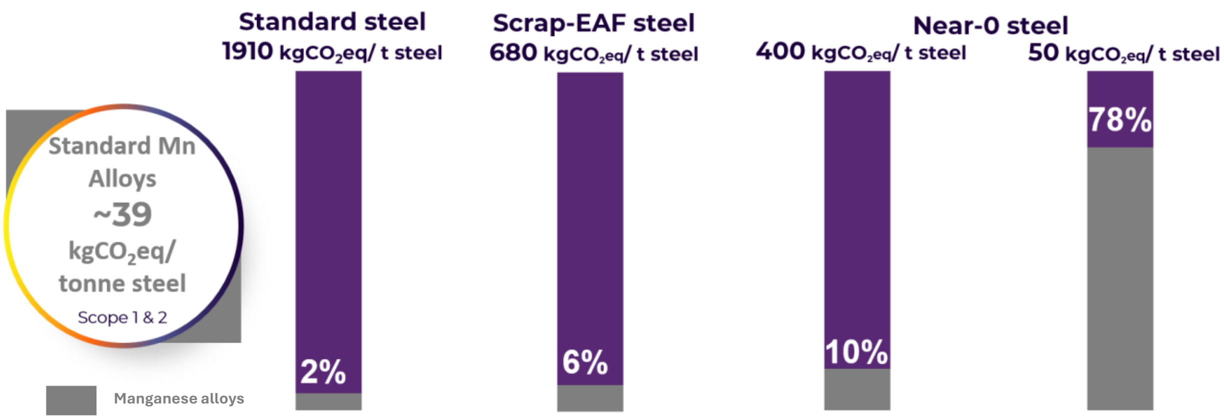


Figure 6. Standard manganese alloys impact in different steel types Source : World Steel Association, Responsible Steel Standard, CRU

" At ResponsibleSteel, we adopt a holistic supply chain approach to decarbonisation and broader social and environmental sustainability outcomes. Ferroalloy suppliers, including manganese alloys, are an integral part of steel's upstream supply chains, and must be collaborators on this journey. "

