The role of scrap in steel decarbonisation:

Key facts and considerations for the construction sector

April 2025

1. Key messages

1. Maximising the recovery and recycling of ferrous scrap is fundamental to keeping the global steel industry's greenhouse gas emissions as low as possible.

2. However, ferrous scrap is a constrained resource, limited by levels of steel production in the past, lifetime of steel products, and the rate of recovery of products reaching their end of life today. Around 80-85% of all steel is currently recovered and recycled at the end of its life in use, with little evidence to suggest a substantial increase on this percentage is achievable (even when the overall volume recovered/recycled increases).

3. Global scrap availability is currently only sufficient to meet around one third of global steel demand, a figure expected to rise to around 50% by mid-century, due to the steady increase in historic steel production and subsequent volume of scrap becoming available, rather than any significant increase in recovery rates. Decarbonising steelmaking processes, whether they are based on the use of scrap or primary iron, is therefore critical to global steel decarbonisation.

4. To reduce global emissions, policy, investment, and incentives must therefore focus on a **dual decarbonisation approach** to steelmaking, decarbonising both the production of new steel and the recycling of scrap. Production of low/zero-carbon iron, decarbonisation of electricity production, and improving the quality of scrap being recycled are all required to deliver a decarbonised steel sector. This will require significant time and investment at national scales, and a level global playing field.

5. The construction industry can support decarbonisation most effectively by using steel more efficiently in design and by specifying steel from producers aligned with a dual decarbonisation approach, such as those acting in accordance with the initiatives listed in this paper. Supporting steel recovery and reuse, and designing for future reuse and disassembly, will also help reduce emissions. Specifying project- or national-level limits/targets that promote increased use of recycled steel is unlikely to lead to significant global reductions in greenhouse gas emissions.

2. Executive Summary

Of the two billion tonnes of steel produced each year, around half is used by the construction industry. This steel is a mixture of primary steel produced mostly using iron ore, and secondary steel produced mostly from ferrous scrap. This paper is the product of a literature review undertaken by a group of experts drawn from across the steel industry, construction sector, and academia, who wished to understand how much of all ferrous scrap in circulation is successfully recycled, how this might change in the future, and what this means for the construction industry. This paper is relevant to all those wishing to reduce greenhouse gas (GHG) emissions through their use of constructional steel. This includes, but is not limited to, policymakers, investors, local authorities, clients, developers, designers, contractors, and the iron and steel supply chain.

The use of ferrous scrap in global steelmaking is well-established and the material is traded internationally. Producing steel by recycling ferrous scrap currently produces approximately 30% of the GHG emissions compared to producing primary steel from iron ore, tonne for tonne. Evidently, maximising the recovery and recycling of global scrap supplies is an important aspect of keeping global steelmaking emissions as low as possible.

However, the review indicates that around 80-85% of all post-consumer ferrous scrap that becomes available each year (through steel reaching the end of its life) is already currently recycled. While there is some uncertainty around this figure, we have found no evidence of significant stockpiles of unrecycled ferrous scrap, and note that the economical maximum will never be 100% (some scrap will always be uneconomical to recover, such as that which is left in foundations, under water, or is contaminated). As such, we consider ferrous scrap to be highly utilised already.

Our review also indicates that global steel demand is currently three times as high as global ferrous scrap supply. Both steel demand and ferrous scrap supply are anticipated to grow. Projections for 2050 are that demand will be closer to two times as high as scrap supply: but this means that half the world's steel will still need to be made from iron ore.

This demonstrates that ferrous scrap will continue to be a constrained resource, and will continue to be close to fully utilised globally, even as the absolute quantity of available scrap increases. An increase in its use in one location is therefore highly likely to result in a reduction in use elsewhere, negating any overall GHG emission benefits.

This paper therefore concludes that while global supplies of ferrous scrap must continue to be fully utilised to reduce overall GHG emissions from the steel industry, increasing scrap consumption in any single location is unlikely to significantly change the total amount of ferrous scrap being recycled globally. Steel with a high recycled scrap content (such as that generated by most electric arc furnaces) should be used by the construction industry where appropriate, but it should not be specified purely in the hope of reducing global greenhouse gas emissions. This also means that where project-level carbon limits or targets are met through specifying high percentages of recycled steel, this won't lead to global GHG emission reductions.

Instead, the authors recommend that a **dual decarbonisation** approach is followed, decarbonising primary steelmaking that uses iron ore, and decarbonising the steel recycling process at the same time. This means increasing the supply of low- and zero-carbon iron production, improving the grade (quality) of scrap through better sorting of ferrous scrap, and decarbonising electricity supplies. Due to the time and investment involved in this, such a transition needs to be led by policymakers, investors and supply chains (with some policies already starting to implement these changes to varying levels). While this transition is happening, designers and specifiers should specify steel from producers aligned with the dual decarbonisation approach, and should further reduce GHG emissions by minimising the total tonnage of steel products specified, rather than just substituting for products with higher recycled content.

3. Introduction

Global steel demand is around two billion tonnes of steel each year, half of which is used by the construction industry[1]. The global iron and steel industry accounts for 7-9 % of global carbon emissions[2]. Steel is critical both for achieving net zero emissions (e.g., through its use in creating infrastructure for renewable energy production) and for advancing human and economic development across the world. Global steel use is expected to continue to increase until at least 2050, and therefore decarbonising steelmaking is essential if the world is to achieve net zero emissions by then.

Recycled ferrous scrap has been used within the steelmaking process since the 19th century. Scrap is generated during iron and steelmaking, throughout the manufacturing process of final/consumer products, and at the end-of-life of steel-containing products such as buildings, vehicles, and white goods.

Today, producing steel by recycling ferrous scrap results in around 30% of the greenhouse gas (GHG) emissions compared to producing primary steel from iron ore using coke, and so maximising the recovery and recycling of global scrap supplies is an essential aspect of keeping global steelmaking emissions as low as possible.

Ferrous scrap meets around one third of today's steel demand[3]. This proportion is expected to rise, but only to the point of meeting around half of total demand by 2050, even as the absolute quantity of available ferrous scrap grows. This is mainly because, by definition, the supply of end-of-life scrap will always lag behind new steel production, and will therefore fall short of meeting demand for as long as production is growing.

Therefore, while it is important to continue to recover and recycle our ferrous scrap worldwide, we need to look beyond scrap use if we are to succeed in reducing GHG emissions at a global level.

