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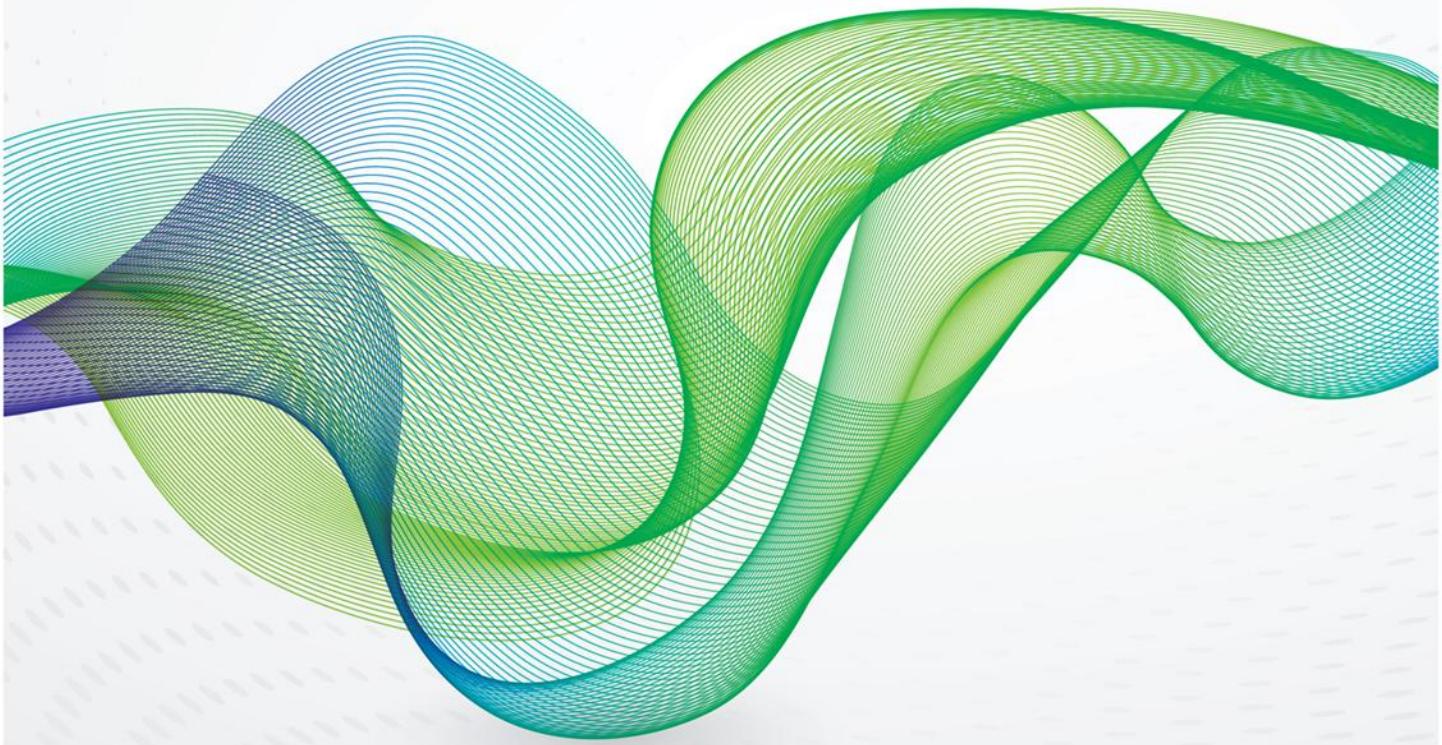
50 Shades of Green: Unpacking What Green Means for Steel



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Nomenclature

BF-BOF	Blast Furnace-Basic Oxygen Furnace
CBAM	Carbon Border Adjustment Mechanism
CISA	China Iron and Steel Association
CLC	Construction Leadership Council
CO2	Carbon Dioxide
CO2eq	Carbon Dioxide Equivalent
CSRD	Corporate Sustainability Reporting Directive
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EPD	Environmental Product Declaration
ETS	Emissions Trading System
IEA	International Energy Agency
FMC	First Movers Coalition
GSCC	Global Steel Climate Council
GWP	Global Warming Potential
H2	Hydrogen gas
LCA	Lifecycle Assessment
LCESEM	Low Carbon Emissions Steel Evaluation Method
LESS	Low Emissions Steel Standard
PCF	Product Carbon Footprint
SBTi	Science-based Targets Initiative
TfS	Tonne of Finished Steel

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1. Introduction

Steelmaking represents one of the most carbon-intensive industries – second only to cement – and is responsible for 8% of global CO_2 emissions[1]. Decarbonising such an industry is thus key to decarbonise society as a whole and represents a critical component of the energy transition. While several breakthrough low-carbon technologies exist to reduce emissions from different steelmaking routes – notably hydrogen reduction, carbon capture and storage, and direct electrolysis, their deployment has so far been hampered by a few factors, particularly high costs[2].

Recent studies[3,4,5] suggest that the creation of a market for premium, low-carbon emission steel products could serve as a means of creating a revenue stream to accelerate the implementation of those technologies. Indeed, green product development had been for long prescribed as a market-driven mechanism to boost emissions reduction from the largest carbon-intensive sectors, such as steel. This naturally raises further questions: whether there is enough demand for the premium green product (and where it exists), what is the level of the green premium, what consumer claims can be made through the product's purchase, and what policies could support the development of such a market.

At the heart of all the above is the need for a common understanding of what the green product entails. The term 'green steel' has been widely and loosely used by market participants and observers, yet no widely accepted definition or standard has emerged so far, with a myriad of voluntary, corporate, or regional definitions risking confusing end-users and hampering policy support. *Unpacking what greenness means in the steel industry context is the central issue that this paper aims to address*.

In fact, the term 'green steel' has been in use for over a decade, and since around 2019 its usage by market participants, policy makers, and other organisations has increased significantly[6]. Broadly speaking, the term refers to steel with lower embedded carbon footprint: 'lower', of course, is a relative concept; in this case, it is relative to steel produced via conventional methods[7] (Figure 1).

That said, there is wide dispersion in carbon emission intensities associated with different conventional steelmaking routes, ranging from 0.70 tonne of CO_2 per tonne of crude steel in the scrap-EAF route (20% of global production in 2023), to 1.43 tCO_2/t in the DRI-EAF route (8% share), rising to 2.32 tCO_2/t in the most common BF-BOF route (72% share), according to industry averages reported by the World Steel Association based on its emissions data collection methodology (which includes all three scopes)[8]. This complicates efforts to compare to a relative benchmark and thus for a common understanding of what should be considered as green.

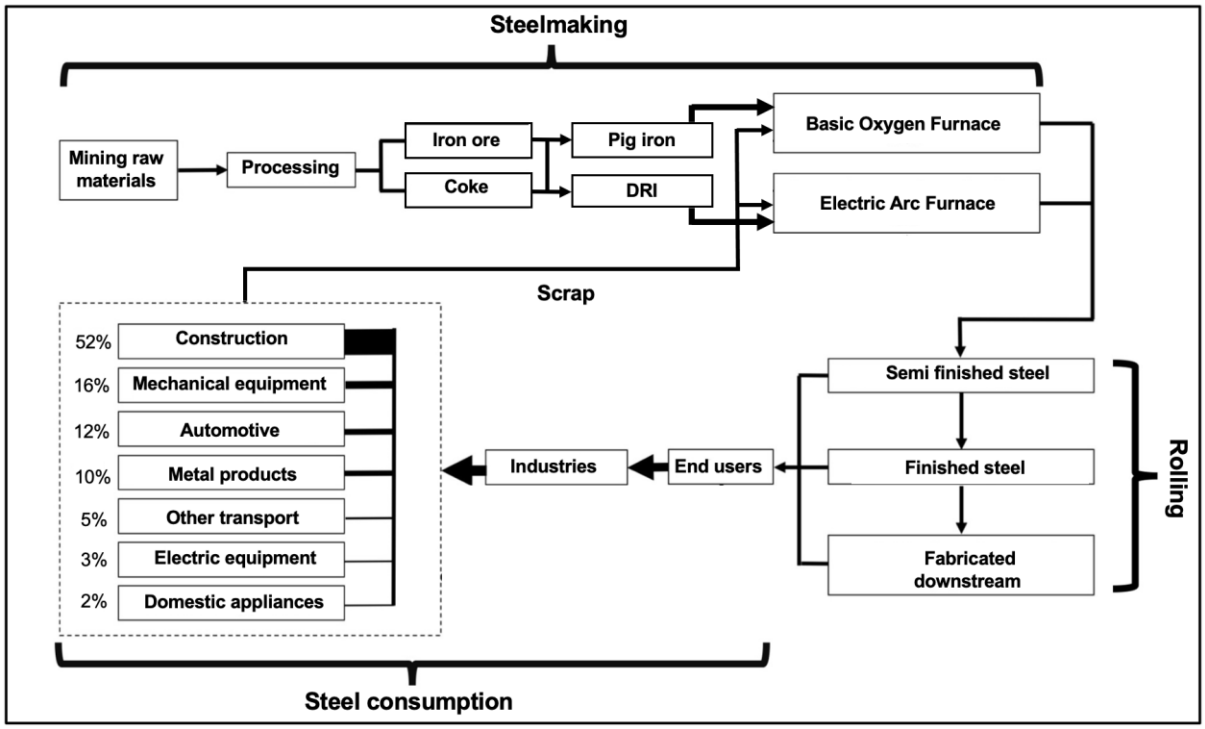
Even for individual conventional production routes, there is a wide range of associated carbon intensities, depending on level of efficiencies achieved, plant age, and fuels and reductants used, amongst other factors, as well as different accounting methodologies and boundaries included. For