ResponsibleSteel™

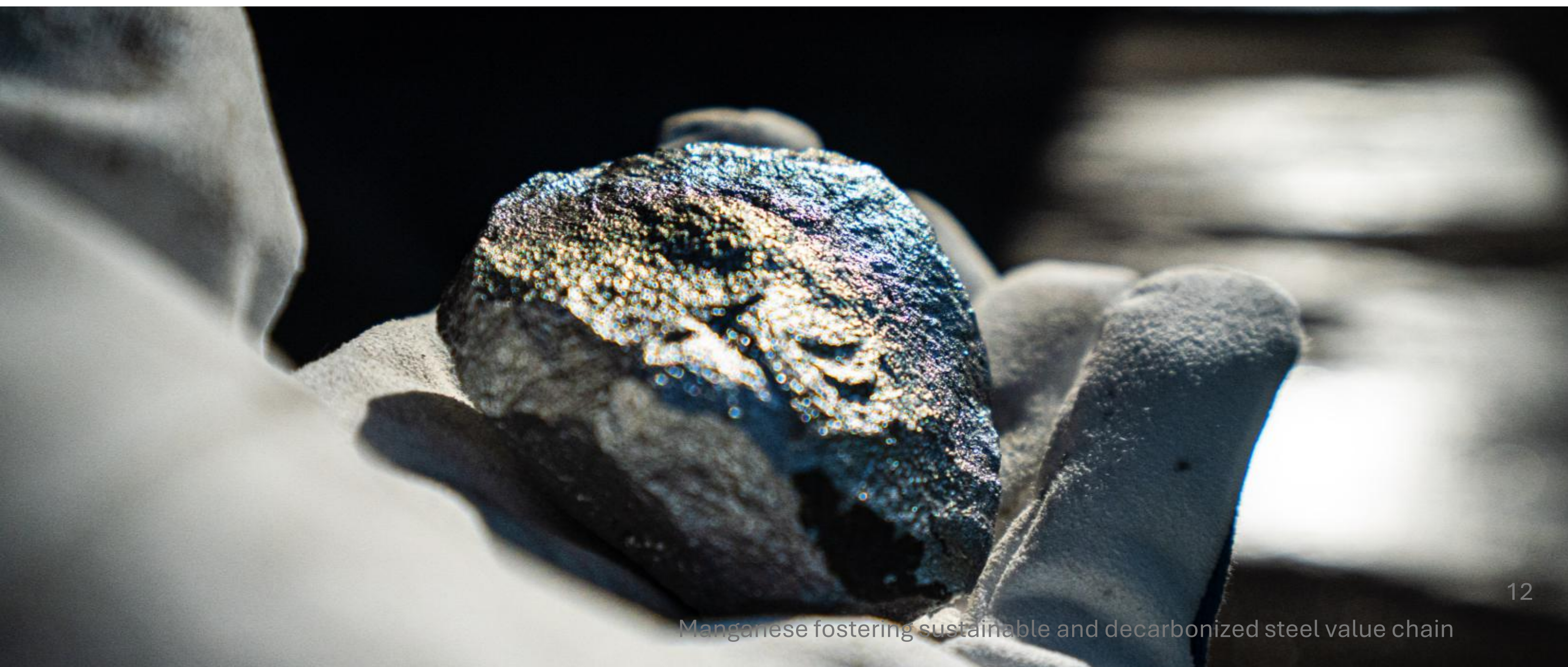
- **Low CO_2 manganese alloys case**

Low CO_2 manganese alloys, with a maximum footprint of 1.9 tonnes CO_2eq per tonne of manganese alloy, contribute 19 kg CO_2eq per tonne of steel (Scope 1, 2), effectively cutting their impact on steel's carbon footprint in half compared to standard manganese alloys.

To achieve near-zero steel as defined by ResponsibleSteel, low CO_2 manganese alloys stand out as a key quick win.

*“SSAB has developed the world's **first fossil free steel**. After eliminating coal, oil, and fossil gas from our own production processes, the next critical step is reducing the carbon footprint of the alloys we use-starting with manganese, the most impactful among them. “*

Johan Anderson, Emission Eliminator SSAB



Manganese alloys impact on the automotive industry

The automotive industry stands as a major steel consumer, with **steel constituting approximately 55% of a vehicle's total weight**. On average, each vehicle incorporates around 900 kg of steel, predominantly in the skeletal body, commonly known as the “body-in-white”. In the last decades, the automotive industry has been faced with an enormous challenge: simultaneously ensuring passenger safety, fuel efficiency, and environmental sustainability. The key to meeting these escalating demands lies in enhancing the strength of automotive sheets. Remarkably, the automotive industry has undergone a revolution, with the tensile strength of steel skyrocketing from below 350 MPa to over 1500 MPa in less than 20 years.

The manganese content in the different steel parts of a vehicle varies according to the specific application and the required properties of each component, **typically ranging from 0.5% to 2.7%.** However, AHSS steel grades, engineered to meet the automotive industry's challenges by offering significantly greater strength while maintaining the high formability essential for manufacturing, demand higher manganese levels, **typically above 1.2%,** making them substantial consumers of manganese. Finally, certain specialized steel grades, such as high Mn TRIP and TWIP steels, demand **exceptionally high manganese contents, ranging from 15% to 30%.** These steels are engineered to deliver superior performance, making manganese an indispensable element in their composition.

Automotive steel grades:

Up to
30%
Mn

The weight of a car is closely linked to its CO_2 emissions. With the emergence of electric vehicles, which are generally heavier due to the battery systems, the demand for lighter and more resilient steel has become increasingly critical.

Manganese plays a key role in **enhancing the strength of automotive steel sheets, enabling the production of lighter and more fuel-efficient vehicles, without compromising safety or performance**. Moreover, as the automotive industry advances in its decarbonization path, there is a growing demand for near-zero steel, and **low CO_2 manganese alloys are therefore key**.