3.1 Scope

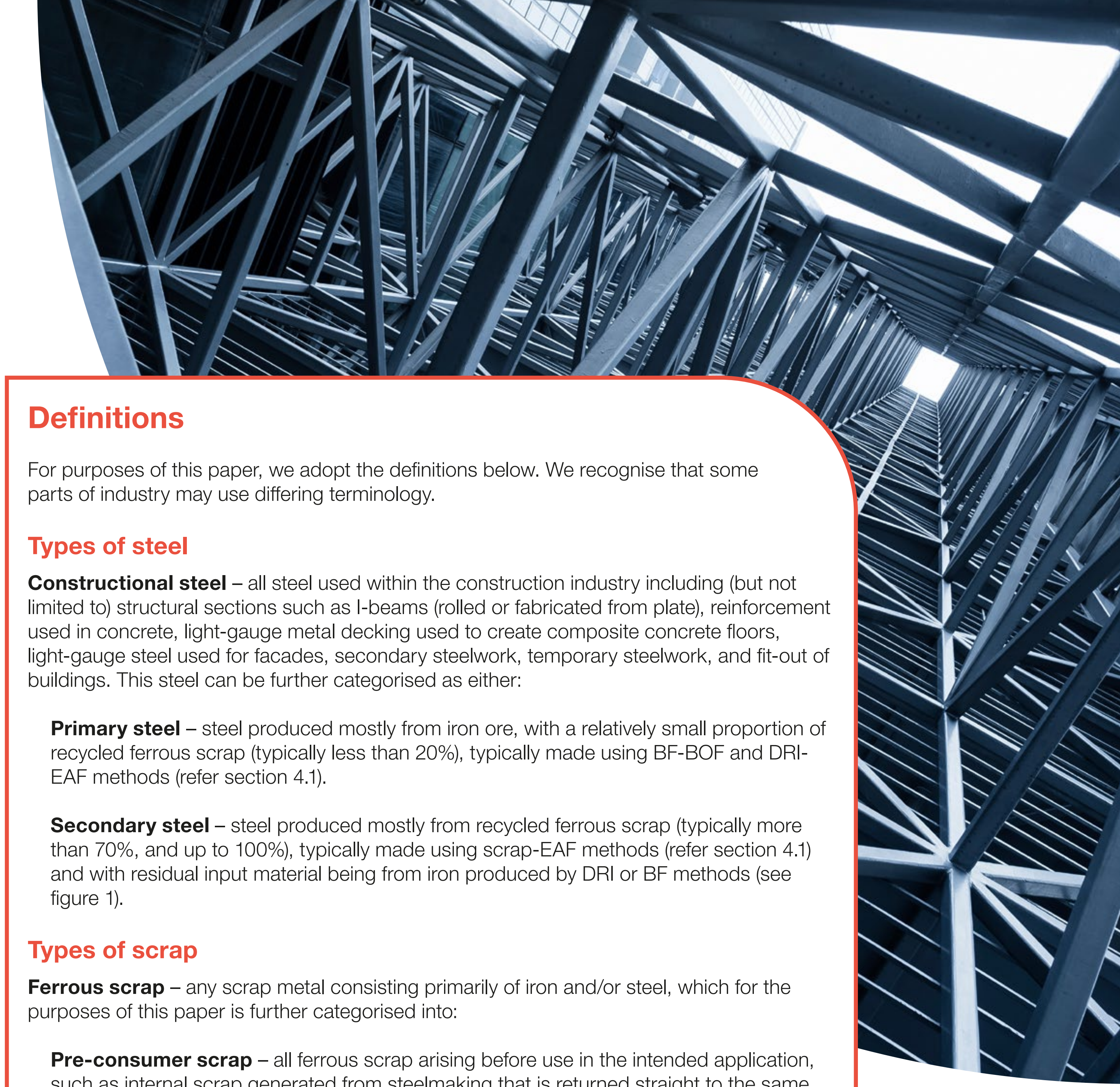
This briefing paper aims to provide:

1. An objective overview of global ferrous scrap availability and steel demand, both now and in the future.
2. An appraisal of the relevance of this to the UK market.
3. Recommendations for the use of ferrous scrap in steelmaking to reduce global GHG emissions.

The paper focuses on the impact of scrap availability and use with respect to global GHG emissions only. The authors wish to stress that this is only one aspect of sustainability, and that sustainable steel must account for other aspects such as resource depletion, social equity, biodiversity, etc.

This paper is relevant to all those involved in the design, specification or procurement of constructional steel, including policymakers, investors, local authorities, clients, developers, designers, contractors, and the iron and steel supply chain. It covers the use of constructional steel within the construction industry, including reinforcement steel used in concrete construction, as this supply chain is interlinked with the production of other constructional steel. When referring to ferrous scrap (or just 'scrap'), we refer to all sources of ferrous scrap from all industries and market sectors – as they are all included within the same global supply chain – and so the paper's conclusions are also expected to be true for these other markets.

While the data reviewed are global, it should be noted that the authors' most direct collective experience is based on the UK market.



Definitions

For purposes of this paper, we adopt the definitions below. We recognise that some parts of industry may use differing terminology.

Types of steel

Constructional steel – all steel used within the construction industry including (but not limited to) structural sections such as I-beams (rolled or fabricated from plate), reinforcement used in concrete, light-gauge metal decking used to create composite concrete floors, light-gauge steel used for facades, secondary steelwork, temporary steelwork, and fit-out of buildings. This steel can be further categorised as either:

Primary steel – steel produced mostly from iron ore, with a relatively small proportion of recycled ferrous scrap (typically less than 20%), typically made using BF-BOF and DRI-EAF methods (refer section 4.1).

Secondary steel – steel produced mostly from recycled ferrous scrap (typically more than 70%, and up to 100%), typically made using scrap-EAF methods (refer section 4.1) and with residual input material being from iron produced by DRI or BF methods (see figure 1).

Types of scrap

Ferrous scrap – any scrap metal consisting primarily of iron and/or steel, which for the purposes of this paper is further categorised into:

Pre-consumer scrap – all ferrous scrap arising before use in the intended application, such as internal scrap generated from steelmaking that is returned straight to the same furnace, home scrap generated within steelworks, and manufacturing or prompt scrap generated during the production of final steel products in manufacturing plant including offcuts from fabrication.

Post-consumer scrap – ferrous scrap arising after use in the intended application, at the end of product life, for example from the demolition of buildings or scrapping of cars. Also known as 'obsolete scrap' or 'end of life scrap'.