[1] Or 10% if indirect emissions from electricity generation are included. Source: IEA (2023). Emissions measurement and data collection for a net zero steel industry.
[2] Muslemani, H., Craen, S., Butterworth, P., Duma, D., & Lambert, M. (2024). *Ironing out the way for green steel financing a green hydrogen-based: Ironmaking plant in an emerging market* (No. 10). OIES Paper: CM10, Oxford, UK.
[3] https://www.renewable-ei.org/pdfdownload/activities/S3-1_JuliaMetz_AgoraIndustry_250305_EN.pdf
[4] Muslemani, H., Liang, X., Kaesehage, K., Ascui, F., & Wilson, J. (2021). Opportunities and challenges for decarbonising steel production by creating markets for 'green steel' products. *Journal of Cleaner Production*, *315*, 128127.
[5] https://rmi.org/wp-content/uploads/2019/09/green-steel-insight-brief.pdf
[6] The term 'Greensteel' also refers to a strategic plan adopted by the UK steel manufacturer Liberty Steel which aims at lowering proportions of exported scrap and instead promoting efforts for national scrap recycling.
[7] Although generally used to refer to lower-carbon emissions steel, green steel is sometimes used to refer to a much wider array of sustainability attributes beyond carbon footprint, such as the product's impacts on biodiversity, labour rights, human rights, water pollution, health & safety, etc. This usage occurs interchangeably with terms like 'sustainable' steel or 'responsible' steel. Regardless of its merit, this wider-meaning usage is, in the authors' understanding, much less frequent and further complicates comparability. In this paper, we focus the discussion on green steel as associated with lower-carbon emissions only.
[8] World Steel's data collection methodology primarily accounts for CO_2 emissions (i.e. not other greenhouse gases). It includes all scopes (1, 2, and some scope 3) but excludes certain Scope 3 emissions such as those from mining, scrap procurement, and transportation activities. Data and methodology can be found in https://worldsteel.org/wider-sustainability/sustainability-indicators-2024-report/

example, looking at steel produced via the BF-BOF route (where the majority of emissions in conventional steel making comes from, at 86.5%), Canada saw an average of 1.6 tCO_2/t of crude steel in 2019, whereas in India the intensity was nearly double, at 3.0 tCO_2/t[9].

Moreover, due to the high recyclability rate of steel as a material, many argue its production should be considered as a global system rather than a one-way supply chain[10], otherwise efforts to produce the greener product may lead to perverse outcomes and distort market competition[11] (i.e. put recyclers at an advantage when meeting a lower carbon intensity threshold compared to producers relying primarily on raw iron ore).

Figure 1: Schematic diagram of conventional steelmaking routes and supply chain[12]



Note: Adapted from Muslemani et al. (2021)

What's more, while 'green steel' has been by far the term most widely adopted by industry players, there is a plethora of related terms used to broadly refer to the same concept, albeit with potential important nuances[13]. To name a few, '*low-carbon'*[14], '*low-carbon emission steel'*[15], '*low embodied carbon'*[16],

[9] Hasanbeigi, A. (2022). Steel Climate Impact - An International Benchmarking of Energy and CO2 Intensities. Global Efficiency Intelligence. Florida, United States.
[10] Broadbent, C., (2016). Steel's recyclability: demonstrating the benefits of recycling steel to achieve a circular economy. Int. J. Life Cycle Assess. 21 (11), 1658–1665.
[11] ibid
[12] Percentages of steel consumption by sector sourced from World Steel Association (2024). Steel use by sector. https://worldsteel.org/data/steel-use-by-sector/
[13] ibid
[14] Here, it is key to make a definitional distinction between 1) steel products which have lower GHG or carbon footprints (due to different production processes), and 2) 'low-carbon steel' products which are an existing type of product with minimal carbon content (0.04–0.30%) in the final products themselves.
[15] https://corporate.arcelormittal.com/climate-action/low-carbon-emissions-steel-standard
[16] https://www.kingspan.com/gb/en/campaigns/lower-embodied-carbon-steel/

'*carbon-lean*'[17], '*net-zero*'[18], '*near-zero*' and '*low-emissions*'[19], '*fossil-free*'[20], '*CO_2-neutral*'[21] and '*clean*'[22] steel have all been widely used but differently and/or not always precisely defined. While some steel suppliers explicitly market their products as 'green', others avoid usage of the term altogether and instead offer products using one of the other terms – as will be presented later in this article – or under proprietary brand names and trademarks.

Ultimately, the relevance of terminology, particularly in the aftermath of the 2015 Paris Agreement, is linked to the purpose behind its usage: the need for society to decarbonise production of hard—to-abate sectors such as steel which is a key material, integral to most aspects of day-to-day life (from the cars we drive to the buildings we live in). As noted earlier, and as with any carbon-intensive industry, mobilising the vast investments – both private and public – required to decarbonise would largely benefit from a common understanding of key terms adopted when referring to the final product, as is the case for green energies or organic foods.

In light of increasing efforts to decarbonise steelmaking, this paper aims to shed light on the current state of the green steel market with regards to observed definitions, corporate branding, industry standards, and emerging regulations, to subsequently make recommendations to foster investment, production capacity growth and market adoption. We do this first through a review of the literature, followed by analysis of data collected through primary interviews with green steel buyers and other key market stakeholders.

2. Inherent challenges in defining green steel

An initial challenge to defining greenness for steel is that steel is **not one single, homogenised product** but comes in thousands of grades and types, differing in shape, chemical composition, and physical dimensions. For instance, steel bars for concrete reinforcement (or rebars) are thick and round (~12m-long) bars of steel typically containing basic chemistry without the addition of metal alloys and are produced after one stage or rolling. In contrast, automotive hot-dipped galvanised steel coils are typically ultra-thin flat sheets of steel (spanning hundreds of meters of length, before coiling) containing a metallic coating for corrosion resistance and various additional alloying elements for extra strength and flexibility, produced after several stages of rolling.

Because of these intrinsic differences and because – ultimately – they are *not* the same product, the carbon footprint associated with a rebar can be expected to vary widely from that of an exposed automotive panel made from hot-dipped galvanised steel. Case in point, a rebar marketed as a low carbon steel product by a leading global steel supplier comes with a carbon footprint of 0.3 tCO_2 per tonne of finished steel (tfs)[23], whereas galvanised sheet from the same supplier is nearly three times as emission-intensive, at 0.877 tCO_2/tfs, even though in both cases the products are made via the EAF route, using at least 75% scrap[24].

A second challenge is that conventional methods of producing steel differ substantially in their average **carbon footprints** per tonne of steel produced (Figure 1). Even within a given method, wide variation in emission intensities exist, as noted earlier.

An additional challenge stems from how steel scrap which is recycled into the steel production process should be treated with regards to its emissions footprint. The amount of scrap used is a key determinant

[17] Organisation of Economic Co-operation and Development (OECD) (2010). Challenges and opportunities for the steel industry in moving towards green growth. In: Green Growth Workshop, March 2010, Seoul, South Korea
[18] Energy Transitions Commission (2022). https://www.energy-transitions.org/publications/making-net-zero-steel-possible/
[19] International Energy Agency (IEA) (2024): https://www.iea.org/reports/definitions-for-near-zero-and-low-emissions-steel-and-cement-and-underlying-emissions-measurement-methodologies
[20] HYBRIT, 2017. Summary of Findings from HYBRIT Pre-feasibility Study 2016-2017.
[21] Eurofer (2019). Low Carbon Roadmap – Pathways to a CO_2-Neutral European Steel Industry.
[22] In contrast to the noted range of terms, the term 'clean steel' is used to exclusively refer to high-purity steel products.
[23] i.e. including emissions at the rolling stage, after crude steelmaking.
[24] https://europe.arcelormittal.com/sustainability/xcarb/RRP/recycled-and-renewably-produced-flat-long-epd

of the emissions intensity of a steel product, regardless of production route: in some cases, for certain steel products, up to 100% of steel scrap can be used as input material; that is, no primary iron intermediate is used (such iron intermediates are typically made through the carbon-intensive reduction of iron ore).