Manganese alloys impact on the rail industry

Rail transport is more environmentally friendly and offers cost savings compared to road transport. It can move large quantities of products efficiently and trains are a safer option for transporting heavy goods. The choice of steel grade for rail applications reflects the diverse requirements of the rail industry, from heavy-duty freight transport to urban passenger services. Each application has its own set of challenges, and the choice of steel must be tailored to meet these specific demands. Wear damage and rolling contact fatigue damage (primarily caused by repeated contact stresses with the wheel) are the two main factors that can accelerate rail degradation and shorten their service life.

The reference parameter for rail steel has shifted from tensile strength to the minimum hardness of the running surface. **To enhance hardness and consequently reduce wear, the levels of alloying elements like manganese have been increased**. Manganese, due to its unique properties, is a key alloying element in rail steel **that enhances strength, hardness, and wear resistance, while also influencing toughness, ductility, and microstructure**. The exact effect of manganese depends on its concentration. Typically, **the manganese content in rail steel grades ranges from 0.70% to 1.70%. It can go way higher for some special parts.**

In recent years, railway lines have faced the challenge of accommodating trains with heavier axle loads and higher speeds, alongside evolving vehicle characteristics. These demanding operating conditions necessitate the development of advanced rail steel grades that offer exceptional durability and performance. Simultaneously, the expansion of infrastructure projects and sustainability initiatives underscores the critical role of manganese. This indispensable material enhances the safety, reliability, and efficiency of railway systems, ensuring they meet the rigorous demands of modern rail transport.

RAILSPONSIBLE

"The rail industry is on the way to sustainable development and decarbonization. We're counting on all suppliers to help us get there, and the Manganese industry is actively involved."

Manganese alloys impact on the wind turbine industry

The implementation of wind turbines is crucial for the global energy transition towards renewable and sustainable sources. Wind energy, generated by the force of the wind, is one of the cleanest ways to produce electricity, significantly contributing to the reduction of greenhouse gas emissions and the mitigation of climate change.

Steel is predominantly used in the tower and substructure of wind turbines, which endure high cyclic loading from wind and normal operation. This repeated stress can cause fatigue damage in metals. In offshore environments, additional forces from waves and sea currents further challenge the structural integrity. The steel grades used in these components, known as structural steels, must exhibit high mechanical properties, possess good welding aptitude and perform well under fatigue stresses.

Manganese plays a crucial role in the steel grades used in wind turbines. It is essential for **enhancing the resistance of steel, enabling the use of thinner sheets and thereby reducing the overall weight of wind turbine towers.** Manganese also **improves the wear resistance of steel**, which is vital for the longevity and reliability of wind turbine components, especially in harsh environmental conditions. By adjusting the manganese content, manufacturers can tailor the properties of steel to meet the specific demands of each wind turbine component, ensuring optimal performance and longevity. The manganese content in the steel used for various parts of a wind turbine can vary widely, **typically ranging from 0.50% to 1.70%.**

Wind turbine steel grades:

Up to
1.70%
Mn

As the wind energy market, especially offshore, expands rapidly, the demand for green steel is set to soar. Offshore wind turbines, each potentially using up to 3,500 tons of steel, highlight the immense transformative impact of green steel. Consequently, the rising demand for near-zero steel can dramatically **accelerate the adoption of low CO_2 manganese alloys**, driving a significant shift towards more sustainable manufacturing practices.

Manganese alloy production can be decarbonized

Achieving Net-Zero emissions requires a multi-faceted approach, leveraging technological advancements, alternative raw materials, and process optimization.

SCOPE 1

Achieving Net-Zero Scope 1 emissions by 2035: Ferroalloy producers can reach net-zero fossil CO_2 emissions using existing production facilities and maintaining current product specifications. This goal relies on two primary strategies:

Biocarbon substitution: Replacing fossil-based reductants with sustainable biogenic reductants (biocarbon) eliminates emissions from fossil origin. To ensure sustainability and avoid environmental harm, biomass used for biocarbon production must comply with stringent sustainability criteria. While complete substitution is not yet feasible due to metallurgical constraints and limited availability of suitable biocarbon, it remains a key decarbonization lever.

