# Beyond the Recycled Label

*Production Route, Carbon Accounting and Mechanical Evidence in the Assessment of Recovered Steel for Civil Infrastructure*

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## Abstract

Civil infrastructure requires steel that performs reliably, efficiently and enables a strong foundation. However, the production process of steel also causes the emission of greenhouse gases. Therefore, this paper seeks to answer the question as to whether steel made using recovered material can aid in the reduction of greenhouse-gas emissions all the while fulfilling the basic requirements of civil infrastructure.

This review examines the process of how steel is produced, the different available methods that are available for assessing its environmental effects, understanding the mechanical performance of the material and how each of these factors are taken into consideration while building different projects.

Classifying steel as the primary or recycled only answers a part of the question. The overall impact varies on other different factors such as the source of electricity, furnace inputs, the manufacturing process and the method of calculation that is used.

The reviewed literature does not support a single carbon value or a mechanical disadvantage for recycled steel. The finished product is therefore assessed using the evidence relevant to the source material properties and the application that it's intended for.

The proposed study intends to combine steel origin data, laboratory tests and carbon calculations. At this stage in time, this merely stands as a research proposal, and no experimental results from that study have been reported here.


**Keywords:** *Primary steel; secondary steel; life-cycle assessment; mechanical properties; structural reliability; embodied carbon*

## 1 Context and carbon policy drivers

Civil infrastructure requires steel that can carry the specified loads, that can handle excessive deformation and remains usable throughout its service life. The requirements therefore concern strength, serviceability and durability, all the while making sure that the cost is reasonable too. The greenhouse gas emissions require that an engineer be cautious while taking these steps to make sure they fit within the sustainable development objective. The paper therefore seeks to examine whether or not the steel can reduce emissions while making sure it meets the requirements that it is intended for. Classifying the product as recovered steel or primary steel is only a starting point of this process.

The production of iron from its ore requires a lot of energy, whereas remelting recovered steel avoids a lot of that work. It is important to note that the scrap that comes in from manufacturing leftovers and the products that have reached the end of their use. The steel used inside the buildings and bridges and other products also remains unavailable for recycling while those products are still being used. Therefore, all available scrap cannot actually meet the on-going demand for steel production, especially when it's growing. Hence, to meet the growing demand for steel, both recycling and reducing emissions from ore-based productions are necessary (IEA, 2020).

Another issue to consider is that suppliers often may use different definitions and calculation methods when describing steel as "low emissions". Comparable definitions, measurement methods and certification systems are needed to assess suppliers' emissions claims consistently (IEA, 2025). A plant's ability to produce near-zero-emission material from the way they operate and the actual emission from its functioning is a distinguishing factor, when understanding the environmental impact of a single manufacturing unit (IEA, 2025). A production plan therefore does not establish the exact way the footprint of the final product that is in use (IEA, 2025). Therefore, it is necessary that supplier information also needs to identify the actual route of production and report the period relevant to the purchased steel.

The EU building policy stresses upon why the material emissions matter when it comes to structural designs. The European Commission (2026) illustrates that the effects on global warming must be calculated and disclosed for new buildings with floor plans exceeding 1,000 $m^2$ from the January of 2028. This requirement extends to all buildings from the year 2030. This assessment covers material production and transport, construction, operation, replacement and end-of-life activities. Within this framework, both the quantity of steel and its production footprint contribute to the building's climate impact.

The studies outline a gap between the mechanical performance and evidence that needs to be used to calculate the emissions. Experimental studies examine the alloys or the metal in the finished products whereas the environmental studies examine the production and supply chain without testing the same material. The difficulty that thus arises is the engineering requirements intended for the product usage the carbon advantage applies to the traceable product. Therefore this paper intends to argue that the production origin alone does not adequately use the basis for selection, and the useful comparison would be in reference to the manufacturing conditions, the properties of the product and the environmental data for the supply.