A fourth challenge relates to differences in **carbon accounting methodologies**: for the same type of steel, produced via the same method, two steelmakers may report emissions intensities using different accounting approaches. Specifically, methodologies differ in setting of site boundaries (e.g. whether downstream rolling processes are included), in greenhouse gases coverage (whether accounting for only CO_2 or other GHGs), and in the treatment of the re-injection of process gases back into the production process, to name a few.

3. Examples of green steel terminology use

All of the above create an issue of a lack of (or, at best, limited) comparability between what is currently referred to as green steel.

Companies currently have no limitation, in any jurisdiction, on how they can use the term green steel for claims they make on products they produce, sell and use – although this is fast evolving as we illustrate in the following sections[25]. Currently, any steelmaker can claim to be selling green steel, whatever the carbon footprint of their product (except in India, as we discuss later) – whether such claims pass muster with consumers is another matter.

Table 1 presents eight examples of how terms related to green steel have been in use in the market. All of these are examples of products that have already been produced in operational plants (only one in pilot stage) and sold in the market. All the examples have been physically produced, i.e. are not based on emissions reduction certificates[26]. In various cases, information on the emissions accounting methodology, boundaries and scopes used is not easily available.

In addition to these examples, various companies are currently developing hydrogen-based green steel projects, some of which have successfully pre-sold part of their expected production. For example, in Sweden, Stegra (formerly H2GreenSteel) has pre-sold over half of their planned production to customers, achieving a 20-30% green steel premium over conventional steel[27,28]. In Spain, Hydnum Steel has announced agreements to supply green steel to at least two customers[29]. These examples are not included in the table as not yet operational, with no actual emissions intensity information yet available, but are good indications of the fast-moving nature of the evolution of the market.

Although various other instances of use exist across products and regions, the examples in the table above already highlight the nuances and complexities in comparability between green steel and related terms in the market: the varied terminology, the wide range in intensities and scopes, the lack of information on emissions accounting methodologies and boundaries, etc.

[25] The EU's proposed Green Claims Initiative which aims to combat greenwashing and ensure accurate environmental claims is expected to have significant implications for the steel industry.
[26] Since 2020, paper certificates representing emissions savings from specific production sites, paired with the sale of conventional steel products made via the BF-BOF route, have also been traded in the market as green steel certificates, although the authors understand their use (and value) has reduced in recent years.
[27] https://www.reuters.com/business/finance/swedens-h2-green-steel-raises-16-bln-private-placement-2023-09-07/
[28] For assessments of current market green steel premia levels across various regions (e.g. Europe, USA, Asia) and products (e.g. HRC, rebar), see Fastmarkets' green steel 'differential' and 'base price' indices, available in https://www.fastmarkets.com/insights/key-topics/low-carbon-steel/.
[29] https://hydnumsteel.com/press/agreement-between-hydnum-steel-and-thyssenkrupp-materials-processing-to-promote-clean-steel-in-europe/ and https://hydnumsteel.com/prensa/hydnum-steel-and-gonvarri-industries-sign-a-strategic-agreement/

Table 1: Examples of green steel related terminology in the market[30]

Product	Since	Description	Emissions Intensity	Other Info
'Fossil-free steel', by SSAB/Hybrit (Sweden)	2021	steel produced via the **DRI-EAF** route using iron ore and **hydrogen**.	**less than 0.05** tCO_2eq / t of steel at scopes 1 and 2	Pilot production, used in prototypes in customers such as Volvo Group and watch maker TRIWA.
'Carbon neutral steel', by AVB (Brazil)	2021	steel produced in a **small-scale blast furnace**, using iron ore and eucalyptus **charcoal** (instead of metallurgical coal).	**0.06** tCO_2eq / t of crude steel in 2019; and **negative 0.40** tCO_2eq / t of crude steel in 2020.	AVB claimed to have become the first carbon neutral steel producer globally.
"Recycled and renewably produced steel", by ArcelorMittal (Europe)	2022	steel produced via the **EAF** route using 100% renewable electricity and a minimum of 75% recycled steel scrap.	**0.30** tCO_2eq / t of rolled steel (rebar), **0.33** (sections), **0.60** (hot-rolled coils), to **1.03** (organic coated steel), as per EPD.	72% reduction in CO_2eq emissions compared to conventional steel (calculated for steel pipes).
'Zero steel', by SSAB (Sweden)	2023	steel produced via the **EAF** route with a high proportion of recycled steel scrap and fossil-free energy.	**0.470** tCO_2eq / t of rolled steel (hot-rolled coils), to **1.030** (organic coated steel), on cradle-to-gate basis (covering upstream raw materials), as per EPD.	Used by customers including Volvo Group. SSAB also states that, in its own operations (incl. transportation), its 'Zero Steel' has **less than 0.05** tCO_2eq / t of steel at scopes 1 and 2.
"Certified carbon neutral steel", by Acciaieria Arvedi (Italy)	2023	steel produced via the **EAF** route using 100% renewable electricity and a high proportion of recycled steel scrap.	**0.924** tCO_2eq / t of rolled steel (hot-rolled coils), to **1.290** (organic coated steel), as per EPD.	Arvedi also states that, at site level, it achieves **0.133** tCO_2eq/t of steel at scopes 1 and 2, offset to zero via the purchase of voluntary carbon credits (VCUs).
"Green Steel" sections, by SWT (Germany)	2023	steel produced via the **EAF** route using 100% renewable electricity and a high proportion of recycled steel scrap.	**0.335** tCO_2eq / t of rolled steel (sections), at scopes 1 and 2.	Green steel products marketed in contrast with conventional "SWT steels" for all purposes.
"Green Steel sheet piles", or "Sustainable Sheet Piles", by Emsteel (UAE)	2023	steel produced via the **DRI-EAF** route using iron ore and **natural gas**.	**0.350** tCO_2eq / t of steel produced, "40% less carbon than that generated by the processes of other manufacturers".	A 'Green Steel Certificate' is provided, confirming the GHG emissions associated with the mass of products sold.
'Net zero steel' billets, by Arabian Gulf Steel Industries (UAE)	2024	steel produced in an **induction furnace** using 100% recycled steel scrap.	**0.007** tCO_2eq / t of crude steel at scope 1, offset to net zero via the use of carbon credits (VCUs).	AGSI also claims to have become the first steel plant in the world to achieve Carbon Neutrality.

[30] When the table indicates that renewable electricity is used in the steel production process, that may be from dedicated electricity supply, PPAs, or via the use of renewable electricity certificates or equivalent; often, information on the precise nature of the renewable electricity used is not easily available.

4. Role of standards for green steel

Global standards

At global level, there is currently no standard specifically designed to determine what constitutes green steel, whether mandatory or voluntary. That is, no global organisation (such as the WTO, the World Steel Association, or others) requires, imposes, or recommends that, to be called green steel, a steel product must meet certain criteria.

This distinguishes steelmaking from other industries[31], where specific standards define, for instance, what green electricity[32], green hydrogen, or green ammonia are. In the case of hydrogen, the Green Hydrogen Standard, established by the Green Hydrogen Organisation, stipulates that '*green hydrogen is that produced through the electrolysis of water with 100% or near 100% renewable energy with close to zero greenhouse gas emissions (<=1 kg CO_2eq per kg H_2 taken as an average over a 12-month period)*'[33], whilst also requiring other environmental, social and governance consequences of green hydrogen production to be considered.

Voluntary standards

Currently, the two main global voluntary sustainability standards in steel are arguably ReponsibleSteel's 'International Production Standard' and the Global Steel Climate Council (GSCC)'s 'Steel Climate Standard'[34]. Neither seek to explicitly define what is or is not green steel; however, they do – amongst their varied purposes – specify thresholds for classifications of steel according to the emissions intensity of the products made in the steelmaking sites under their evaluation, thus providing useful inputs to the discussion around green steel.

Two other relevant standards are the 'Low Emissions Steel Standard' (LESS) originally proposed by German Steel Association, and the 'Low Carbon Emissions Steel Evaluation Method' (LCESEM) launched by China Iron and Steel Association, both of which focusing exclusively on the carbon emissions intensity performance of steel products, albeit also falling short of using or explicitly defining the term green steel. Despite their voluntary nature, both standards are likely to inform upcoming regulation on green products in the European Union and China, respectively, and to see increasing adoption in their regions of origin.