Rates

Steel recovery rate – the percentage of potentially available ferrous scrap that is recovered (unrecovered scrap is almost entirely post-consumer scrap, and may include items such as steel in foundations, undersea structures, steel lost to landfill, steel exposed to radiation, etc.)

Steel recycling rate – the percentage of potentially available ferrous scrap that is recycled. This will be the same as the steel recovery rate, if all recovered steel is recycled.

Recycled content – the percentage of a steel product that was made from recycled ferrous scrap. Pre-consumer and post-consumer recycled content may be calculated and reported separately.

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[1] https://worldsteel.org/steel-topics/statistics/world-steel-in-figures-2022 and https://www.statista.com/statistics/1107721/steel-usage-global-segment

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

[3] Steel Arising, Opportunities for the UK in a transforming global steel industry (2019). University of Cambridge. Available at: 10.17863/CAM.40835

4. A global overview of steel demand and ferrous scrap supply

4.1 Steel production

Global crude steel production was 1.9 billion tonnes in 2023[4] and continues to rise, mainly as a consequence of industrialisation and population growth in developing economies and particularly, over recent years, growth in China which accounted for 54% of all steel production in 2023[5].

Today steelmaking is dominated by two main production processes:

1. **Blast furnace-basic oxygen furnace (BF-BOF)**. This involves the reduction of iron ore in a blast furnace (BF) using coke (a processed form of coal) to produce liquid iron. The iron is then converted into steel in the basic oxygen furnace (BOF). The blast furnace accounts for the majority of the GHG emissions associated with the BF-BOF steelmaking process (through both the burning of fuel and the chemical process of reducing the ore) and therefore is the priority for decarbonisation. In 2023, 1345Mt, 71% of the world's steel, was produced using this method[6].
2. **Electric arc furnace (EAF)**. This uses an electric arc furnace to melt ferrous scrap, which may be combined with a quantity of iron from primary production methods.
    - **Scrap-based EAF**. This production method reduces the need for primary production of iron to happen first by being mostly based on recycling ferrous scrap. In 2023, approx. 408Mt, 22% of the world's steel was produced by this method[6].
    - **Direct reduction ironmaking with EAF (DRI-EAF)**. This uses natural gas based direct reduction methods to produce iron from iron ore, which is then typically fed into an EAF (usually in combination with some scrap). In 2023, approx. 137Mt, 7% of the world's steel, was produced by this method[6].

It is important to note that both BOFs and EAFs typically take a mixture of virgin iron and ferrous scrap; on average BOFs use a mix of input materials containing around 12% scrap, but it is possible to use as much as 25%. EAFs use on average 71%, but it is possible and common to use 100%[7]. It is also possible to feed DRI iron into a BOF, or to feed BF iron into an EAF, although these routes are generally uncommon today. Decarbonisation of the steel industry will likely result in more combinations of routes in the future, with different sources of iron and scrap feeding into different steel production processes.

The global dominance of BF-BOF production is driven by the constrained supply of ferrous scrap and growing global demand for steel at scale, particularly in developing economies where ferrous scrap supply is insufficient to meet new steel demand. In some regions, electricity supply or price issues also contribute to the dominance of BF-BOF over EAF. Finally, it's worth noting that replacement cycles of most furnaces are measured in decades, and so this dominance is set to continue in the short term.

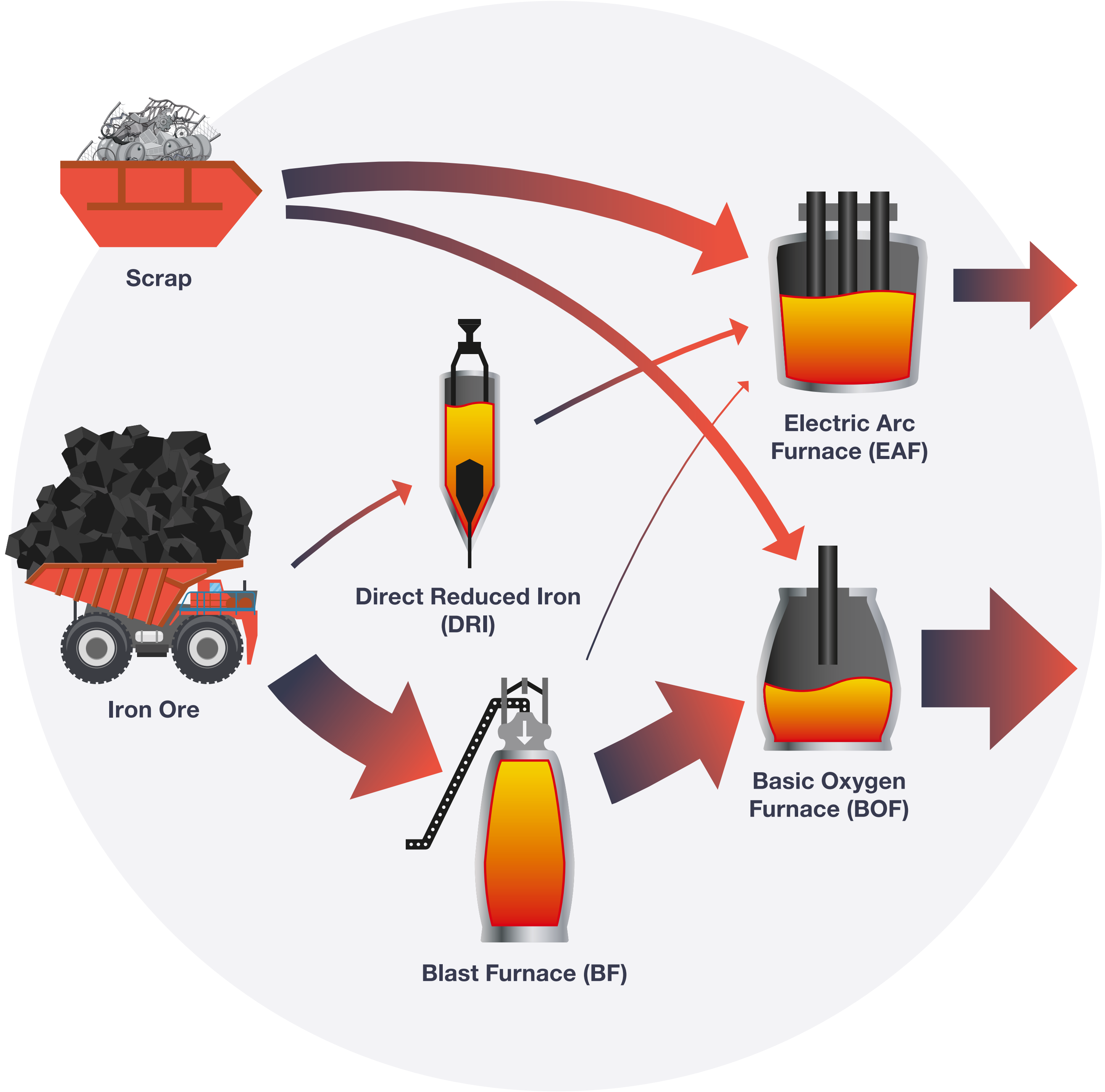

FIGURE 1: Main steel production routes (arrow width proportional to approximate global quantities).