This paper focuses on a narrative review by discussing relevant publications and connecting their findings. This particular paper review seeks to look at relevant studies from the years 2024 to 2026, which includes older research as and when required to help explain the topic. When comparing the findings, it looks into what type of steel is used, how the steel was produced and the methods that were used in assessing the production of the steel. The results are discussed without actually combining them into a single statistical analysis.

## 2 Production routes and metallurgy

Primary steel production mainly refers to iron obtained from ore whereas secondary production mainly refers to production using recovered steel scrap. The main production method of steel is BF-BOF which means *blast furnace–basic oxygen furnace* (IEA, 2020). The blast furnace produces iron from ore and then the basic oxygen furnace refines that iron into steel. Another method of production is using the *Electric Arc Furnace* (EAF). In this method, electric arcs melt inputs that can include scrap and newly produced iron (IEA, 2020). These inputs can include *direct reduced iron* (DRI) which comes from iron ore (IEA, 2020). Consequently, EAF steel is not necessarily entirely recycled. On the other hand, BF-BOF production can also incorporate scrap metal. It is important to note that both production route and the inputs matter.

Recycling and direct use are two different ways of recovering steel. In recycling the steel is melted to recover that steel to manufacture a new product. Direct use however, is when an existing product or component is used without remelting. This difference affects the checks required while using such steel. Recycling needs control over scrap quality and manufacturing, while reuse needs evidence about the existing component's condition and suitability. These two approaches therefore require a separate environmental and engineering assessment for each approach (IEA, 2020). One more thing to consider is that reuse still requires preparation and inspection immediately before being used.

Recycled steel requires the composition of scrap to be of a certain level, thus making it an important consideration. Depending on how it was previously used and sorted, the scrap can contain different mixtures of elements. Elements such as copper and tin can remain in finished steel and their effects depend on their amounts and interactions. The subsequent manufacturing process also affects the final properties such as the rolling shapes of steel while heating and cooling can also affect its internal structure. It is therefore necessary to consider the difference between the steel products and therefore must be considered alongside their composition and processing, rather than attributed to the recycled content alone. (Mehta et al., 2025)

Mehta et al. (2025) explored the issue with simple iron alloys that contained copper and tin and investigated how these elements are concentrated in particular areas as the molten metal solidifies. This is what is known as segregation. Under the tested conditions, the resulting product showed cracking in some parts of the composition and grain size. However, it is important to note that these observations came from model alloys tested under very specific conditions. This explains why the results have a limited scope. The study helps in understanding the behaviour of the elements. However, it does not establish the limits of impurity for every construction steel.

This importance of processing of steel is also illustrated in Li et al. (2026) who studied steel that is intended for packaging. Their samples included copper, nickel, chromium and tin. The research assessed the material used after rolling and the heat treatment and for the final product the authors of the paper reported that there were relatively small overall effects on the strength and formability under the tested conditions. However, some individual properties still changed as some of the samples did become stronger but stretched less before breaking. The findings specifically apply to packaging steel and under the processing conditions studied, these findings may not apply directly to construction steel which require their own evidence of suitability.

At the plant level, the options for reducing emissions also depend on the conditions of production. In Wu et al. (2025), the authors have explored these differences through a model and explained and examined the possible emissions-reduction pathways. The model considered the technology involved, costs, equipment upgrades, steel demand and scrap availability. This implies that different plants may need different changes. These possibilities are built on assumptions rather than confirmed future outcomes. These differences make it easy to examine how environmental impacts are therefore calculated and compared, which is the focus of our next section.

Read together, the studies of Mehta and Li are both comparative studies while the former investigated segregation and cracking during solidification of the simplified alloys. On the other hand, Li discusses the properties of rolling and heat treatment in packaging steel. What this comparison intends to highlight is the different compositions, manufacturing stages and products. The evidence suggests that the scrap metal chemistry must be managed through product-specific manufacturing controls. This doesn't support a universal mechanical penalty for recycled steel and it does not establish structural suitability.

