Technical Position Paper

Structural steel and global greenhouse gas emissions

The Institution of StructuralEngineers

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This paper outlines the Institution's recommended approach to minimising greenhouse gas emissions when designing with and specifying steel. It sets out the sources of steel production's emissions, the two main aspects of decarbonisation, and a series of recommendations for structural designers and policymakers.

The paper's scope includes use of steel for all structural applications, including reinforcing steel ('rebar'), structural sections such as I-beams and tubes, plate, cold-formed light-gauge steel such as metal decking, and all types of steel, including mild, stainless and weathering. The paper has a global relevance, but it is recognised that the authors' most direct experience is based in the UK.

The paper does not consider other aspects of sustainability such as human rights or biodiversity loss, nor does it tackle the question of whether steel is the right material for a particular design.

Recommendations

The Institution recommends that structural designers should:

1. **Support and inform clients in setting appropriate carbon limits** for their project, explaining the concepts in this paper to avoid overambitious and unachievable limits being agreed that require the use of high quantities of recycled scrap steel. Check for compatibility with the embodied carbon factor limits in point 4 below.
2. **Where steel is to be used, do so as efficiently as possible and target low steel tonnages**, rather than focussing purely on low resulting carbon footprints, which could lead to overconsumption of scrap-based secondary steel (refer context below). Achieve this by working collaboratively with the wider design team, from the start of the project, to identify key design decisions that **follow the Institution's Hierarchy of Net Zero Design**[1], enabling inherent efficiencies from aspects such as closer column spacing, straightforward load-paths to ground, and efficient beam depths. Publication P499[2], written by the Steel Construction Institute and the British Constructional Steelwork Association, follows the hierarchy and provides practical guidance for designers.

continued overleaf...

[1] https://www.istructe.org/resources/blog/the-hierarchy-of-net-zero-design/

[2] https://steelconstruction.info/images/0/0d/SCI_P449.pdf

3. **Prioritise the use of reclaimed steel** where it can be used efficiently[3]. As a rule of thumb, if the reuse of reclaimed sections involves an increase of steel weight of more than 20-30% compared to an efficient new steel solution using average carbon factors, then any benefit in terms of global carbon emissions could be lost. For information on this percentage, refer to *Circular economy and reuse: guidance for designers*[4].
4. Use **generic national consumption average embodied carbon factors** in decision-making processes at early design stages, as these indicate the most likely blend of steel that will arrive on site, such as those included in the Institution's guide *How to calculate embodied carbon*[5]. A full assessment with as-procured embodied carbon factors should be undertaken post-completion in accordance with the RICS Professional Standard[6].
5. **Avoid specifying minimum percentages of scrap**, specifying the use of scrap-based Electric Arc Furnace (scrap-EAF) steel, or setting static embodied carbon factor limits ($kgCO_2e/kg$) that would encourage large amounts of scrap-EAF to be procured. Instead, embodied carbon factor limits should be set based on the percentage of scrap that has been used to produce the steel – often referred to as a sliding scale – following the approach laid out by ResponsibleSteel[7] and SteelZero[8].
6. **Specify steel from producers aligned with dual decarbonisation commitments** such as SteelZero, ResponsibleSteel and SBTi.

The Institution recommends that policymakers should:

1. **Understand how steel emissions relate to your country's net zero pathways (and consumption-based footprint)**, forecasting future use and emissions, and thus steel's emissions relative to your national net zero trajectory[9].
2. When setting embodied carbon limits, **enable designers to use national in-country consumption average ECFs** to meet them at early stages of design, to disincentivise the over-use of recycled scrap steel.
3. Work in collaboration with steelmakers to **invest in technologies or global supply chains that will lead to the decarbonisation of ironmaking and primary steelmaking**, rather than focussing too much on scrap recycling. This investment could include support to other countries that are producing low-carbon iron, that could be exported to the policymaker's region for use in local EAFs.
4. Use **publicly funded projects to accelerate the adoption** of the policies contained within this paper, where appropriate to do so.

Context

Globally, steelmaking is responsible for 7-9% of global carbon emissions[10]. Around half of all steel produced goes into buildings and infrastructure. Minimising steel-related emissions is key if the world is to decarbonise on a 1.5°C trajectory and reach net zero by 2050.

At least 90% of the emissions related to global steelmaking come from the production of 'primary steel', reducing iron ore into pure iron, and then creating steel.