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[4] https://www.bir.org/images/BIR-pdf/Ferrous_report_2017-2021_lr.pdf and https://worldsteel.org/steel-topics/statistics/world-steel-in-figures-2022

[5] https://worldsteel.org/data/world-steel-in-figures-2024/#major-steel-producing-countries%3Cbr%3E2022-and-2023

[6] https://worldsteel.org/data/world-steel-in-figures-2024 for data both on BOF:EAF production split for steelmaking, and on DRI:scrap ratio for feedstock into BOF and EAF. Production percentages here assume all DRI enters EAF steelmaking, though it is recognised that a small amount is currently used in BOFs too.

[7] https://worldsteel.org/wp-content/uploads/Fact-sheet-raw-materials-2023.pdf

4.2 Ferrous scrap availability

Global scrap consumption in the last few years has been in the order of 650 million tonnes, approximately one third of the level of overall global steel production[8]. While iron ore supply can flex with demand for new steel, the availability of ferrous scrap is a function of historic steel production and the arisings of scrap at the end of life of steel products. Currently around half of the total quantity of ferrous scrap is pre-consumer[9], close to 100% of which is recovered and recycled. The remainder is post-consumer. Ferrous scrap availability is therefore fundamentally constrained by the quantity of steel that was produced in the past, and the length of life of those products.

Post-consumer steel recovery and recycling rates are difficult to determine accurately, varying both regionally and by product type, and many countries do not collect or publish data. worldsteel estimates that on average, the post-consumer recovery rate across all sectors is around 80-85%, and that all of this is recycled[10].

The remaining 15-20% of ferrous scrap arising from products reaching end-of-life is unrecoverable today based on economic or practical reasons (e.g., ships that have sunk, or reinforcement inside foundations that remain buried deep in the ground, or contaminated steel such as that used by the nuclear industry). It may become economically viable to recover some of this in the future in response to an increased demand for scrap, though it is unlikely for the maximum possible recovery rate to ever be as high as 100% as some scrap will always be uneconomical to recover.

Variation

While different industries and sectors have varying recovery and recycling rates, all ferrous scrap is suitable for use in some form of constructional steel, once properly sorted and processed.

Recovery rates also vary by region, as what is uneconomic to recover in one region may be economically viable in another, due to the relative cost of labour and value of scrap.

Uncertainty

There is uncertainty around the 80-85% range of estimates for ferrous scrap recycling (which is actually a combination of recovery and recycling rates). A figure of 83% is often quoted from the worldsteel publication, ‘Sustainable steel: at the core of a green economy’, published in 2012. This figure is generally agreed with in other more recent literature, though worldsteel and the authors of this paper recognise that it is difficult to scientifically quantify such a figure given the complexities of global steel markets. This is due to the huge number of applications using steel, the difficulty involved in estimating the quantity of steel in all products reaching their end of life in a given year, a lack of data relating to stockpiles, corrosion, wear and tear, unrecoverable scrap, informal trade, and informal recycling. We have therefore chosen to state a range in this paper, rather than a specific figure.

worldsteel also notes that the economic value and ease of recovery of ferrous scrap means that all recovered steel has always been highly recycled, therefore arguing that it is the recovery rate itself that instead dictates the 80-85% figure (i.e., the assumption is that 100% of all scrap recovered goes on to be recycled). Neither worldsteel nor the authors of this paper have seen any evidence to demonstrate that at the global level, the quantity of ferrous scrap going unrecovered each year is significantly higher than estimated.

We conclude that despite the uncertainty, the recovery rate of ferrous scrap is still likely to be in the range of 80-85% of that which is potentially available from products reaching end of life. Assuming that the maximum possible recovery rate is less than 100%, this leaves little room to increase ferrous scrap recovery significantly – with the law of diminishing returns adding to the economic costs of doing so.

Other losses of material

Finally, it may be noted that some ferrous material is lost from the cycle of scrap recovery and recycling through air emissions and in slag. These losses may be between 3% and 8%[i]. They do not affect the estimates of the scrap recycling rate, or the 80-85% figure given above, but they do reduce the extent to which scrap can fully substitute the primary production of steel.

4.3 Ferrous scrap grade

Not all ferrous scrap is of the same quality or grade, as poorly-sorted/processed scrap will include higher levels of impurities from non-steel constituents (e.g., copper, where not removed from motors before recycling). The grade depends on the source of scrap, access to processing machinery, and the economic incentive for the recycling industry to sort and separate it. Pre-consumer scrap is cleaner and better sorted, and therefore of higher value than post-consumer scrap.

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[8] The Bureau of International Recycling, Ferrous Division ‘BIR Global Facts and Figures, 13th edition, gave a figure of 630 MT of scrap consumption for 2019. Worldsteel fact sheet (“Scrap use in the steel industry”, 2021) gave a figure of 650 MT for 2021. Those figures translate to an average recycled content of 34%.

[9] US Geological Survey, Mineral Commodities Summaries, January 2023 and Daehn et al (2018), DOI: 10.1021/acs.est.7b00997

[10] The worldsteel publication ‘Sustainable steel: at the core of a green economy’ (2012) shows a figure of 83%.

[i] Dovetail Partners, Understanding Steel Recovery and Recycling Rates and Limitations to Recycling (2015)

All grades of recycled ferrous scrap can be used by steel mills to generate different forms of constructional steel – higher grade scrap is typically used for flat plates and hollow tubes, while lower grade scrap is typically used to produce reinforcement – normally for economic reasons. Construction is one of the industries that can accommodate high levels of impurities[11].

However, the recycling industry should aim to improve the quality of scrap sorting going forwards (as is being done by some parts of industry already). This brings two benefits:

1. Lower levels of impurities means that less energy is required to recycle the scrap and less slags and/or waste is generated.
2. It also ensures that the quality of scrap in circulation is high, maximising the options as to what it can be used for.