Eramet has a program for implementing biocarbon in all its Mn alloys smelters.

grupo maringá

"At Maringá Ferro-Liga, bioreductants are an integral part of our production process. We currently avoid 46% of direct carbon emissions (Scope 1) compared to fossil-based reductants, equivalent to 64,500 tons of CO_2 avoided annually. Ongoing projects will further reduce emissions by 25,000 tons annually. This initiative reflects our commitment to innovation and sustainability."

Carbon Capture and Storage (CCS) or Carbon Capture, Utilization, and Storage (CCUS): Capturing and permanently storing CO_2 from process off-gases (CCS) or adding an additional process step to utilize CO_2 as a raw material in the production of chemicals, fuels, and other products before storing the remaining CO_2 (CCUS), can complete the transition to net-zero emissions. When CO_2 is captured and securely stored, it is not emitted into the atmosphere, resulting in zero increase in atmospheric CO_2 levels. If more than just fossil CO_2 is captured, this can lead to net-negative emissions (or "carbon removals," namely the capture of biogenic CO_2). However, due to technological limitations and dispersed sources of flue gases, a typical smelter can capture around **75% of total CO_2 emissions**.

The figure below illustrates the impact of biocarbon, CCS, and their combined application on CO_2 emissions.

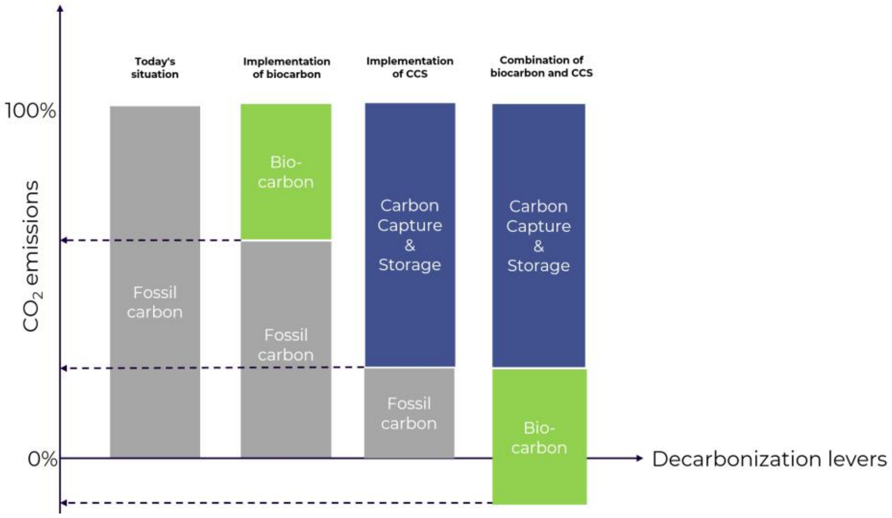


Figure 7. Typical qualitative impact from decarbonization levers

Achieving Net-Zero Scope 1 emissions by 2035 can also rely on efficiency improvements, circularity and long-term disruptive technologies:

Efficiency improvements and circularity (Scope 1 Reduction, 5% potential): Material contributions to decarbonization can be achieved through enhanced resource efficiency (both energy and carbon) and increased circularity.

Long-term disruptive technologies (Scope 1 Reduction, 95% potential): Beyond 2035, the industry is exploring innovative technologies with relatively low Technology Readiness Levels (TRLs). These include:

- **Carbon Capture and Looping (CCL)**: Recycling furnace off-gases to produce a reductant for in-house production. Eramet is a partner in the EU project MECALO to develop CCL for the ferroalloy industry, in cooperation with Elkem.
- **Green hydrogen reduction**: Using hydrogen for pre-reduction or complete reduction in plasma furnaces.
- **Molten oxide electrolysis**: Electrically reducing oxides directly.
- **Metallothermic reduction**: Exploring alternative reduction reactions.