## 3 LCA frameworks and allocation debates

The environmental impact of steel can be examined through life-cycle assessment. The life cycle assessment, shortened to the LCA, examines the impact of a defined product system on the environment. It involves the process of studying, collecting information about the inputs and outputs of the product and interpreting the results. Thus, this led to the introduction of the standards that provide the main framework, ISO 14040 as the principles that guide the framework and ISO 14044 which act as the requirements and guidance. (ISO, 2006a; ISO, 2006b). These ISOs perform these stated roles as given in the official descriptions. Each study still needs to identify the individual product, processes, data and the assumptions that go along with it. A standard does not merely establish compliance.

Before comparing results, it is necessary to establish what each figure represents. One tonne of crude steel is significantly different from a tonne of finished beams or an installed structural product. Shaping, fabrication and installation can introduce different additional materials and use emissions. For a structural comparison there are many alternatives that should perform an equivalent task, for example, carrying same loads over the same span. This expression of two results in the same units does not make their products or functions equivalent. A fair comparison requires that there be a consistent basis of comparison (European Commission JRC, 2010).

The comparison also depends entirely on which activities each assessment includes. This is where we introduce the term system boundaries which identifies the processes counted in the assessment. A single calculation might include raw-material extraction and steelmaking but stop right before fabrication. Another calculation might include transportation and installation. The result for crude steel therefore cannot automatically represent an installed structure. These minute differences need to be identified as a lower reported result may reflect fewer activities being counted. To be exact the proposed study would identify and record the stages included and excluded before the figures are compared.

Authors Krekel et al. (2026) provide a valid example of how the production assumption inevitably affect the LCA results. They particularly examined the steelmaking scenarios in Germany using the 2022 electricity mix and a cut-off approach to scrap. With the comparable scrap shares, the natural-gas direct reduction/EAF scenario had 26% lower global warming potential than the BF-BOF reference but 10% higher fossil fuel consumption potential (Krekel et al., 2026). The latter concerns the use of fossil fuel resources. This methodology excluded secondary metallurgy furnace refractory materials and carbon electrodes. The result of these findings concerns the defined crude-steel scenarios. They are not ready-made emissions factors for finished construction products (Krekel et al., 2026).

Another big reason for the differences between studies is the treatment of recycled material. This is done through allocation. Allocation determines how environmental burdens and benefits are assigned between connected product systems or successive uses. A cut-off approach is when recovered material can enter a new product system without carrying the burdens of the original manufacturing (Krekel et al., 2026). Other approaches however assign these burdens differently (Krekel et al., 2026). Choosing the accounting can also change the footprint attributed to a product even when the physical material flows are similar (Krekel et al., 2026).

In Yang et al. (2024) they examined the issue for modular building components used across several life cycles. The modular unit they included in the three approaches cut-off with Module D, Product Environmental Footprint (PEF) and Circular Footprint Formula (CFF) included a steel frame, concrete slab and connectors. The assumptions about reuse, repair, replacement and recycling affect the burdens assigned to each use (Yang et al., 2024). The results describe the complete assembly and its assumed uses. They cannot be applied directly as the emissions factor for an individual steel beam (Yang et al., 2024).

Keeping the materials in circulation does not by itself establish the carbon footprint of the materials used. This is where we introduce the term circularity which is defined as keeping materials and products in use through recovery, reuse and recycling. Rumsa et al. (2026) examined the environmental assessment alongside circularity indicators. The proposed plant's inventory in the study used engineering design information and performance from reference facilities (Rumsa et al., 2026). However, one shortfall to note is that the data was not based entirely on locally collected data from a fully commissioned plant. Circularity indicators and carbon results answer different questions. The modelled results must also remain identifiable as estimates of the proposed production system (Rumsa et al., 2026).

The age of underlying data is another consideration. The World Steel Association released its updated inventory database in 2026 but used production data from 2024. A recent publication therefore does not necessarily show when the production activities occurred. The

product is to be thoroughly checked, its location, technology and period represented by the data. The release announcement confirms the database's coverage and age; the actual product dataset is still needed for a numerical assessment. (World Steel Association, 2026)

Uncertain assumptions have an undue influence that need to be explored through a sensitivity analysis. Such an analysis examines the results that might change when selected inputs or assumptions might change. Such a proposed procedure would begin with a baseline calculation, which would then change according to the electricity emissions factor, all the while making sure the quantity and allocation rules remain fixed. A separate comparison could change the allocation method while retaining the same physical inputs. These checks would show which assumptions influence the result. Combined scenarios could then explore several changes together. This is a proposed procedure, not work already completed (European Commission JRC, 2010).