This requires active collaboration between the metal recycling industry and the steel mills working together to produce higher grade recycled inputs to enable the production of higher-grade new steel outputs.

4.4 Projections of future ferrous scrap use

Global steel demand is expected to increase in the future, before reaching a plateau once a certain amount of steel is used annually per person. While steel production continues to increase over time, scrap supply will always lag behind. Once production has plateaued, and enough time has passed for annual scrap generation to have increased to match this level, it may be possible to meet almost all steel demand through the recycling of ferrous scrap. However, such a ‘steady state’ would require 100% recovery of scrap each year, and existing 3-8% material losses in recycling would need to be eliminated. It is also noted though that if this plateau were to happen, it is unlikely this would occur until the latter part of this century[12].

Projections typically expect 2050 steel demand to range from around 2000Mt up to 2600Mt[13]. The level of production, as well as the expected date when demand eventually plateaus, are of course hard to predict.

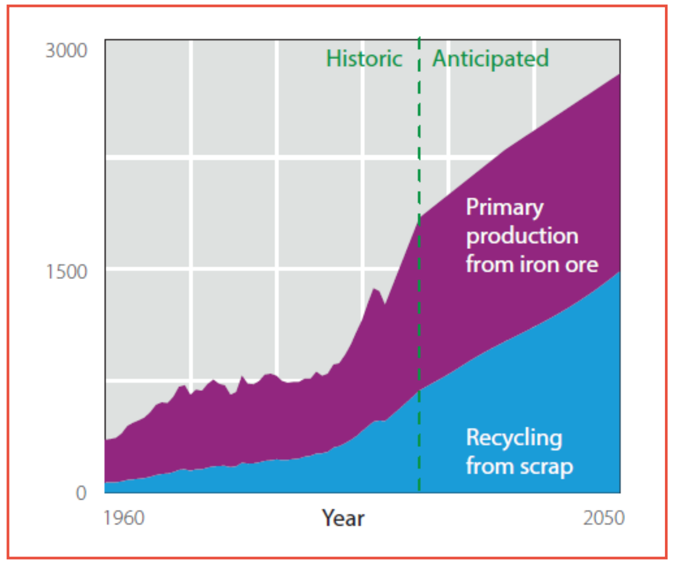

FIGURE 2: Predicted future scrap use.[16]

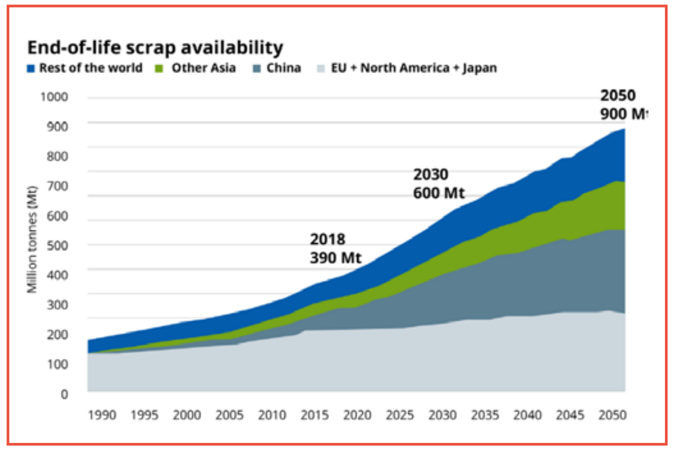

FIGURE 3: Predicted global end-of-life scrap availability.[14]

Projections for the increase in the amount of scrap inevitably follow projections for the increased production of steel and assumptions about the rate of scrap recovery. A study by worldsteel indicates available scrap increasing to 900Mt in 2050[14]. Most studies indicate that demand for ferrous scrap will continue to far outstrip supply for decades to come[15].

Studies generally tend towards a prediction that by 2050 around half of all steel demand could be met through the recycling of ferrous scrap – refer Figures 2 and 3. However it is hard to determine the certainty of such predictions. Increasing the lifespan of existing steel products and the use of reclaimed steel in construction reduces scrap availability, however if this leads to an

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[11] How will copper contamination constrain future global steel recycling?’ Daehn et al, Environmental Science and Technology, 2017, 51, 6599-6606, DOI: https://doi.org/10.1021/acs.est.7b00997; Cooper et al (2020) The potential for material independence and circularity in the US Steel Sector, https://onlinelibrary.wiley.com/doi/abs/10.1111/jiec.12971

[12] Pauliuk et al., The Steel Scrap Age, Environmental Science & Technology 2013 47 (7), 3448-3454, DOI: 10.1021/es303149z

[13] International Energy Agency, https://www.iea.org/reports/iron-and-steel-technology-roadmap [accessed 10 January 2025]

[14] https://worldsteel.org/climate-action/climate-change-and-the-production-of-iron-and-steel

[15] https://rmi.org/wp-content/uploads/dlm_uploads/2022/05/steel_yourself_implications_of_peak_demand_in_energy_transition.pdf

[16] Steel Arising, Opportunities for the UK in a transforming global steel industry (2019). University of Cambridge. Available at: 10.17863/CAM.40835

overall decrease in steel demand then the percentage of demand met through recycling could increase.

Either way, all studies suggest that primary steelmaking will still be required at a significant scale through to at least mid-century, the target date by which the global steel industry needs to decarbonise.

4.5 The limits to ferrous scrap in decarbonising steelmaking

Where a resource is globally constrained and already highly utilised, it offers limited opportunity to increase its use further. Any local increase in use will likely result in a reduction in use elsewhere, balancing each other out overall. A simplification of this principle is shown in Figure 4.

The previous sections demonstrate that recovery and recycling rates for ferrous scrap are already very high. This high recycling rate has been driven by economic factors independent of any kind of demand for 'green' steel to combat climate change. It also demonstrates that current scrap availability is only sufficient to meet around a third of global steel demand, a proportion that is projected to increase to only 50% by 2050.

There is some uncertainty about the quantity of potentially recoverable ferrous scrap which is currently not recovered each year. However, no evidence exists to suggest there are large stockpiles available, and the scale of uncertainty is not large enough to affect the conclusions that ferrous scrap is a constrained and highly utilised resource.

Ferrous scrap must continue to remain highly utilised to minimise overall industry emissions, but the fact that it is constrained and highly utilised means that any increase in the amount of scrap being used in one locality is more likely to result in a decrease in its use elsewhere, rather than a decrease in overall global emissions.