ReponsibleSteel's 'International Production Standard'

ResponsibleSteel is a multistakeholder standard-setting body founded in 2015 with over 160 members to date, including steelmakers such as BlueScope Steel, ArcelorMittal, Tata Steel, US Steel and Liberty Steel Group, as well as steel end-users, raw materials suppliers, industry associations, civil society and others. Its stated purpose is "to maximise steel's contribution to a sustainable society", and its mission is "to be a driving force in the socially and environmentally responsible production of net-zero steel[35], globally". One of its aims is to drive "positive change through the recognition and use of responsible steel".

Initially launched in 2022, ResponsibleSteel's 'International Production Standard' is arguably the most encompassing voluntary steel sustainability standard, aiming "to support the responsible sourcing and production of steel, as a tool (…) to maximise steel's contribution to a sustainable society". To achieve

[31] For a comprehensive review of the current landscape of initiatives and standard-setting processes for a wider group of key low-emissions industrial products including not only steel but also others such as aviation fuel, ammonia, methanol, aluminium, cement and concrete, indicating that the current level of uptake of such products in steel is 'low' in absolute terms and also relatively to some other industrial products, see ITA and RMI (2024): Mapping the Landscape of Low-Emissions Product Standards for the Industrial Transition (available in https://ita.missionpossiblepartnership.org/ita-standards-map/).
[32] Green-e® Renewable Electricity Standard, https://www.green-e.org/international
[33] ibid
[34] Throughout this paper, these two standards will be referred to as 'ResponsibleSteel' and 'GSCC', for simplicity.
[35] ResponsibleSteel does not define 'net-zero steel', but its standard does create a definition for 'near-zero steel', as described further in this section.

this, this standard seeks to define "the fundamental elements that characterise the responsible sourcing and production of steel" and the "levels of performance within these fundamental elements". It defines 13 'principles' a steelmaking site must meet to achieve certification, encompassing a wide array of sustainability attributes including corporate leadership, ESG management systems, responsible sourcing, labour and human rights, health & safety, water, biodiversity, as well as climate change and greenhouse gas emissions – the principle most directly related to this paper's discussions on green steel. To date, over 80 steelmaking sites have been certified under ResponsibleSteel's International Production Standard.

In addition to site certifications, this standard also creates a steel product certification. If – besides receiving site-level certification – a steelmaking site also meets other requirements such as achieving 'progress level 1' under both responsible sourcing and greenhouse gas emissions decarbonisation principles, it may label its products with the ResponsibleSteel 'Certified Steel' label[36]. To achieve this decarbonisation requirement, a steelmaking site must demonstrate emissions intensity at or below 2.8 tCO_2eq per tonne of crude steel if operating with 0% scrap (or 0.5 tCO_2eq / t crude steel if operating with 100% scrap, or a proportional threshold following a sliding scale, if in between), under the carbon accounting methodology outlined in this standard, including some upstream scope 3 emissions e.g. from input materials. Importantly, meeting these carbon intensity thresholds is only a requirement for steelmaking sites who wish to use a 'Certified Steel' label; to achieve ResponsibleSteel's core site certification, no carbon emissions intensity maximum is required. To date, only one steelmaking site – US Steel's Big River Steel site in Arkansas, USA – has had their steel product certified as 'Certified Steel' under ResponsibleSteel's steel certification label.

ResponsibleSteel's standard also defines three other 'Progress Levels' – 2, 3 and 4 – for greenhouse gas emissions decarbonisation, with increasingly strict emissions intensity requirements for higher Progress Levels. The strictest of all, Progress Level 4, brings a definition for 'near-zero steel': that produced at a site whose emission intensity is at or below 0.4 tCO_2eq/t crude steel if operating with 0% scrap (or 0.05 tCO_2eq/t crude steel if operating with 100% scrap, or a proportional threshold, if in between).

No steelmaking site has yet been certified as achieving ResponsibleSteel's 'near-zero' steel status, although some non-member sites might have achieved this level in pilot or small scale, without certification. US Steel's Big River Steel site in the USA has reported a carbon emissions footprint of 1.34 tCO_2eq/t crude steel at a 57.3% scrap share (as of 2022, audited in 2023, certified in 2024), still falling above the implied maximum threshold for 'near-zero' steel in the standard[37].

Importantly, ResponsibleSteel's classification of steel products according to their carbon intensities has had acceptance and application beyond the organisation's core site and steel product certification programmes. Through partnerships with initiatives promoting the creation of markets for low-carbon products in hard-to-abate sectors like steel – for example the SteelZero initiative by the Climate Group, and the World Economic Forum's First Movers Coalition's Steel Commitment – ResponsibleSteel's classification now influences what steel products can qualify for pledges under these initiatives:

- SteelZero: public commitment to procure 50% of steel meeting ResponsibleSteel's Progress Level 2 threshold by 2030, in addition to a broader long-term commitment to transition to 100% 'net zero steel'[38] by 2050. Over 40 organisations have made this pledge, including Volvo Cars, Orsted, CIMC, Iberdrola, SKF, and Vattenfall.

[36] Allowing, for instance, the steelmaker to include in sales and delivery documentation of products sold from that site a 'ResponsibleSteel Certified Steel' mark.

[37] https://www.ussteel.com/documents/40705/43725/ResponsibleSteel+Certified+Steel+Certification+%26+Report+20240809.pdf/82384453-22b9-175e-09dc-e9df3ee51ff7?t=1729667130730

[38] In this context, SteelZero defines net zero steel as "steel with a GHG emissions intensity minimised to be as close as operationally possible to zero metric tonnes of CO_2e / metric tonne crude steel, and any remaining emissions offset as a last resort using a recognised offsetting framework". See: https://www.theclimategroup.org/sites/default/files/2024-06/SteelZero%20Commitment%20Framework%20v1.1_June%202024.pdf

- FMC: public commitment that "at least 10% of all our steel purchased per year will be near-zero emissions (as per FMC definition) by 2030"[39], with FMC's definition being consistent with ResponsibleSteel's. Over 26 organisations have made FMC steel pledges, including Enel, Engie, Ford, Iberdrola, Orsted, Volvo Group, and ZF Group[40], many of whom are also SteelZero members.

In addition, the FMC also launched in 2023 its 'Near Zero Steel 2030 Challenge', in partnership with ResponsibleSteel and other organisations, "to support the emergence and commercialisation of innovation in the steel sector through offtake agreements with buyers of steel, connection to breakthrough technologies, support for funding and access to renewable energy" [41], ultimately promoting the development of new near-zero steel projects. For this challenge, ResponsibleSteel is providing a self-assessment methodology to enable steelmakers to assess if their project is likely to be within the thresholds for near-zero steel once in production, and its certification is being listed as an option for projects to verify their emissions intensity once in production.

Finally, ResponsibleSteel's classification of 'near-zero steel' was also used in a recent bill proposed in the US House of Representatives to promote the transition of the US steel industry and the development of near-zero steel production in the country, the 'Modern Steel Act' bill of August 2024. The bill's text specifies that, for its purposes, ''near-zero emissions intensity steel'' means "steel that has an emissions intensity that is equal to or less than progress level 4 emissions intensity that is determined, using a sliding scale of emissions intensity based on scrap share of metallics input, in accordance with criterion 10.6 of Responsible Steel International Production Standard"[42]. It is unclear what the status of this proposed legislation is, especially given recent changes under the new US Federal administration[43].

Global Steel Climate Council's 'Steel Climate Standard'

The Global Steel Climate Council (GSCC) is a non-profit organization that "leads efforts to reduce steel carbon emissions and encourages investments in lower-carbon emission technology as part of the global effort to decarbonise economies and societies", founded in 2022 by 6 entities including steelmakers Nucor, Steel Dynamics, and CELSA Group, now counting over 20 steel producers as members including Liberty Steel USA and Tokyo Steel, in addition to 15 associate members and supporters. Its mission is to "lead the way toward a truly effective low-emission steel standard for all producers that accurately counts carbon emissions – regardless of the production methods"[44].

In 2023, GSCC launched its 'Steel Climate Standard'[45] as a dual framework for both steel product certification and corporate science-based emissions targets. In this regard, this standard encompasses two components: a "science-based emissions target setting criteria" for steel producers; and a "product certification criteria" for lower-carbon emission steel products. In other words, both companies and products can be certified under GSCC's standard. Whilst setting science-based emissions targets is a requirement for all GSCC steel producer members, certifying their steel products is optional. To date, the corporate emissions targets of 4 steelmakers have been certified under GSCC's standard as 'certified science-based emissions targets', those of Steel Dynamics (in October 2024), Nucor (in January 2025)[46], Arkansas Steel Associates (April 2025), and AFV Beltrame (April 2025). To date, no steel product has yet been certified, but the authors understand that some members are planning to achieve this in the near future.