The conclusions must also match the question being assessed. Comparing two supplies can establish their calculated footprints under selected accounting rules. However, the wider consequences of a purchasing decision may include changes in demand that affect other producers and the use of available scrap; evaluating those responses requires additional modelling. The proposed capstone would compare its defined material alternatives using a consistent assessment basis. It would report differences within that comparison, without claiming to have calculated the total change in worldwide emissions (European Commission JRC, 2010).

A carbon footprint only represents one aspect of the environmental effect. Carbon dioxide equivalent expresses the effect of greenhouse gases using a common measure of such emissions. Krekel et al. (2026) illustrate why an improvement in global warming potential can occur alongside a worse result in another impact category. The proposed study would focus specifically on climate impact. The resource consumption, pollution or overall sustainability would require further evidence and any missing information must be identified as a gap in assessing the overall environmental performance. Steel must also be assessed for its mechanical properties when it is being required for its intended application.

## 4 Mechanical properties and structural reliability

Steel's response to loading forms another part of the assessment, alongside its environmental impact. Yield strength indicates when substantial permanent deformation begins. Ultimate tensile strength records the maximum engineering stress reached as the specimen is pulled during a tensile test. Elongation expresses the increase in a specimen's gauge length, usually as a percentage of its original length. Toughness concerns how much energy the material absorbs before it fractures, with the result depending on the testing method. These properties describe different aspects of performance, so describing one steel simply as "stronger" provides an incomplete comparison. Which properties matter most will depend on how the steel is used.

Abbas et al. (2023) varied carbon content and finishing rolling temperature in reinforcing bars produced from scrap. Their tests covered finishing temperatures of 640–800 °C. Bars with higher carbon content showed greater strength but less elongation. At higher finishing temperatures, grain size increased; yield strength, tensile strength and hardness decreased,

while elongation increased (Abbas et al., 2023). The measured differences could therefore be linked to the steel's composition and manufacturing conditions, rather than explained by its scrap origin alone. These observations apply to the bars tested in that experiment; they do not demonstrate that primary or secondary steel will consistently outperform the other.

These results also raise a practical issue for comparisons between primary and secondary steel. A difference between samples could arise from their grade, diameter or treatment during heating and rolling, making it harder to determine how much material origin contributes to the result. Using consistent preparation and testing procedures would help reduce additional sources of variation. Even matching the stated strength grade does not isolate the influence of recycled content. For the proposed study, grade, diameter, available composition information and processing history would be recorded for each sample. Any remaining differences would need to be acknowledged before the results were attributed to material origin.

Fabrication can introduce further changes after the steel has been manufactured. Abatta-Jacome et al. (2025) studied 228 ASTM A706 reinforcing-bar specimens from five commercial brands, of which 114 were welded. The authors reported changes in mechanical response and greater variability after welding, while also reporting that the specimens met the specified mechanical strength requirements (Abatta-Jacome et al., 2025). For a comparison of material origins, welded and unwelded specimens should therefore be identified separately. The study offers evidence about welding and differences between commercial products, without establishing a separate effect attributable to recycled content.

A conventional tensile test measures a specimen's response as it is pulled along one axis. Fatigue involves repeated loading over time; a bridge experiences this as vehicles pass over it. Successive loading cycles can extend small cracks until failure occurs (Russo et al., 2016). If fatigue testing is outside the proposed programme, fatigue performance would remain unverified. The study would draw conclusions only about the properties covered by its tests.