Therefore, instead of trying to increase scrap supplies to individual locations, or on specific projects, global efforts must focus on decarbonising steelmaking itself – both primary and secondary. This requires a **dual decarbonisation approach**:

1. For ironmaking and primary steelmaking this means increasing the supply of low/zero-carbon iron production from iron ore.

2. For secondary steelmaking this means investing in the decarbonisation of the electricity grid supplying those furnaces, along with increasing the quantity and quality of scrap being fed into them.

The transition to low-carbon primary and secondary steelmaking requires significant increases in global energy production, along with significant financial investment and time. As such, steel must be used efficiently in the interim period. For designers and specifiers, this means aiming to reduce GHG emissions by minimising the total tonnage of steel products used through efficient design and reuse, rather than by substitution of products for those with higher recycled content.

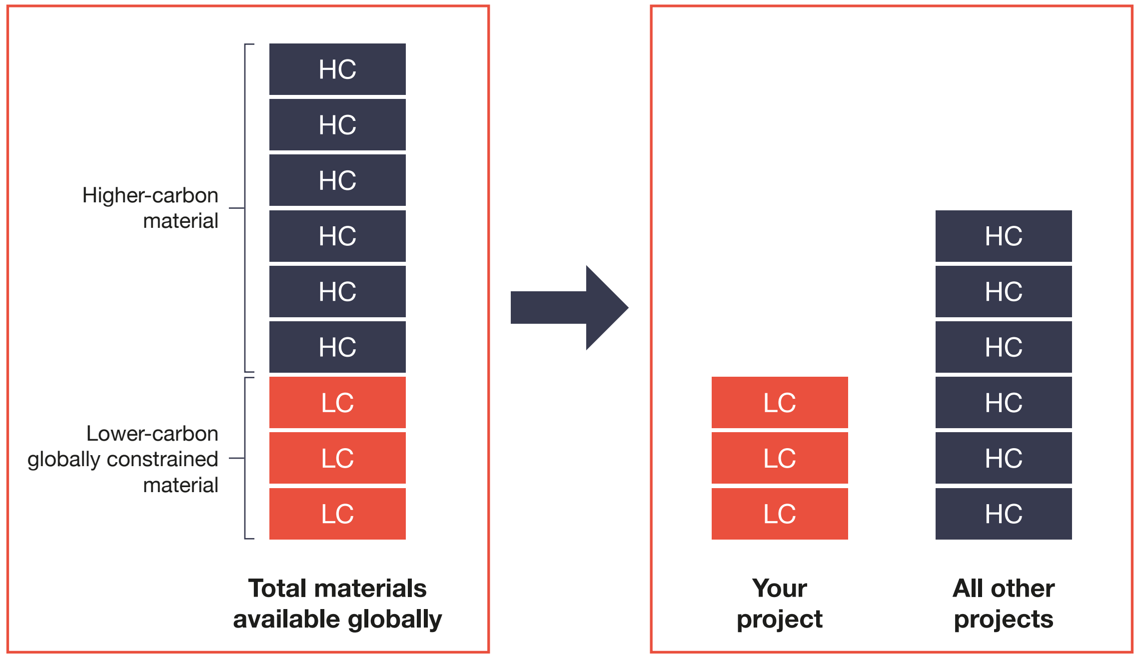

FIGURE 4: Procuring higher than average proportions of a limited lower carbon supply has little to no overall benefit to global emissions.

5. Decarbonising steelmaking

From the previous sections of this paper, we see that both primary and secondary steelmaking need to decarbonise in order to reduce global emissions – it is simply not possible for the world to make substantial increases in the amount of secondary steelmaking by trying to increase global recycling rates significantly beyond the rates that are already being achieved.

The good news is that even today, we see that not all steelmaking is equally carbon intensive for a given proportion of scrap. Variations come from production efficiency, electricity source, fuel replacements and so on. Figure 5 shows the range in GHG emissions intensity of crude steel across 300 steel production sites. The horizontal axis shows the percentage of ferrous scrap used in the mix, and the vertical axis is the level of GHG emissions.

Each point on the graph is a different production site – the cluster to the left of the graph is mostly BF-BOF production, and to the right is scrap-based EAF production.

This spread of emissions demonstrates that for any given percentage of ferrous scrap input, there is significant variation in the GHG emissions coming from different sites. Equivalent diagrams exist with indicative 'bandings' to differentiate between how much different sites could contribute to the total decarbonisation of the steel industry if they were to move from one banding to another (better) band, for example in the ResponsibleSteel Standard (figure 6 in version 2.1).

Primary steelmakers producing steel with lower-than-average GHG emissions are shown below the dashed line, to the left side of the chart; and primary steelmaking using low or near zero-carbon iron would sit at the bottom-left corner. Meanwhile, secondary steelmakers with high percentages of scrap, but that have decarbonised through lower-carbon electricity grids and better scrap sorting, are shown below the dashed line in the bottom-right corner of the chart.

Requiring that all steelmaking transitions to scrap-based secondary production would suggest that all steelmaking sites must move towards the right on this graph, requiring an impossible increase in the total amount of scrap recovered globally. Conversely, requiring that steelmakers adopt a dual decarbonisation approach would indicate that all steelmaking sites must move