[3] The Institution maintains a circular partnerships database at https://www.istructe.org/resources/climate-emergency/circular-partnerships-database/

[4] https://www.istructe.org/resources/guidance/circular-economy/

[5] https://www.istructe.org/resources/guidance/how-to-calculate-embodied-carbon/

[6] https://www.rics.org/profession-standards/rics-standards-and-guidance/sector-standards/construction-standards/whole-life-carbon-assessment

[7] https://www.responsiblesteel.org/

[8] https://www.theclimategroup.org/steelzero

[9] In some countries, this has led to adoption of policies aligned with the 'sliding scale' or 'dual decarbonisation' approach referenced in footnotes 7 and 8, e.g. Germany (www.wvstahl.de) and China (www.c2fsteel.com)

[10] https://worldsteel.org/data/world-steel-in-figures-2024

The main form of primary steelmaking is blast furnace-basic oxygen furnace steelmaking ("BF-BOF"). Here, iron ore is reduced into iron in a blast furnace using coke (a processed form of coal), before converting this into steel in a basic oxygen furnace. In 2023, 71% of the world's steel was produced in this way[10].

The next most common form of primary steelmaking starts with direct reduction ironmaking, which uses natural gas to reduce iron ore into iron. This is typically then fed into an electric arc furnace to turn it into steel ("DRI-EAF"). In 2023, 7% of the world's steel was produced using this method.

Most of the remaining steelmaking is classed as secondary steelmaking, as the main ingredient is scrap steel. The scrap is put into an electric arc furnace, often mixed with a small quantity of iron produced by one of the above methods ("scrap-EAF"). In 2023, 22% of the world's steel was produced using this method.

As global scrap supplies are already almost fully recycled into secondary steel each year[11], it is ineffective to advocate for increased recycling and decreased primary steel production. Instead, a dual decarbonisation approach must be taken – reducing the emissions related to both primary and secondary production.

As 90% of the steel industry's emissions come from primary production, this is where the main focus should be. More information as to the origin of carbon emissions for steel can be viewed on the Institution's website[12].

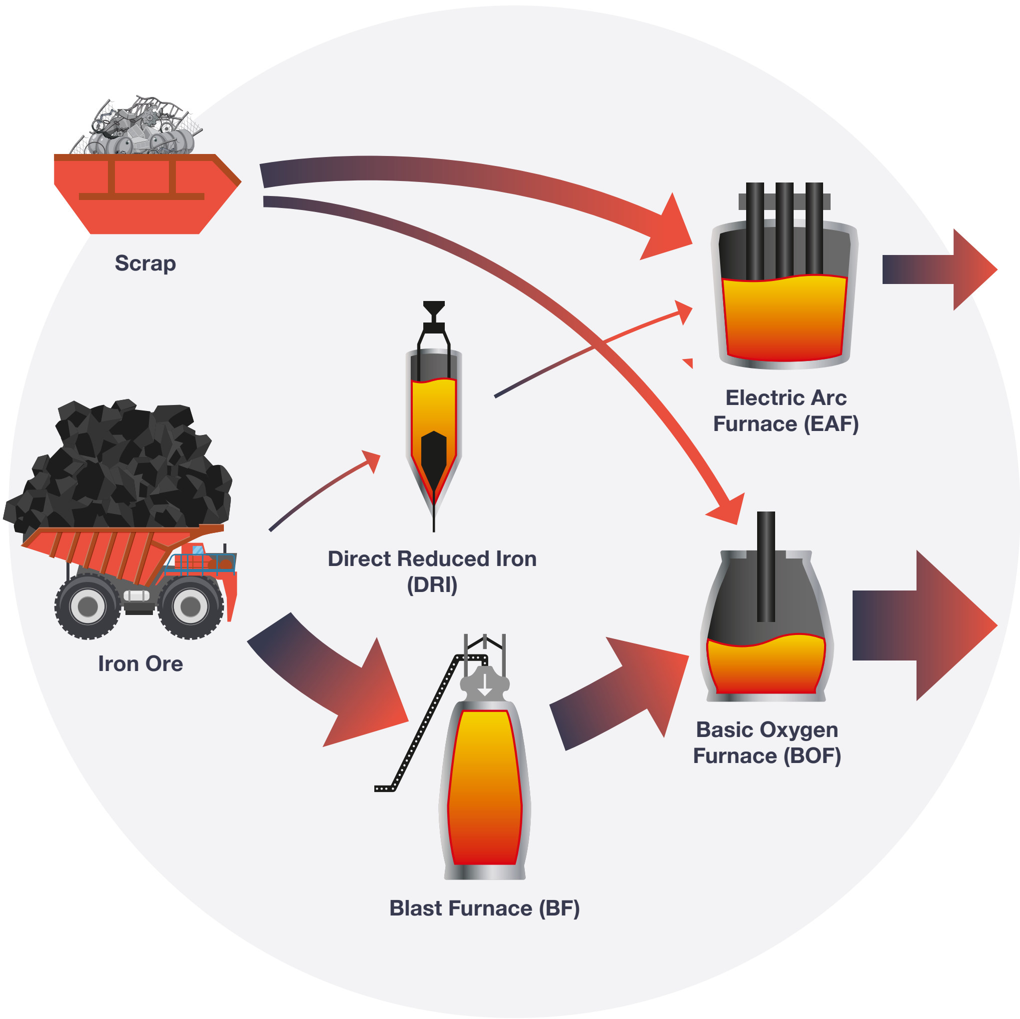

Figure 1: Main steel production routes (arrow thickness indicates approximate global quantities)