Assessing an existing member for reuse requires evidence about its material properties and condition. Direct reuse retains an existing member without remelting it. Kingsley et al. (2026) examined data from 182 recovered structural members, drawing on tensile, hardness and impact tests alongside chemical measurements. For members classified as S275 and S355 under the study's specified grading conditions, the researchers reported material safety factors close to those used for new steel. Designers use these factors to allow for uncertainty in material strength when calculating resistance to loads (Kingsley et al., 2026). The finding must be interpreted within the study's grading and testing conditions. It does not justify accepting an unidentified reclaimed member without assessment or establish the performance of newly remelted scrap steel.

The spread of the results also matters when assessing a steel supply. Two groups can have similar average strength but different variation between specimens. Several specimens cut from one bar provide limited information about other production batches. A heat is a batch of steel produced in one melting operation, and sampling different heats would help investigate variation between batches. Results should identify both each specimen and its source. For this reason, individual results would remain visible alongside averages. A small sample would support conclusions about the tested material, with limited scope for wider generalisation.

Consistent handling of the test records would be another requirement of the proposed study. Stress–strain curves show how a specimen deforms as stress is applied. Each curve would be calculated from the recorded dimensions and deformation measurements, using the same definitions and procedures for every specimen. Original measurements would be retained, while corrections, filtering and excluded results would be documented. This would allow readers to check how the curves were produced and investigate unexpected results. Where the curves differed, the study would investigate the reasons and retain any unexplained variation in the reported results.

Laboratory findings must also be considered in relation to the member's position and function within a structure. A tensile specimen provides information about the material, but it does not reproduce the dimensions, supports or connections of a beam or column. These features can affect how a member carries load. A slender column, for instance, can bend sideways and buckle under compression despite having steel of the required strength. In the proposed capstone, a simplified structural calculation could illustrate the use of the measured material properties, with the assumed loads and design conditions recorded. That calculation would help establish the quantity of steel needed for the selected structural task. Section 5 then examines how this quantity can be combined with emissions data to calculate carbon impacts at building level.

## 5 Building-level carbon accounting

Product-stage emissions are calculated by multiplying each steel quantity from the design by its corresponding emissions factor.

$$C_{\text{product}} = \sum_{i=1}^{n} m_i \, ef_i \tag{1}$$

Here, $m_i$ is the mass of a particular steel product, while $ef_i$ is its production emissions per unit of mass. Multiplying these gives that product's contribution, and the summation sign adds the contributions together. With steel mass entered in kilograms and the factor in kg $CO_2$e/kg, the calculation gives emissions in kg $CO_2$e. This follows the use of material quantities and emissions factors described in the RICS methodology (RICS, 2023). The calculation depends on the emissions factor accurately representing the product and production stages being assessed. A factor reported for crude steel production cannot automatically be assumed to represent a finished, fabricated structural member.

The assessment must also identify which stages of the building's life are included. Whole-life carbon reporting is typically organised into life-cycle modules. Modules A cover production and construction-related activities, Modules B cover activities during use, and Modules C cover end-of-life processes. Potential benefits and burdens from later recovery, including recycling, are recorded in Module D when they fall outside the assessed system boundary. The RICS whole-life total includes Modules A–C, with Module D reported separately (RICS, 2023). Emissions from supplying the steel are therefore distinguished from potential benefits associated with its later recovery. Readers can then see both contributions without treating them as the same part of the calculation.

The importance of the production chain is illustrated by La Rosa et al. (2025). Their study examined an AISI 4145H steel pup joint used in oil-and-gas drilling and reported a production-chain result of 466 kg $CO_2$e per finished component. A hypothetical alternative scenario located in Norway produced a substantially lower result of 215 kg $CO_2$e per component. In the modelled Norway scenario, La Rosa et al. (2025) changed both electricity supply and transport arrangements (Figure 1). The resulting difference therefore reflects the combined production and transport assumptions. The figures concern a drilling component and cannot be used as emissions factors for building beams. The separate effect of electricity cannot be determined from these two scenarios.