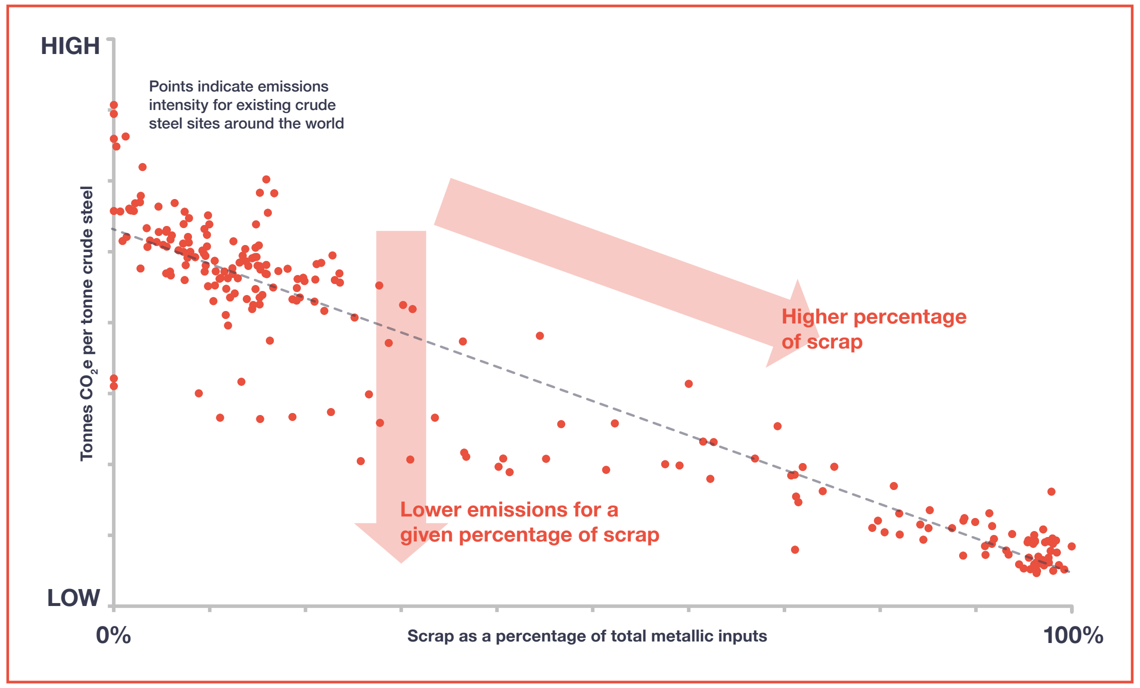

FIGURE 5: GHG emissions (y-axis) compared with scrap levels (x-axis) for 300 steel production sites.[17]

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[17] Data from modified 2021 CRU Steel Cost Model and Emissions Analysis Tool (ResponsibleSteel, 2022)

vertically downwards on this graph, significantly reducing overall emissions while requiring little or no extra scrap to be found.

5.1 Decarbonising ironmaking and primary steelmaking

The most cited technological route to decarbonising primary steelmaking is the use of hydrogen-based direct reduction ironmaking (H-DRI) to create iron from iron ore, that can then be fed into an EAF to produce H-DRI-EAF steel. Natural gas DRI-EAF, mentioned in Section 4.1, is already common in some countries such as the USA. The use of hydrogen as the primary fuel source has been demonstrated, with the first initial commercial operations for 100% hydrogen blend scheduled by early 2026[18]. Where the hydrogen is produced using low-carbon electricity, this would lead to low-carbon ironmaking, and if little or no scrap was needed to supplement the iron, the resulting steel production would sit towards the bottom-left corner of Figure 5.

Other decarbonisation routes being explored by industry also include electrolysis (a similar method to aluminium-making) and using carbon capture and storage with existing steel plants, which would also sit towards the bottom-left of figure 5 if little or no scrap was needed in addition.

These new steelmaking technologies are all currently occurring at a very small scale, and are reliant on new technology, ore quality, and low-carbon hydrogen. As such, it will be some time before such steel is widely available across the market, and it is likely that all of these technologies, and more, will be required in order to decarbonise the whole industry. However, these all demonstrate possible transition routes for decarbonising primary steelmaking that leads to truly global reductions in GHG emissions.

As noted in Section 4.1, replacement cycles of furnaces are measured in decades rather than years. With only 25 years to go until 2050, this means that incremental improvements applied to existing ironmaking and steelmaking facilities are also important to deliver emissions reductions today.

5.2 Decarbonising secondary steelmaking

It is important that all recoverable ferrous scrap continues to be recycled (or reused, where recovered as complete steelwork, rather than in ‘scrap’ form), and that this is done with the lowest possible levels of GHG emissions. Locating EAFs where low- and zero-carbon electricity is plentiful and affordable, ideally close to the source of the steel scrap, and ensuring well-sorted grades of scrap are used in the recycling, are ways of reducing the GHG emissions related to secondary steelmaking.

An idealised EAF utilising 100% scrap, sourced locally, with minimal or low level of contaminants, and powered by zero-carbon electricity, would sit at the bottom-right corner of Figure 5.

5.3 Precedent

This approach is not novel. The principle of dual decarbonisation is already followed by global initiatives including worldsteel[14], ResponsibleSteel[19], SteelZero[20], and the Science Based Targets Initiative[21]. It is also followed by the China Iron and Steel Association[22] and German Steel Association[23].

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[18] https://www.h2greensteel.com
[19] https://www.responsiblesteel.org
[20] https://www.theclimategroup.org/steelzero
[21] https://sciencebasedtargets.org
[22] https://www.c2fsteel.com
[23] https://www.wvstahl.de/wp-content/uploads/20240422_concept-paper_LESS_final.pdf

6. The UK context

The UK currently produces around 5.6 million tonnes of crude steel per year (as of 2023). It also exports around 2.5 million tonnes of steel products, and imports nearly 6 million tonnes back into the country. Overall, the UK consumes approximately 10.5 million tonnes[24].

The production split between BF-BOF to EAF in the UK was 80:20 in 2023, compared to a European split of 56:44[25] and a global split of 72:28. Plans to convert British steelmaking facilities from BF-BOF over to EAF in the coming years will affect this split.

The UK generates 10-11 million tonnes of ferrous scrap each year of which 2.6 million tonnes is used in domestic steel making; both BF-BOF and EAF production[26]. The remaining 8 million tonnes is exported with most going to Turkey followed by Egypt, India, Bangladesh and Pakistan, with associated transportation emissions.

The current UK strategy for decarbonising steelmaking is through a transition to EAF steelmaking with the aim of recycling all scrap originating in the UK. At a territorial level, the transition to EAF steelmaking and scrap recycling will significantly decrease the emissions of the UK’s steel industry, with predictions from industry of savings of up to 80%[27]. It will also lead to global reductions in emissions due to the UK having a lower-carbon electricity grid than many of the countries that currently recycle the UK’s scrap, as well as through the avoidance of emissions currently arising from global transportation of that scrap.

A dual decarbonisation aligned strategy would also assume that in the medium- and longer-term, the UK’s EAFs would be partly fed by lower-carbon iron, in addition to recycling the UK’s scrap. This iron could be produced by low emissions methods, either within the UK, or imported from overseas in the way that iron ore is currently imported today, helping catalyse the global decarbonisation of ironmaking.