[10] https://worldsteel.org/data/world-steel-in-figures-2024
[11] https://www.istructe.org/resources/guidance/the-role-of-scrap-in-steel-decarbonisation/
[12] https://www.istructe.org/resources/guidance/arup-material-guides/

Reducing greenhouse gas emissions related to structural steel at a global scale

Both primary steelmaking and scrap recycling need to be understood to effectively reduce steelmaking emissions at a global level. For more information on this, refer to the cross-industry paper 'The role of scrap in steel decarbonisation: Key facts and considerations for the construction sector' hosted on the Institution's website[11].

1. Decarbonising primary steelmaking

More than 90% of global steelmaking emissions come from primary steelmaking, mostly from Blast Furnace Basic Oxygen Furnace (BF-BOF) production. As such, this must be the focus of the industry's decarbonisation.

Emissions arise principally from both the burning of fossil fuels to create heat, and from the chemical reactions that take place as iron ore is reduced into iron. However, as insufficient scrap is available to meet global steel demand (see section on recycling below), primary steelmaking will continue to be the dominant process long after 2050. The industry must therefore focus on decarbonising the production of primary steel, through both incremental short-term changes to BF-BOF production, and eventually either replacing it entirely or retrofitting it with technology that eliminates emissions.

As demonstrated in Figure 2, there is considerable variation in levels of emissions for steelmakers using the same technology and equal amounts of scrap content. This demonstrates that incremental technology improvements can help reduce emissions in the short term, and should be encouraged. ResponsibleSteel[13] use a similar approach to this figure to identify the most carbon-efficient steel producers today.