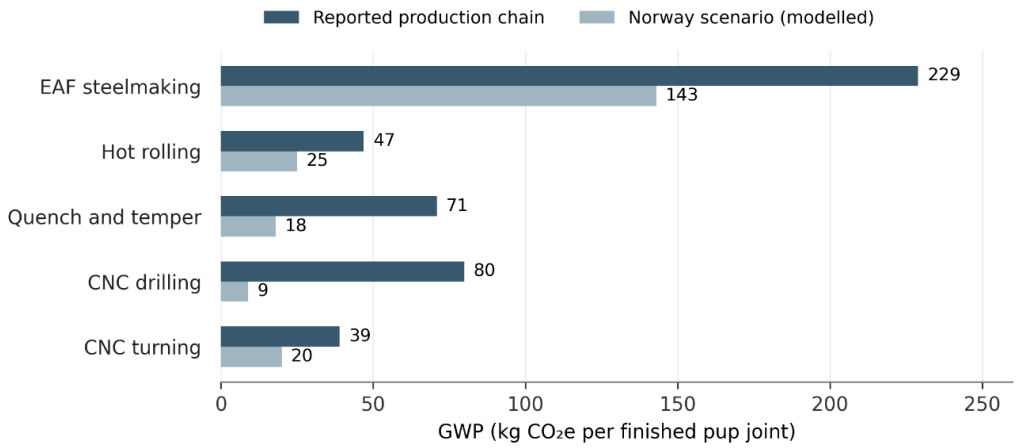



**Figure 1.** Comparison of pup-joint production emissions, measured in kg $CO_2$e per finished component, from La Rosa et al. (2025). The Norway scenario is modelled.

The carbon result for a structure also depends on how much steel the design requires. Alternatives that meet the same engineering objective may use different amounts. The benefit of a lower emissions factor may disappear if the design requires enough additional steel. A higher-strength grade also offers no automatic reduction in section size, since deflection, buckling or connection requirements may determine the dimensions. The design therefore needs to demonstrate equivalent structural performance before environmental comparisons are made. Its required material quantity can then be used in the carbon calculation.

Building information modelling (BIM) offers one way to obtain and organise material quantities. Its digital model links the building's geometry with information about components, materials and how they fit together. Mohammed et al. (2025) used a factory's BIM model as the basis for assessing the life-cycle impacts of its steel-framed building. Material quantities were extracted directly from the model and connected to environmental datasets to estimate impacts. Some gaps in the available information had to be filled with estimates. Results also differed according to the regional environmental datasets used (Mohammed et al., 2025). This suggests that automating quantity collection addresses only part of the assessment. The emissions factors still need to represent the relevant materials and location and cover the activities included in the study.

A reuse option would require an account of the work needed to bring recovered members into the new structure. This would include inspection, testing where necessary, and transport from the original site through any storage or processing facilities to the destination. Alterations to the members and any extra connections or supporting materials would also enter the assessment. Each activity would have a recorded quantity and a suitable emissions dataset; where information was unavailable, the assumption used would be stated. Uncertain recovery arrangements or future reuse opportunities would be assessed as scenarios.

The alternatives would first need to meet the same loading and structural performance requirements. Any later life-cycle stages would be compared over a common assessment period. For each option, the same set of activities would be assessed, with results shown by stage and as a total. Differences would be examined against the steel quantities, production emissions factors and assumptions about recovery or reuse. This would help readers understand the reason for a lower result. The results would then indicate which changes contributed to a reduction. Where the calculation covers only structural steel, the report would state this limitation and identify the building materials and activities excluded.

Both steel quantity and emissions per unit determine which alternative has the lower product-stage result. For two alternatives, A and B, alternative B will have a lower product-stage impact when

$$m_B \, ef_B < m_A \, ef_A \tag{2}$$

Assuming all masses and emissions factors are positive, this may be rearranged as

$$\frac{m_B}{m_A} < \frac{ef_A}{ef_B} \tag{3}$$

The relative steel masses and emissions factors must be assessed together to determine which option has lower product-stage emissions. This calculation covers only the stated product stage. Activities outside that boundary would need to be added separately. Applying the comparison would require reliable quantities and emissions factors on a consistent basis, together with evidence that both designs meet the same structural requirements. Section 6 sets out the gaps in the available evidence and the work proposed to address them.