Except for CCL, these technologies will require new production processes. Their future adoption will depend on further technological advancements and economic feasibility.

SCOPE 2

Energy Transition (Scope 2 Reduction, 30-50% potential): Switching from fossil fuel-based electricity to fossil-free sources such as hydro, wind, and solar can significantly reduce indirect emissions. Replacing coal-based electricity with renewables can cut emissions by up to 1 tonne of CO_2 per tonne of ferroalloy [(1)].

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Manganese helps build a sustainable value chain beyond decarbonization

Context: CSR transparency, a nice to have today, a must have for the future

Regulations across all EU sectors have emerged, emphasizing transparency in the supply chain. These regulations convey a clear message: transparency will be required for future business as a license to sell and operate.

One notable example is the emergence of Digital Product Passports (DPPs). In short, a DPP acts as a product's identity card, providing key CSR KPIs to enable informed purchasing decisions for customers. DPPs are central to several regulations, such as:

- **EU Digital Product Passport Regulation**: DPP will be mandatory by February 2027 for all industrial and electric vehicle batteries.
- **Eco-design for Sustainable Product Regulation (ESPR)**: It will require all goods entering the EU to have a DPP. Starting in 2027 for batteries, this requirement will progressively extend to textiles, construction materials, steel, and more.
- **New Construction Products Regulation** (CPR): Applicable since March 2022 to construction products. The new CPR introduces the possibility for manufacturers to provide a declaration of conformity and include information via electronic devices (DPP).

EU regulation is also reinforcing supply chain due diligence requirements:

- **The EU Critical Raw Materials Act (effective May 2024)**: Recognizes the importance of mining in the EU and aims to secure sustainable supply chains. It includes traceability, monitoring, and auditing of strategic raw materials.
- **The Corporate Sustainability Due Diligence Directive (CSDDD)**: Ensures that companies operating in the EU conduct thorough due diligence on their supply chains.

All these regulations aim to promote responsible business conduct where transparency is essential. Responsible business conduct means ensuring that the activities of businesses and investors align with the needs of society, both today and in the future.

"Responsible business conduct drives us to continuously enhance our daily operations and crucially, dismantle silos between stakeholders. Our interactions with clients on CSR and decarbonization have reached unprecedented levels."

Paul Desportes, Senior Vice-President Commercial eramet

Concrete actions possible for a responsible supply chain

Standards such as IRMA, regarded as one of the most stringent CSR frameworks for mining activities, are part of the solution to reassure stakeholders. Mercedes-Benz recognized IRMA as the strongest voluntary initiative[6] compared to eight other standards. There is no better proof than an on-site audit by a third party to objectively assess human rights, social, and environmental impacts.

IRMA is already supporting miners on their sustainability journey by building value chain ecosystems. The standard brings together the needs of miners, NGOs, companies purchasing mined materials, affected communities, organized labor, and financial institutions.

Eramet has committed to audit all its mines against the IRMA standard by 2027.

Traceability, used as a tool to enable more informed purchasing decisions, can also be part of the solution. Collecting data is time-consuming for Responsible Purchasing departments, so traceability tools can help. These tools, often online platforms, automatically collect and organize data based on specific needs. They can gather information such as supplier certifications, product CO_2 intensity, physical flow mapping, and adapt to different industries.

In short, they answer questions like: *Under what conditions was the product produced? By whom? Where? What are the environmental and social impacts?*

When optimized, these tools can push relevant data downstream in the value chain, enhancing transparency.

As an example, since 2025 Eramet has deployed its traceability platform across all eraLow production sites. Every order is backed by a Digital Product Passport, giving Eramet's customers complete visibility into their purchases. The platform aims to be rolled out across all group sites.

"Traceability solutions are designed to facilitate data exchange between actors in the same value chain in order to create the visibility needed for due diligence and compliance with EU regulations."

Joseph Azar, Chief Operations Officer TILKAL

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Challenges to move forward

Stringent regulations are being deployed: ESPR, EU Critical Raw Materials Act, CSDDD, CBAM, EU ETS and EU Taxonomy.