[39] https://reports.weforum.org/docs/WEF_First_Movers_Coalition_Steel_Commitment.pdf
[40] https://initiatives.weforum.org/first-movers-coalition/community
[41] https://challenge.greenhouse.tech/nearzerosteelemissions
[42] https://khanna.house.gov/sites/evo-subsites/khanna.house.gov/files/evo-media-document/KHANNA_056_xml%20FINAL%20118th.pdf
[43] The bill also borrows from ResponsibleSteel the definition of a "mine-to-metal'' concept used as a basis for a GHG accounting rule, under ResponsibleSteel's criterion 10.4. Interestingly, the bill also defines "near-zero emissions intensity iron", but instead of referring to a standard, it specifies a fixed emissions intensity threshold of 0.35 tCO_2eq/t of iron.
[44] https://globalsteelclimatecouncil.org/newsroom/gscc-publishes-2024-annual-report/
[45] Standard developed by Trinity Consultants in collaboration with members of the GSCC. Available at: https://globalsteelclimatecouncil.org/wp-content/uploads/2024/07/GSCC-Final-Standard_7-12-24.pdf
[46] https://globalsteelclimatecouncil.org/members/

GSCC's is unique in specifically offering steelmakers a corporate-level emissions target certification against an alignment to future Paris Agreement emissions reduction goals[47]. Although ResponsibleSteel requires companies that want their sites certified against its standard to demonstrate their corporate commitment to the goals of the Paris Agreement "through the development of science-based targets to reduce their GHG emissions", it does not offer a certification or validation of such targets itself, like the Science Based Targets Initiative (SBTi) – or, also, the GSCC – does.

GSCC's standard's product certification offers a classification of steel products according to their carbon intensities. Importantly, differently than other standards, it explicitly distinguishes between flat and long steel products, "recognizing that at this time, it is technically infeasible to manufacture flat products and long products that have equivalent carbon intensities because they are different in terms of their chemical composition". To have its products certified under its standard in 2025, the GSCC requires that a flat steel producer demonstrates an average product carbon emissions intensity of 1.63 tCO_2eq/t of hot rolled steel. Long steel producers need to demonstrate a 1.34 tCO_2eq/t of hot rolled steel intensity. Over time, these intensity thresholds are decreased in a 'glidepath', converging in both cases to 0.12 tCO_2eq/t of hot rolled steel by 2050, a threshold based on a scenario in IEA's "Net Zero by 2050: A Roadmap for the Global Energy System" report of 2021, which "provides a global pathway to achieve net zero CO_2 emissions by 2050"[48].

Differently than other standards, although conformity to the standard is required at a 'facility level', a subset of a given product produced at a single facility may be certified to GSCC's product standard; for example, procurement of renewable energy may be attributed specifically to a subset of the facility's production manufactured specifically to achieve a lower product intensity, thus being eligible for GSCC's product certification, whereas the remainder of the facility's production might not.

Although the GSCC's standard has yet to yield its first certified product, its emissions accounting procedures have started to find use in some applications beyond GSCC's core company and product certification programmes. For example, in April 2024, the UK's Construction Leadership Council (CLC) launched a set of 'Five Client Carbon Commitments'[49] that companies involved in construction can voluntarily adhere to help set a path to net zero construction in the UK[50]. Amongst other materials, these include a commitment for signatories to "eliminate the most carbon intensive steel products" from their steel purchasing contracts. Although CLC uses a purposefully-created scale to classify steel products according to various levels of carbon intensity (from the least stringent intensity threshold 'F' of 1.47 tCO_2eq / t hot rolled steel, to the most stringent threshold 'A' of 0.12 tCO_2eq / t hot rolled steel), it refers to the GSCC's Steel Climate Standard for 'carbon scoping'[51].

Rather confusingly, in CLC's commitments, each signatory sets its own chosen threshold / category for green steel (within CLC's scale) as well as the year from which it commits that its construction sites will only purchase green steel. Also, separate commitments can be made for different steel types (flats vs. longs) or products (rebar, sections, etc). For example, Heathrow Airport commits to procure only long steel products with under 0.66 tCO_2eq/t hot rolled steel by 2032 and under 0.39 tCO_2eq/t hot rolled steel by 2036 as 'core targets', with an additional 'long-term stretch target' of buying only long steel of the most stringent 'A' category of under 0.12 tCO_2eq/t hot rolled steel by 2040. In any case, CLC's Five

[47] One of GSCC's stated goals is "to provide a set of technology-agnostic standards which accelerate the transition to lower-carbon steel and incentivise the industry to achieve lower carbon emissions by 2050 in alignment with the 1.5°C scenario for the steel sector". Its emissions target standard requires convergence to a time-bound 'glidepath' that steelmakers need to meet to achieve 2050 net zero goals, requiring self-audit of corporate emissions intensities yearly vs. the glidepath "to demonstrate continuous decarbonisation progress".

[48] See Appendices C and D of GSCC's Steel Climate Standard for further explanations on its decarbonisation pathway and basis for product standards between flats and longs.

[49] https://www.constructionleadershipcouncil.co.uk/wp-content/uploads/2024/04/Five-Client-Carbon-Commitments-29.04.24.pdf

[50] As with other buyers-led initiatives, CLC's Five Commitments is founded on the belief that "clear projection of client demand for green steel will help manufacturers plan the investment needed to supply it and see the phasing out of carbon intensive production".

[51] For example, using the hot rolling stage as a point of measurement of emissions, and stipulating that offsets cannot be used to achieve the desired carbon intensity.

Commitments illustrate how steel buyers are using self-created definitions and thresholds for green steel, as well as being informed by carbon accounting methodologies developed under the voluntary standards emerging in the industry such as the GSCC's.

'Low Emissions Steel Standard' (LESS)

In April 2024, the German Steel Association launched the 'Low Emissions Steel Standard' (LESS), building on its initial 2022 proposal for a green steel classification system[52] and following a stakeholder engagement process led by Germany's Ministry for Economic Affairs and Climate Action. Following its launch, the LESS standard is now managed by Brussels-based entity LESS aisbl, open to all steel producers on a voluntary basis. One of its core goals is to "provide labelling as a basis for distinguishing between conventionally produced and low-emission steel".

The LESS standard focuses exclusively on the carbon emissions intensity performance of steel products, not covering other sustainability attributes. Its centrepiece is a label system, which uses a graduated classification scale to classify steel produced with low emissions. It requires companies under its certification to disclose both their scrap shares, as well as their product emissions intensity indicated in either Product Carbon Footprint (PCF) or Global Warming Potential (GWP) values from Environmental Product Declarations (EPD), and to have such values verified by independent auditors.

It involves a six-stage classification system with the aim "to depict this phased transformation process and strategically incentivise and support the efforts and additional expenses associated with each individual transformation step"[53], initially based on an IEA proposal – similarly to ResponsibleSteel, involving a sliding scale of thresholds dependent on scrap use[54] – but with an extended scope including steel refining, casting and hot rolling of steel products[55]. In other words, LESS uses the hot rolling stage as a point of measurement of emissions, whereas ResponsibleSteel uses the crude steel stage.

In the LESS classification system, steel products[56] with emissions intensity at or below 2.35 tCO_2eq/t hot rolled steel if operating with 0% scrap (or 0.6 tCO_2eq/t hot rolled steel if operating with 100% scrap, or a proportional threshold following a sliding scale, if in between) is classified at the less stringent 'D' low emissions mark, under the carbon accounting methodology outlined in this standard, which also includes some scope 3 emissions. This is then followed by thresholds for marks 'C', 'B' and 'A. Finally, to meet LESS' strictest definition for 'near-zero steel', a steel product must demonstrate emission intensity at or below 0.47 tCO_2eq/t hot rolled steel if operating with 0% scrap (or 0.12 tCO_2eq/t hot rolled steel if operating with 100% scrap, or a proportional threshold, if in between).

All in all, LESS' thresholds for near-zero steel broadly align with ResponsibleSteel's, with a difference of 70kg probably due to these standards' different production stages measuring points (hot rolled vs. crude steel). For less stringent classifications, however, differences in thresholds between these standards are more pronounced.

To date, no steel has been certified under the LESS classification. We understand that, as of early 2025, a test phase has been completed, robustness checks are taking place, third-party certification bodies are being approved, with LESS expecting its first certificates to be issued around mid-2025.

[52] "Green Steel Definition - A Labelling System for Green Lead Markets", in https://www.wvstahl.de/wp-content/uploads/2022-11-25_Green-Steel-Definition-A-Labelling-System-for-Green-Lead-Markets.pdf

[53] https://www.wvstahl.de/wp-content/uploads/20240422_Rulebook_Classification-System-for-LESS_v1.0.pdf

[54] LESS explains that its sliding scale approach is meant to "recognises the limited availability of scrap and incentivises the transformation and use of clean energy".

[55] Another differentiating characteristic of LESS is that it allows for existing facility-level data from the EU Emissions Trading System (EU-ETS) to be used, aiming to ensure simplicity in reporting and "a very high level of accuracy in capturing the relevant Scope 1 emissions".