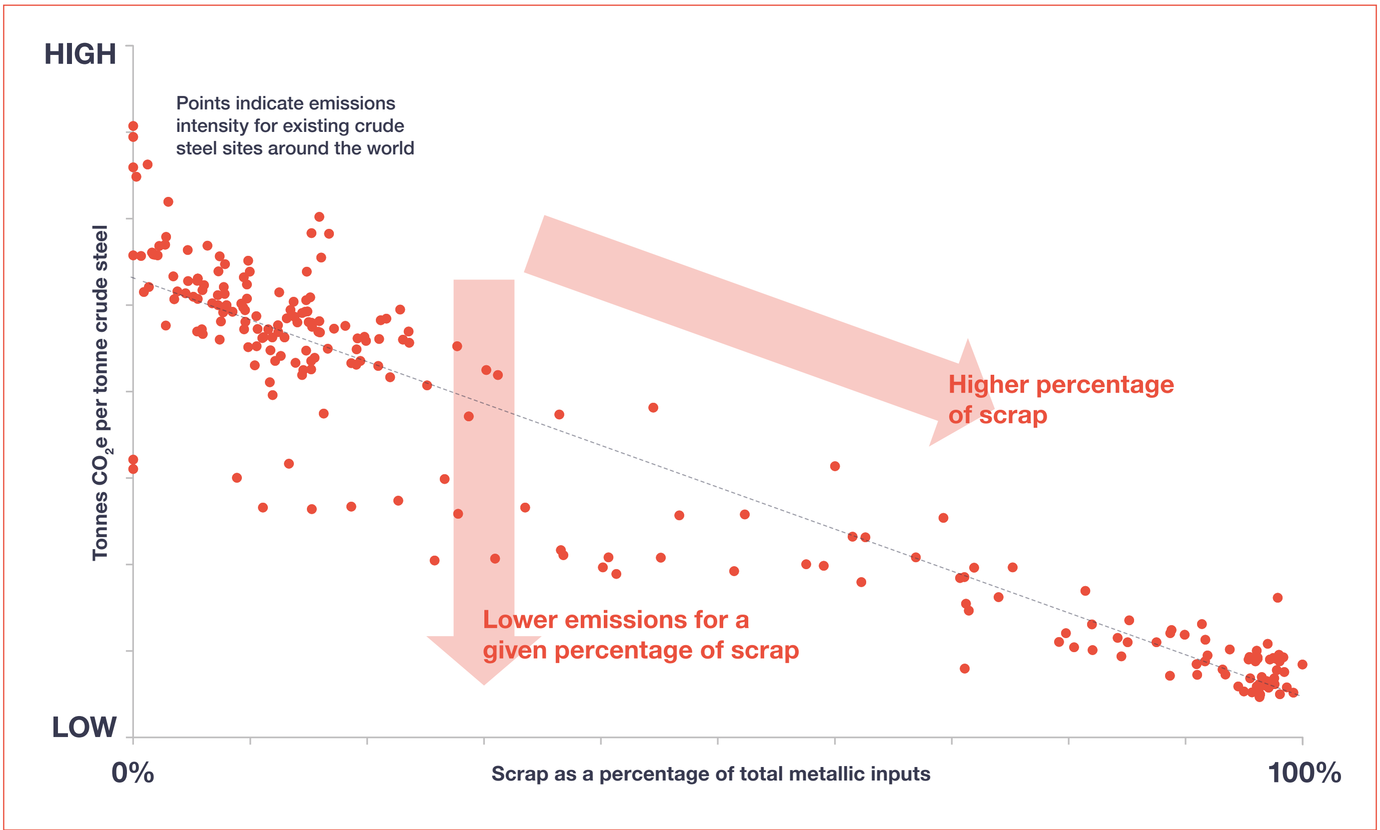

Figure 2: Points indicating emissions for different steel sites globally[11]

[13] https://www.responsiblesteel.org/

Longer-term, a number of alternative technologies for primary steel production are being developed at scale.

As mentioned, a small amount of primary steel is produced by DRI-EAF methods, for example in the USA and the Middle East. Where natural gas is used (instead of the coking coal used in BF-BOF, and in some coal-fired versions of DRI), emissions are typically reduced, as some of the chemical reactions result in water vapour rather than harmful GHG emissions. Hydrogen-based DRI (HDRI), which has been demonstrated at scale, reduces the GHG of iron further still as all of the reduction reaction has a water vapour by-product. Where such hydrogen has been produced using low- or zero-carbon electricity (so-called ‘green hydrogen’), this results in low- or zero-carbon iron and steel.

Other decarbonisation routes such as electrolysis (a similar method to aluminium-making) and retrofitting carbon capture and storage to existing BF-BOF are also being explored by the industry. These technologies can accommodate the use of less-pure iron ores than is needed for HDRI, and don’t rely on the use of green hydrogen, which is not yet available at scale.

Due to the time and investment involved in this, such a transition will require policymakers, investors and supply chains to work together with the construction industry to provide simultaneous demand-side pull and supply-side momentum.

2. Recycling scrap steel.

Most scrap steel is recycled through the use of an Electric Arc Furnace (EAF), but around a third is also recycled through BF-BOF steel production.

Recycling scrap through an EAF typically emits around one third of the Greenhouse Gas (GHG) emissions compared to producing primary steel in a BF-BOF. As such, maintaining the already high recycling rate of global scrap is an important aspect of keeping global steelmaking emissions as low as possible.

Around 30% of all steel demand is satisfied through recycling. Scrap steel is a globally constrained material that is already near-fully utilised, with around 80-85% of all scrap being recovered and recycled each year, the remainder being economically unviable to recover[11]. As such, increasing its use in one location will result in a decrease in use somewhere else in the world – and so global emissions will not significantly reduce. While the volume of scrap available for recycling is expected to increase with time, estimates suggest that at most 50% of all steel production could come from scrap recycling by 2050, resulting from today’s existing steel products reaching the end of their life[14] and being sent for recycling.

Scrap recycling using an EAF is an electrified process, and so most related emissions are due to the carbon footprint of the associated electricity. The main route to decarbonising secondary steelmaking is therefore through decarbonisation of the electricity grid. Further savings in emissions come from recycling close to the source of the scrap (saving on transport emissions) and through good sorting of materials (reducing energy required to recycle). Material sorting also increases the quality of the scrap being recycled, better moving towards a circular economy.

3. Efficient use of steel.

Given the constraints on supply of lower-carbon primary steel, the quickest way to reduce emissions when using steel is to use (and reuse) the material as efficiently as possible. The Institution’s Hierarchy of Net Zero Design[15] drives inherent carbon efficiency in the design through prioritising reuse where possible, followed by sensible structural configuration and optimisation. Steel Construction Institution Publication P499 provides practical guidance towards achieving this[16].

Note also that while increasing future circularity and reusability is of vital importance, this should not come at the expense of efficiency today. The future is uncertain, while today’s emissions are well-understood. Instead, aim to create future flexibility and usefulness through robust detailing that enables strengthening works to be easily undertaken.

[14] Due to everything from demolition of buildings, cars and ships being sent for scrap, and planned obsolescence of household goods such as washing machines.
[15] https://www.istructe.org/resources/blog/the-hierarchy-of-net-zero-design/
[16] https://steelconstruction.info/images/0/0d/SCI_P449.pdf

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