At the same time, stakeholders are reinforcing their ESG expectations, and end-customers are becoming more demanding, requiring products to demonstrate strong CSR performance.

While end-market players dealing directly with customers, such as car manufacturers, communicate their sustainability efforts and can reflect this in car pricing, this value creation does not yet appear to have cascaded throughout their supply chain. The only exception could be low-CO_2 steel production, which is starting to command some premiums.

Some regulations include **scope exclusions**:

- **The EU Digital Product Passport regulation** requires operators to disclose the origin of nickel, lithium, cobalt, and graphite, but not manganese.

- **The Sectoral Decarbonization Approach (SDA) for steel by the SBTi** excludes ferroalloy production emissions from its core boundary, even though high-alloy steel producers are recommended to set a separate Scope 3 target covering these emissions. This contradicts other standards that clearly include ferroalloys, such as ResponsibleSteel, the Steel Climate Standard, LESS, or methodologies from the World Steel Association, the American Iron and Steel Institute, and the Net-Zero Steel Pathway Methodology Project.

The impact of these exclusions has already materialized. Some customers explain that manganese is not their priority and that they focus first on EU-mandated materials.

Furthermore, the role of manganese is sometimes undervalued. Yet, the conditions under which all earth mineral resources are extracted deserve equal attention, whether nickel, graphite, or manganese, since the reputational risks linked to social and environmental impacts are comparable.

Additionally, while some industries, such as aluminum, have organized themselves to propose a **decarbonization pathway**, this is not yet the case for manganese. For example, the International Aluminium Institute has published two reports: Aluminium Carbon Footprint Methodology and Aluminium Sector Greenhouse Gas Pathways to 2050.

These reports are essential because carbon footprint rules allow customers to compare product intensity, and clear **industry pathways** can help finance decarbonization projects.

Overall, these industry trends are positive, fostering responsible business conduct practices. However, deploying a multi-year assessment scheme like IRMA, investing in CCS, developing R&D to reduce ESG impacts, or implementing traceability tools is capital-intensive.

Therefore, securing funding and financing is crucial, and this is only possible with robust business cases.

Today, some mining actors facing global competition and embarking on a sustainability journey are being publicly recognized for their efforts. **However, this recognition does not always translate into economic benefits**.

Key recommendations

This paper aims to explain the role of manganese in our daily lives and its place in various value chains. Manganese alloys are essential for steelmaking and can help address current challenges by contributing to steel decarbonization. Solutions to support manganese alloy producers in decarbonizing were explored, along with ways to ensure responsible and transparent production from the mine. Today, **a low CO_2 manganese alloy offer is already available as a quick win for steelmakers**. Building a sustainable supply chain is achievable with effort and financial investment.

Recommendations to tackle challenges in the manganese value chain:

→ **Ensure deployment of the IMnI carbon footprint standard**: The IMnI published a robust standard on manganese carbon footprint in November 2024. Effective implementation among industry players will clarify offerings for customers and markets.

→ **Build a decarbonization pathway for manganese**: Developing a clear roadmap with all stakeholders involved seems the logical next step. This could be done within the IMnI framework, similar to the work of the International Aluminium Institute.

→ **Increase visibility of low CO_2 manganese alloys**: A low-carbon offer exists but is not well-promoted. Raising awareness about manganese's role in value chains and highlighting positive impacts and industry efforts toward decarbonization and responsible practices is crucial.

→ **Set minimum thresholds for responsible sourcing**: Some actors already apply criteria such as IRMA engagement and low CO_2 products. To ensure responsible materials represent a significant share of purchases, minimum thresholds should be established for each industry. This requires strong support from downstream customers and ESG standards.

→ **Reinforce CSR subsidies and funding mechanisms**: Continued support from programs like the EU Innovation Fund is vital to maintain competitiveness. These funds help companies de-risk projects by reducing upfront capital requirements and improving financial indicators.