[56] LESS thresholds shown are for 'structural and reinforcing steel' products, which largely refer to non-alloy carbon steel products. LESS stipulates different thresholds for 'quality steel' products, largely alloy steels (including stainless steel), not shown here as not as directly comparable to other standards shown.

Although voluntary, on its launch, LESS was endorsed by the German Federal Ministry for Economic Affairs and Climate Action, hinting on a potential intention to inform regulation at least at national level. Indeed, we understand that LESS aims to embed its standard in upcoming European Union regulation on green products and to become the go to standard for low- and near-zero emission steel in Europe, as well as to reach a membership of over 50 percent of EU steel production in the near term. If this were to be the case, LESS is likely to see increased adoption and acceptance in coming years – at least in the European market.

China Iron and Steel Association's Low Carbon Emissions Steel Evaluation Method (LCESEM)

In October 2024, the China Iron and Steel Association (CISA) launched its "evaluation methodology of low carbon-embodied emission steel"[57]. Led by China's Baowu Steel group, the standard was developed in collaboration with 44 steel industry entities and over 100 experts. It was designed to address the lack of global standardisation in low carbon emission steel, aligning with the country's "development characteristics and resource endowments while adhering to international rules"[58]. Its development also benefited from collaborations with the IEA, ResponsibleSteel, and the World Steel Association, as well asl from inputs from end users in automotive and construction. CISA is understood to be currently working on developing supporting guidelines and conducting initial assessments under the standard.

Although largely influenced by the IEA's and ResponsibleSteel's approach, CISA's standard determines slightly different thresholds and classifications for low emissions steel at crude steel level. In CISA's LCESEM classification system, steel products with emissions intensity at or below 2.19 tCO_2eq / t crude steel if operating with 0% scrap (or 0.41 tCO_2eq/t crude steel if operating with 100% scrap, or a proportional threshold following a sliding scale, if in between) is classified at the less stringent 'E' mark. This is then followed by thresholds for marks 'D', 'C', and 'B'. Finally, to meet the strictest 'A' mark, a steel product must meet emission intensity at or below 0.15 tCO_2eq/t crude steel if operating with 0% scrap (or 0.11 tCO_2eq/t crude steel if operating with 100% scrap, or a proportional threshold, if in between).

Differently than IEA and ResponsibleSteel, CISA's approach also establishes threshold values at hot rolled stage, and for different types of steel products (hot rolled coils, thick plate, wire rod, seamless pipes etc). It is unclear what specific carbon accounting methodologies and boundaries are used, for example to which extent scope 3 emissions is included.

Although it is unclear whether CISA's method has started to be applied in practice or has led to certifications confirming a steel's emissions intensity performance, CISA's LCESEM could be expected to enjoy wide adoption in the Chinese market and inform future policy developments in low carbon steel in the country, given CISA's historical relevance in China steel market developments.

Country and regional regulations

Although at global level no standard specifically determines what is and what isn't green steel, many countries and regions are actively considering regulations to specify, within their own jurisdictions, what can be called green steel (or equivalent terms), sometimes under broader green product policies.

India became in December 2024 the first country to mandate a green steel definition. The EU is considering definitions for low emissions steel in its upcoming green products regulations. In the USA, Federal programmes were introduced to determine low embodied carbon steel purchasing in Federal procurement, and a bill was proposed to incentivise the building of new steel plants based on ResponsibleSteel's definitions. All in all, steel suppliers can expect to be increasingly subject to regulation forcing them to meet specific criteria to be allowed to use green steel and related terminology.

[57] http://english.chinaisa.org.cn/do/cn.org.chinaisa.view.Column.d?column=9&article=34458
[58] https://policycn.com/public/commentaries/prc-version-of-low-carbon-emission-steel-standard-launched-42701

India's Green Steel Taxonomy

In December 2024, India launched its "Green Steel Taxonomy", as part of a broader 'National Mission on Green Steel' currently in consultation[59]. This followed initial policy guidance from a comprehensive report by its Ministry of Steel on 'Greening the Steel Sector in India: Roadmap and Action Plan'[60], released in August 2024 as an outcome of 14 task forces aimed at developing an action plan for decarbonising India's steel sector in alignment with a net-zero emission intensity target by 2070, which emphasised the need for a definition of green steel for the country's emission reduction goal to be achieved.

India's taxonomy defines green steel as such: '*"Green Steel" shall be defined in terms of percentage greenness of the steel, which is produced from the steel plant with CO_2 equivalent emission intensity less than 2.2 tonnes of CO_2e per tonne of finished steel (tfs)."*

Within this definition, a classification system using star ratings – similarly to energy efficiently labels used in many countries for household appliances and other goods – then provides nuances of various types of green steel, ranging from 'five stars' as the greenest, to three starts as the least green. The taxonomy states that "*the greenness of the steel shall be expressed as a percentage, based on how much the steel plant's emission intensity is lower compared to the 2.2 tonnes of CO_2eq per tonne of finished steel threshold*":

- **Five-star** green-rated steel: steel with emission intensity lower than 1.6 t-CO_2eq/tfs.
- **Four-star** green-rated steel: between 1.6 and 2.0 tCO_2eq/tfs.
- **Three-star** green-rated steel: between 2.0 and 2.2 tCO_2eq/tfs.
- **No green rating**: higher than 2.2 tCO_2eq/tfs.

In terms of scope boundaries, the star-rating thresholds are to incorporate a 'limited' Scope 3 boundary, excluding upstream mining, downstream emissions, and transportation emissions, both within and outside the gates of a steel plant.

The taxonomy further determines that a national agency will provide measurement, reporting, and verification of the emissions intensity for producers operating in India and will be responsible to issue certificates for the 'greenness' and 'star ratings' for all steel produced in the country.

Many saw India's threshold for green steel at 2.2 tCO_2eq/tfs as unambitious, sitting at the higher end of the spectrum of thresholds for green steel-related classifications in other standards[61]. Others pointed to the fact that India's current country carbon intensity average lags other countries significantly in emissions performance – estimated at 3.0 tCO_2/t of crude steel (as of 2019), as explained in Section 1 – reflecting India's more challenging starting position in its steel decarbonisation journey.

It is unclear at this stage what will be the direct implication, for Indian steelmakers, of being assigned a specific star rating classification, but the authors believe that this is likely to feed into a green steel public procurement policy currently being drafted for consultation. In other words, the extent to which steel suppliers may be able to sell into publicly-funded construction and infrastructure projects will likely be determined by whether the steel supplied is green (or sufficiently green) as per the country's rating system. It is also unclear at this stage whether this new regulation could influence private procurement of steel or affect purchases of imported steel, as well as whether the thresholds for green steel would be reduced in future years to incentivise decarbonisation. India's Green Steel Taxonomy is, nonetheless, the most direct example of a country-specific government-mandated definition of green steel to date.

[59] https://pib.gov.in/PressReleaseIframePage.aspx?PRID=2083839
[60] https://steel.gov.in/en/greening-steel-sector-india-roadmap-and-action-plan
[61] See 'Green Steel Scale' below for a full comparison of thresholds.

European Union

Another example comes from the European Union. The EU will establish, under its recent Clean Industrial Deal initiative of February 2025, regulation on voluntary labels for low-carbon products, starting with steel, where carbon intensity of industrial products will be considered based EU ETS data and building on the EU's CBAM methodology. In the EU's words, "*such labels will allow industrial producers to distinguish the carbon intensity of their industrial production and to benefit from targeted incentives, e.g. for clean steel*"[62]. The EU also makes reference to this new regulation being the basis for "further engagement with international work on measuring carbon intensity", alluding to ongoing global efforts to increase comparability and consistency between carbon emissions accounting methodologies. In this context, LESS, which was endorsed on its launch by the German Government and is hoped to become a go-to standard for low- and near-zero emission steel in Europe, could emerge as a strong candidate as the chosen standard in upcoming EU regulation on green products.

USA

In the USA, multiple federal-level initiatives during the Biden administration sought to define 'low embodied carbon materials', including steel. For example, the US General Services Administration established requirements for 'low embodied carbon steel' as part of its 'Low Embodied Carbon Program'[63] associated with the US's Inflation Reduction Act of 2022 and Buy Clean Initiative, in which product-specific thresholds were set for steel of various types.

In another example, the US Environmental Protection Agency also established a 'Label Program for Identifying Low Embodied Carbon Construction Materials' to *'define what constitutes "clean" construction materials (such as steel) to catalyse demand for clean materials used in federal buildings, highways, and infrastructure projects'*. With this, the program aimed "*to help ensure construction product manufacturers that invest in EPDs and lower their embodied emissions can credibly demonstrate these achievements to their customers. This program is also designed to support construction product manufacturers in lowering operating costs, achieving efficiencies and accessing new markets*" [64].