## 6 Gaps and how the capstone addresses them

The proposed study would bring together two types of evidence considered in this review: emissions associated with steel supply and measured properties of the finished material. The environmental figures and mechanical test results may concern steel from different suppliers or manufacturing conditions. Using them together therefore depends on whether both sets of evidence reasonably describe the material being assessed. The capstone would address this by linking sourcing records, mechanical test results and carbon calculations for the selected products. Each material sample would be connected to its available production and environmental information. The aim would be to produce a documented comparison of selected products rather than a conclusion about every primary or secondary steel supply.

Before choosing samples, the study would define the structural application and the basis of comparison. Reinforcing bars of the same nominal grade and diameter would be one

possible choice (British Standards Institution, 2005). A record for each specimen would identify its supplier and product, together with any declared production route and available chemical composition. Available heat numbers would link each sample to a production batch. Recycled content would be reported only where supplier records or other documents support it. Where the route remained unknown, the comparison would retain the supplier or product labels without classifying the steel as primary or secondary. This would prevent an uncertain material origin from being treated as an established difference between the groups.

The mechanical programme would begin with tensile testing under consistent conditions. Yield strength, ultimate tensile strength and elongation would form the initial set of measurements. Specimens would be prepared and tested using a consistent procedure selected with the laboratory for the chosen product (ISO, 2019a; ISO, 2019b). Records would include specimen dimensions, gauge length, applied load and deformation. The original measurements used to calculate stress and strain would be retained so the results could be checked and the calculations repeated. Specimens would be identified by both heat number and source, making it possible to distinguish repeated tests from the same batch from tests performed on different batches. Additional properties would require suitable testing methods, equipment, and resources. Toughness, fatigue performance, and weldability, for example, would need their own dedicated investigations. Properties not examined would remain outside the study's demonstrated findings.

The environmental comparison would use a common product-stage boundary for the selected steel supplies. The first step would be to confirm whether any supplier emissions information actually represents the product being tested. Each dataset would be recorded with its geographical coverage, reporting period, units and included activities. Any dataset used in place of supplier-specific information would be identified, with an explanation of its limitations in representing the material being tested. The assessment would also examine how assumptions influence the comparison. Electricity supply, transport conditions, and scrap-allocation methods could be varied individually before combined scenarios are considered. This would make it possible to distinguish between results supported directly by supplier information and results that depend more heavily on modelling assumptions. The mechanical and environmental results would remain separate measures, with each supported by its own evidence.

The final stage could apply the material results to a simplified structural task. A common design requirement, such as identical loading, span, and serviceability criteria, would be defined for all alternatives. Each option would then be checked to confirm that it satisfies those requirements before the required steel quantities are determined. Compatible emissions factors would be combined with the resulting quantities to estimate carbon impacts. Any differences could then be examined to establish whether they arise from material quantity, production emissions, or a combination of both. Specimen test results, sourcing records, and calculation assumptions would be presented together to provide a transparent record of the assessment. The intended outcome would be a comparison that another reader could follow, evaluate, and reproduce using the same evidence and assumptions. These steps define the proposed research programme and the evidence needed to assess the selected steel supplies.

## 7 Conclusion

Using recycled steel can reduce construction emissions, but the benefit needs to be checked for the supply and application being considered. Production methods, electricity sources and further processing affect the result. Comparisons also need common assessment boundaries and clearly stated rules for allocating recycling impacts. Mechanical suitability also depends on the material's composition, manufacturing history, and any subsequent fabrication processes. Regardless of its source, the finished steel requires evidence that it satisfies the requirements of its intended structural use. At building level, environmental performance is determined not only by emissions per unit of material but also by the quantity of steel required to achieve equivalent structural performance. Any saving per unit therefore needs to be considered alongside changes in the amount required. The proposed capstone would examine sourcing information, mechanical tests and carbon estimates for the same selected supplies. Its findings would apply to those materials and the conditions investigated, with the supporting data and assumptions documented.

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