→ **Stimulate demand for green products (Draghi Report recommendation [7])**: Promote transparency by defining EU standards for measuring and communicating Product Carbon Footprints (PCFs), including labeling ; introduce standardized low-carbon and environmental sustainability criteria for public procurement.

Future challenge: Maintaining CSR investments and onboarding more players. Success requires strong customer demand for low-impact products, robust standards, ideally country-level regulations, and a future where costs and value are shared across the entire value chain.

In an ideal world, sustainability in operations will be the norm, not a differentiating factor. We are not there yet, and incentives are needed to fairly reward responsible actors. A positive dynamic has started, but continued pressure from end-market industries is essential.

Sources

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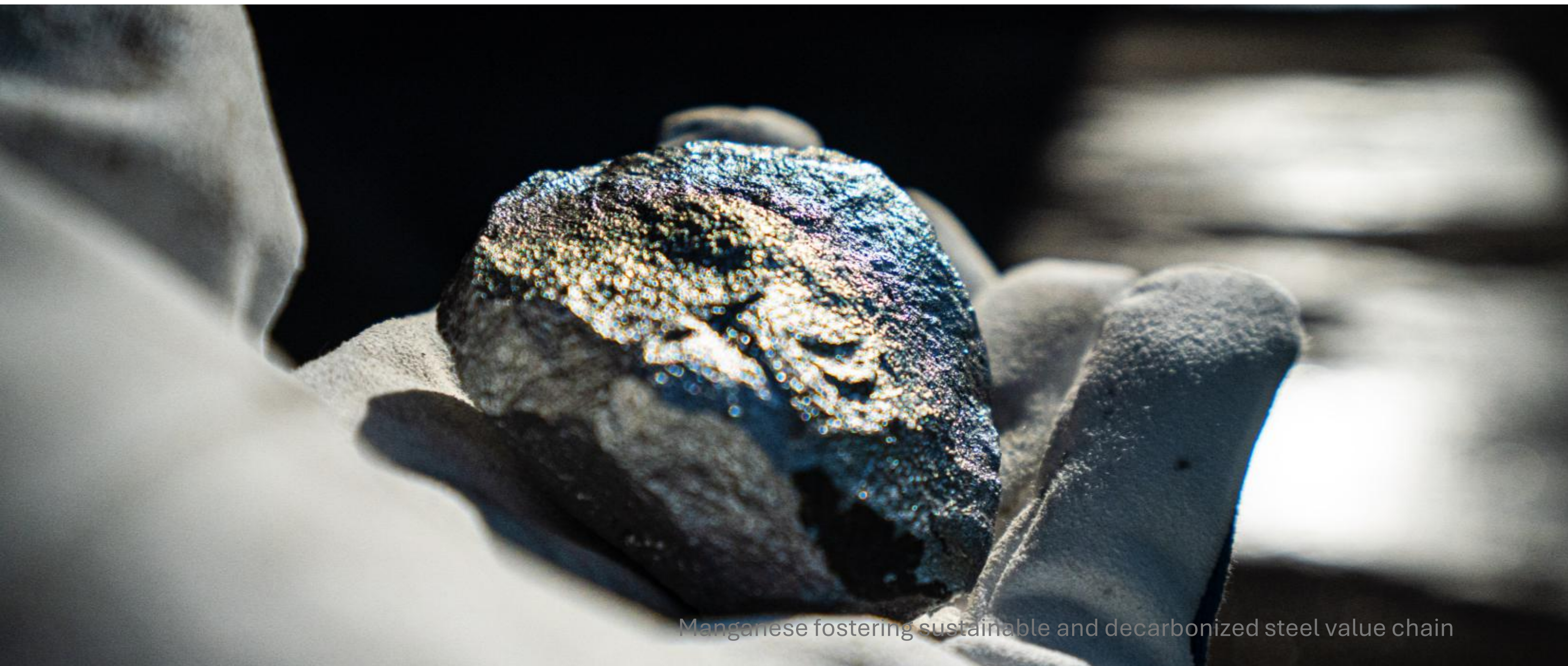

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June 2, 2026