However, the current status of these federal initiatives, now under the Trump administration, is unclear. In any case, they were meant to apply to federal procurement programmes, particularly related to construction and infrastructure, so their impact on broader private steel procurement practices could be limited. The authors understand that a country-wide regulation imposing a definition of green steel (or related terms) is unlikely to emerge in the USA in the short term.

[62] https://commission.europa.eu/topics/eu-competitiveness/clean-industrial-deal_en
[63] https://www.gsa.gov/real-estate/gsa-properties/inflation-reduction-act/lec-program-details
[64] https://www.epa.gov/greenerproducts/labeling-materials-products

The 'Green Steel Scale'

Figure 2: The 'Green Steel Scale'

Whether a steelmaker wishes to market their product as green, or a buyer assessing if a product is truly green, the below chart provides guidance as to how this is achieved in different schemes.

Thresholds for classification of steel emissions intensity by main existing standards addressing carbon emissions intensity in steel production, in increasing order of strictness (decreasing threshold values – in tCO_2eq/t of steel)

0% scrap use

Classification (at 0% scrap)	Threshold
PL1 in ResponsibleSteel (crude)	2.80
D rating in LESS (hot rolled)	2.35
3-star rating in India (finished)*	2.20
E rating in China (crude)	2.19
PL2 in ResponsibleSteel (crude)	2.00
4-star rating in India (finished)*	2.00
C rating in LESS (hot rolled)	1.88
D rating in China (crude)	1.64
GSCC thershold for flats in 2025 (hot rolled)*	1.63
5-star rating in India (finished)*	1.60
B rating in LESS (hot rolled)	1.41
GSCC thershold for longs in 2025 (hot rolled)*	1.34
PL3 in ResponsibleSteel (crude)	1.20
C rating in China (crude)	1.03
A rating in LESS (hot rolled)	0.94
Near zero rating in LESS (hot rolled)	0.47
B rating in China (crude)	0.43
PL4 / Near-zero in ResponsibleSteel (crude)	0.40
A rating in China (crude)	0.15

20% scrap use

Classification (at 20% scrap)	Threshold
PL1 in ResponsibleSteel (crude)	2.34
3-star rating in India (finished)*	2.20
4-star rating in India (finished)*	2.00
D rating in LESS (hot rolled)	2.00
E rating in China (crude)	1.83
PL2 in ResponsibleSteel (crude)	1.67
GSCC thershold for flats in 2025 (hot rolled)*	1.63
C rating in LESS (hot rolled)	1.60
5-star rating in India (finished)*	1.60
D rating in China (crude)	1.38
GSCC thershold for longs in 2025 (hot rolled)*	1.34
B rating in LESS (hot rolled)	1.20
PL3 in ResponsibleSteel (crude)	1.00
C rating in China (crude)	0.87
A rating in LESS (hot rolled)	0.80
Near zero rating in LESS (hot rolled)	0.40
B rating in China (crude)	0.38
PL4 / Near-zero in ResponsibleSteel (crude)	0.33
A rating in China (crude)	0.14

100% scrap use

Classification (at 100% scrap)	Threshold
3-star rating in India (finished)*	2.20
4-star rating in India (finished)*	2.00
GSCC thershold for flats in 2025 (hot rolled)*	1.63
5-star rating in India (finished)*	1.60
GSCC thershold for longs in 2025 (hot rolled)*	1.34
D rating in LESS (hot rolled)	0.60
PL1 in ResponsibleSteel (crude)	0.50
C rating in LESS (hot rolled)	0.48
E rating in China (crude)	0.41
B rating in LESS (hot rolled)	0.36
D rating in China (crude)	0.35
PL2 in ResponsibleSteel (crude)	0.35
C rating in China (crude)	0.24
A rating in LESS (hot rolled)	0.24
PL3 in ResponsibleSteel (crude)	0.20
B rating in China (crude)	0.16
Near zero rating in LESS (hot rolled)	0.12
A rating in China (crude)	0.11
PL4 / Near-zero in ResponsibleSteel (crude)	0.05

Notes: standards included are LESS, China Steel Association's LCESEM, India's Taxonomy, ResponsibleSteel, and GSCC. Thresholds differ in stage of production measured (shown in parentheses), either at crude steel, hot rolled steel, or finished steel stages

* India's Taxonomy and GSCC do not differentiate thresholds based on % of scrap used (thus being the same in all scales)

Take the example of a producer whose emissions intensity was measured, say, at 1.90 tCO_2eq/t of crude steel, and at 1.95 tCO_2eq/t of finished steel, in a process using 20% scrap. By placing these values against the Green Steel Scale at 20% scrap, the producer would see its steel meeting ResponsibleSteel's Decarbonisation Progress Level 1, India's green steel classification with a 4-star rating, and LESS's D classification. It exceeds all thresholds for China Iron and Steel Association's LCESEM and therefore does not qualify for either.

Is this producers' steel green? In India, yes – as it meets the country's taxonomy. For other standards, the answer is less straightforward as they do not specify what green steel is. The producer can claim to meet those thresholds – for example, if their site is ResponsibleSteel certified and meets other additional responsible sourcing criteria, where the producer can apply to label its products as ResponsibleSteel Certified steel (at Progress Level 1). They cannot, however, sell their product to companies seeking to honour SteelZero pledges, which require a minimum of ResponsibleSteel Progress Level 2 to be met.

Now take the example of a buyer seeking to source steel with no more than 0.55 tCO_2eq/t of hot-rolled steel and has no preference for or concern over scrap content. If buying from India, any steel with a green steel rating of 3 or 4 stars would not meet their needs (as it would certainly have an emissions footprint higher than 1.6 tCO_2eq/t), while only some steels with a 5-star rating would (as they would have more than 0.55 tCO_2eq/t, as it is sufficient to be below 1.6 tCO_2eq/t to achieve 5 stars); in other words, the star rating itself would not be sufficient to inform this buyer's decision, and the buyer would instead need to look into specific emissions footprints.

Similarly, if buying from China, this buyer would be reassured by steels achieving a 'B' classification (as this would mean with certainty that their emissions footprint would be less than 0.43 tCO_2eq/t, regardless of scrap content, i.e. meeting the buyer's desire of no more than 0.55 tCO_2eq/t[65]). However, this buyer would not be able to tell whether a steel product achieving China's 'C' level would be sufficient (as a 'C' level only requires emissions footprint to be lower than 0.87 or even 1.03 tCO_2eq/t under some scrap content levels – far from the buyer's desired level of 0.55 tCO_2eq/t of steel).

This highlights the fact that some of these steel classifications by existing standards are not meant primarily to inform sellers' or buyers' decisions where specific carbon emissions footprints are needed, rendering them of potentially limited use.

Intended as more than a tool for steelmakers or buyers to check and compare the performance of steel products, this scale illustrates in a simple, visual way the highly complex, nuanced results stemming from comparing the main existing standards addressing carbon emissions intensity in steel.

5. Perspectives from green steel buyers

With the confusion and complexity stemming from the myriads of voluntary, corporate, and regional classifications for green or low carbon emission steel products, the authors have sought to hear opinions from steel buyers and end users on the topic, to shed light on the preferences and requirements stemming from market participants that are ultimately responsible[66] for procurement decisions for these products.

To complement these insights and bring additional context, the authors have also interviewed global steelmakers, standard-setting bodies, and other organisations. A total of five steel buyers were

[65] Ignoring potential significant discrepancies from crude to hot rolled stages

[66] Interviewee's job titles included 'Director Procurement Global Raw Material', 'Steel Purchasing Manager', amongst others.

interviewed (spanning automotive, construction and technology sectors), as well as four steelmakers (including both BF-BOF and EAF producers and start-ups) and four standard-setting bodies and other organisations, totalling thirteen interviews[67].

Our interview with buyers focused on two simple questions:

1) 'In your view, what is green steel?' and
2) 'What aspects of the 'green' do you seek when buying green steel?'

The breadth and nuanced nature of the answers illustrated that, despite the simplicity of the questions, the reality behind them is certainly not simple.

With regards to the first question, one point of agreement between all green steel buyers interviewed, seconded also by all other non-buyer participants, was that, independently from what they consider green steel to be, they view green steel as the same product as conventional steel with regards to the traditional dimensions of metallurgical, mechanical, and chemical properties. In that sense, both types are well understood to 'look and feel' the same product.