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[24] Figures as of 2023: https://www.uksteel.org/steel-news-2024/key-stats-2024
[25] https://worldsteel.org/data/world-steel-in-figures-2023/#crude-steel-production-by-process-2022
[26] UK Steel & Make UK (2023), Steel Scrap: A strategic raw material for net zero steel and https://www.uksteel.org/scrap
[27] https://researchbriefings.files.parliament.uk/documents/POST-PN-0672/POST-PN-0672.pdf

7. Efficient use of ferrous scrap in reducing global GHG emissions

To summarise the previous sections, we see that while it is critical to maximise the recovery and recycling of ferrous scrap to minimise greenhouse gas emissions, ferrous scrap is still a constrained resource that is almost fully utilised globally. 80-85% of all steel reaching the end of its life is already recovered and recycled each year, and while there is some uncertainty in the modelling around recycling levels of scrap, this is not significant enough to change the conclusion that increasing recycling in one location is unlikely to decrease overall global emissions.

To reduce global emissions, investment and incentives must therefore focus on a **dual decarbonisation approach** to steelmaking, as is advocated for by the global initiatives listed in Section 5.3 of this report. The approach requires that:

- For ironmaking and primary steelmaking, increasing the supply of low/zero-carbon iron production from iron ore, and incentivising improvements in existing iron and steel production facilities where these are not due to be replaced in the short-term.
- For secondary steelmaking, investing in the decarbonisation of the electricity grid supplying those furnaces, along with increasing the quality and quantity grade of scrap being supplied.

In the interim period until steel production is decarbonised, designers should focus on minimising the use of material as far as possible. They should avoid relying on substitution of products for those with a higher recycled content, as this will not reduce overall global emissions.

Ferrous scrap recovery, reuse and recycling

It is still important that steel recovery is maximised for recycling and reuse as far as economically possible, that scrap is well-processed and separated to maximise the quality and quantity of recycled ferrous scrap that is supplied to the mills (see section 4.3), and that steel production has the lowest possible GHG emissions.

However, even if recovery and recycling rates can be increased slightly in the future, by far the greatest contribution to global GHG reduction will be through decarbonising the production of primary, and to a lesser extent secondary, steel. We must do both, urgently.

While this paper is aimed at the constructional steel market, the data reviewed was for all steel, globally, and so the same conclusions are expected to be true for other markets within the steel industry.

Embodied carbon limits

Voluntary and mandatory embodied carbon limits are starting to be used on some construction projects across different regions, countries, and local areas. These are generally set in terms of $kgCO_2e$ per m^2 of gross internal floor area. These limits are most easily met by increasing the proportion of secondary rather than primary steel that is used. However, for the reasons given in this paper, this is unlikely to result in any significant reduction of global GHG emissions. This results in a tension between the need to meet project carbon limits while enabling global emissions reductions. This dichotomy should be acknowledged and discussed at the start of all projects, and an agreement put in place such that designers are incentivised to minimise total steel tonnage (from any source), and contractors are incentivised to procure steel in a balanced manner that best reduces global GHG emissions (rather than simply procuring a high proportion of recycled steel, which does not of itself achieve this outcome).

Measuring and reporting the embodied carbon of buildings is important to encourage clients and their design teams to make low-carbon decisions. However, for the reasons outlined in Sections 4 and 5, it is important that these targets are met through efficient use of steel, and by procuring steel which meets the dual-decarbonisation approach articulated in this paper. Simply targeting high levels of recycled scrap content within the steel used is not inherently sustainable, and where this leads to reduced structural efficiency, may have the perverse effect of increasing global GHG emissions.

8. Recommendations

The following recommendations build on the conclusions of the rest of this paper and take into account the need to consider the global implications of how the steel industry uses its constrained and almost fully utilised supply of ferrous scrap. We recognise the difficulties in reconciling the desire to decrease emissions at a project- or country-scale, while also making decisions that support the decarbonisation of the global steel industry. Again, we also reiterate that this paper is only looking at GHG emissions, and that other aspects of sustainability must also be accounted for in both policy and design.

8.1 Recommendations to policymakers

1. Recognise that policies to increase the local recycling of ferrous scrap can lead to reduction in global emissions only through reduced transport emissions, and through reduced electricity emissions where local electricity grids are relatively low-carbon. Recognise that beyond this, they are unlikely to lead to a significant decrease in global GHG emissions, due to the limitations on supply of scrap around the world.
2. Invest in a dual decarbonisation approach:
   - Decarbonise ironmaking and primary steelmaking by increasing the supply of low/zero-carbon iron production from iron ore, through medium- and long-term investment in green hydrogen, DRI and other low-carbon iron and steel production technologies - in addition to incentivising improvements in existing iron and steel production facilities where these are not due to be replaced in the short-term.
   - Decarbonise secondary steelmaking through decarbonisation of the electricity grid, and increasing the quality of ferrous scrap in circulation, through better scrap sorting and processing to reduce the level of contaminants.
3. Where embodied carbon limits are being set (e.g. by developers, local authorities and planners), recognise how they might be met without relying on increased ferrous scrap consumption, by prioritising the efficient use, and reuse, of steel.
4. Develop policies where steel is specified to align with the lower part of Figure 5, such as those listed under 'Precedents' in Section 5.3. We recognise that policies may vary based on local opportunity, but they should be coordinated at a global level.
5. Research ways to normalise emissions reporting to account for the limitations of using globally constrained materials in this way. Consider how this would be included in carbon border adjustment mechanisms or other trade-related policies. Create simple mechanisms to help industry adopt this approach more easily (e.g. through improvement to current EPD practices).

8.2 Recommendations to designers and specifiers of steel

1. Speak with clients about the implications of this paper before agreeing to embodied carbon limits/targets at a project level. Acknowledge and discuss the paper at the start of each project, and agree an approach to steel procurement and design that reduces global GHG emissions while still reducing project emissions.
2. Minimise the use of material as far as possible[28], through the concepts of material efficiency and the circular economy:
   - Creative retention and reuse of existing buildings and products/materials,
   - Prioritising structural efficiency from the start of the design process,
   - Advanced analysis methods to optimise sizing,
   - Appropriate use of high strength, long-lasting materials.
3. Specify steel from producers aligned with dual decarbonisation commitments and who are therefore helping the industry to decarbonise both primary and secondary steel production, in ways that align with the bottom of Figure 5, such as those listed under 'Precedent' in Section 5.3.
4. Encourage the future flow of ferrous scrap by incorporating deconstruction principles into new buildings and enabling easier separation of materials at end of useful life, provided these measures do not significantly increase the total volume of steel used.

[28] For more guidance on designing to minimise material use, refer 'Design for zero' (2021), Institution of Structural Engineers, and 'P449, Best Practice for Designing Low Embodied Carbon Steel Buildings' (2024), Steel Construction Institute.

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