However, the term green steel was widely seen as ambiguous, given the various definitions and classifications that emerged. For instance, one buyer explained that:

> *"We don't use the term green steel with suppliers or internally, you just can't define it. Everyone has their own definition; every steel mill has multiple options of green steel, so it's not comparable. For me, a better term is CO_2-reduced steel".*

Another common trend across buyers was a clear desire for more simplicity and additional convergence amongst the various definitions and classifications that emerged. In the words of a steel buyer:

> *"We need to make green steel terminology simple. It should be intuitive, no fancy names - we buy from various suppliers and can't afford having one for each".*

To overcome this perceived complexity around terminology and classifications, some buyers went further to develop internal classification systems for various types of green steel, despite (or, perhaps, because of) the abundance of voluntary classification systems and standards already externally available. One buyer explained that:

> *"We wanted a simple system, one dimensional, with basic definitions per tonne of CO_2 and some colour coding, so we developed one. It generates a common language. Internally, we use it to classify all materials – not only steel – according to those categories. In external communication, we use it with all suppliers."*

Whereas the above buyer example saw a color-coded, A-B-C-D type of classification system helpful, others did not agree:

> *"For me, it's not interesting at all a classification like ABCDE. In the end, what matters is what goes into the carbon emissions balance I have to report".*

With regards to the 'green' aspects sought when buying green steel, all of the steel buyers interviewed indicated that the key attribute they see in a steel to be green is the absolute carbon footprint associated with it. For example:

> *"We support new green steel projects and don't want green steel only produced from scrap. But at the end of the day, we are driven by our clients in the construction sector, those commissioning buildings. What their architects and designers now sometimes specify is a certain % of material*

[67] Semi-structured interviews done throughout the second semester of 2024. The authors would like to thank ZF Group, World Steel Association, Fastmarkets, ResponsibleSteel, GSCC, and all other participants who contributed anonymously – all views in this paper are of the authors only, and the participation of the above organisations in this interview programme should not mean endorsement the findings and opinions presented here.

being low-carbon, or – more precisely – the embodied carbon content to be met in the building being built. And that's not even in all cases. In that sense, CO_2 reduction is all that matters, the embodied carbon indicated in the material's EPD – scrap content is not specified for now".

In that sense, in the case of the construction sector, the decarbonisation of buildings was mentioned as the key driver for initial adoption of green steel. But to date, even in Europe, only niche, sophisticated developers pursue low-carbon, energy-efficient buildings, whereas most would not yet do so. Buildings regulation – top-down imposition by governments – was mentioned as the key lever to influence a broader set of developers (and their architects and designers) to require low carbon materials in their buildings.

Two buyers indicated that the share of recycled steel scrap used in the production of the steel they buy is also important, with higher scrap shares being more desirable. For instance:

"In our customer base, only one end customer is requesting specific scrap content in the material we buy for the parts, components and systems we supply. They complain that no-one can tell them the scrap content – but we'd like to have this hard coded in an audit trail to be able to provide full transparency in our value chain".

In that sense, higher scrap content was seen as a positive, contributing to the achievement of upcoming circularity targets, not something that would be required to be compensated by an even further lower carbon footprint as per the 'sliding scale' approach (where it is the carbon footprint *relative to the scrap content used* that matters, not the absolute footprint alone). Emerging mandatory requirements for disclosure of recycled content shares at company level (for example, from the EU's CSRD regulation) drive further attention to scrap content than currently observed amongst steel value chain participants.

The only purchasing decision based on a 'sliding scale'-based classification was from a buyer who had made a corporate-level procure pledge, and in that buyers' case this type of purchasing was limited to the percentage share of the pledge only.

For instance, one large steel buyer, whose corporation is a member of a green steel procurement pledge listed in section 5, explained that they buy green steel for two reasons: first and foremost, to reduce the embodied carbon emissions in purchased materials needed for corporate emissions reduction targets to be met – in that sense, the key attribute sought in the green steel purchased was its product absolute carbon footprint, as each marginal CO_2eq reduction helped equally; secondly, to meet the green steel procurement pledge done at corporate level – in that sense, the key attribute sought was compliance of the steel purchased with the low-carbon steel classification required by the pledge (e.g. ResponsibleSteel Level 2, or equivalent).

Other sustainability attributes beyond carbon emissions and scrap were not mentioned as relevant factors in the purchase of green steel. None of the buyers interviewed indicated that they require steel produced in a site certified by ResponsibleSteel, or from a company certified by the GSCC, or by any other voluntary sustainability standard, at least not for now.

The importance of EPDs and LCAs in providing higher transparency on the carbon footprint of steel products purchased was also a common topic amongst buyers, as well as a desire for further convergence in methodologies behind these documents:

"The construction industry has taken huge steps towards EPDs, requesting EPDs from materials suppliers. It's now fully embedded. So, relying on EPDs for low-carbon materials – specifying carbon footprint – is the best way to reduce carbon footprint in our industry".

"In the automotive value chain, LCAs are becoming the norm. They may have their issues and methodologies may not always align, but the product carbon footprint associated with LCAs is well understood."

6. Conclusions and recommendations

This paper sought to unpack what greenness means in the steel industry context. We presented inherent challenges in defining green steel including real-life examples of how this and related terms are in use today, and reviewed how various definitions and classifications emanating from voluntary standards and national/regional regulations have made it complex to compare the various terms and thresholds currently in use. To illustrate this, the paper presents a 'Green Steel Scale'. We also heard first-hand from steel buyers on what the term means for them, and what product features they seek when purchasing the green product. Considering these, we conclude with some key takeaways and recommendations.

Key conclusions

1. 'Green steel' is a widely used but loosely defined term, with no generally accepted definition or standard.
2. **Inherent challenges** in defining green steel stem from the fact that steel is not one single, homogenised product, that substantial variation exists in carbon footprints between conventional production methods (and within each of them), that it is infinitely recyclable with significant amounts of scrap used in production processes, and that various un-harmonised carbon accounting methodologies are in use.
3. Various **examples** of the use of the term green steel highlight the nuances and complexities in comparability around the term. This uncertainty around terminology and green claims hampers the adoption of green steelmaking, the design and implementation of policies to promote it, and investment financing.
4. Voluntary **standards** can have a key role to play in promoting convergence in meanings and towards a common understanding around the term, however, to date, various standards specify different thresholds to classify steel products according to their emissions intensity profile.
5. New **regulations** are being enacted or proposed across the world to address complexities around green product claims, including green steel: in 2024, India became the first country to mandate a specific definition for green steel within its jurisdiction; the EU, USA and China are also looking at definitions for low emissions steel in green products and public procurement regulations[68]. Steel market participants can expect to be increasingly subject to regulation forcing them to meet specific criteria that allow using 'green steel' and related terminology.
6. **Buyers** of green steel interviewed for the purpose of this research widely saw the green term as ambiguous and showed a clear desire for a simpler, converged definition and classification. A key driver for purchasing green steel was the reduced absolute carbon footprint associated with it, although some buyers also saw the share of recycled steel scrap used in the production of the steel they purchase as important (with higher scrap shares being more desirable).

[68] At a global level, the 'Industrial Deep Decarbonisation Initiative' (IDDI) of the Clean Energy Ministerial (a high-level forum of 29 countries to promote policies to advance clean energy technology) has launched green procurement guidelines to promote green public procurement practices, covering the importance of comparable standards and data, with an initial focus on the steel and cement sectors. See https://www.unido.org/IDDI.

Key industry recommendations

1. **Pursue convergence in definitions of green steel and related terms across standards and regulations, at a global level.** Ultimately, pursue a standard specifically for green steel. A clear, commonly accepted definition will reduce uncertainty amongst market participants around green claims and ultimately promote demand for the green product. It will also facilitate the design and implementation of policies to support green steel adoption, financing of green steel investments in new and existing sites, in turn speeding up steel sector decarbonisation.
2. **Pursue harmonisation in carbon accounting methodologies at a global level – as a minimum – if convergence on definitions cannot be achieved.** This is an essential step towards alleviating the current confusion and allow for claims and products to be compared on a like-for-like basis, across producers and regions, addressing the fundamental question underpinning all discussions around green steel, of what emissions are being taken into account behind each footprint/threshold. Initial encouraging progress has been made with this regard: the 'Steel Standard Principles'[69] initiative led by the World Steel Association and the World Trade Organisation aims to pursue 'common carbon accounting methodologies to accelerate the transition to near zero', endorsed by various standards bodies, steel producers, users, raw materials suppliers and civil society organisations.
3. **Increase transparency around emissions intensity data, at corporate, site and product levels, including on methodologies adopted.** The increasing use and publication of EPDs and LCAs in steel has greatly contributed to the availability of product carbon footprint data, but not all jurisdictions make it mandatory for producers to disclose emissions intensity data, and many companies do not currently disclose their footprints.
4. **Continue to actively prioritise the decarbonisation of existing processes and materials.** This is, ultimately, the goal that producers, users and the industry as a whole shall continue to focus on, not only by setting up emissions reduction targets and decarbonisation strategies, but also by actively implementing, delivering and speeding up on these actions.

[69] https://www.wto.org/english/tratop_e/envir_e/steelstandprincippartner_e.htm