DISRUPT PROJECT ON STEEL REUSE

Delivering Innovative Steel ReUse ProjecT

At the Alliance for Sustainable Building Products (ASBP), we are conducting a study funded by Innovate UK. The "DISRUPT" project aims to develop replicable and scalable business models for steel reuse with the ultimate goal to expand the market of steel reuse. The business models will encompass all parts of the value chain including clients, designers, contractors, stockists, fabricators, and demolition contractors.

The project is co-partnered with *Cleveland Steel and Tubes*, the *National Federation of Demolition Contractors (NFDC)*, and *ISG* and is supported by *Grosvenor.* This is a one-year-long project that started in April 2022 and will conclude in March 2023.

The project includes the following main activities:

- Conducting a *literature review* and *mapping supply chain actors* involved in steel reuse.
- Developing a *business model framework* including technical, economical, logistical and other considerations for each actor in the value chain via available literature and interviews with experts in steel reuse.
- Selecting *10 real-life case studies* covering different project types, sizes, locations, and supply chain models for closer analysis. This includes gathering details via published information followed up with interviews with companies involved in steel reuse projects across the value chain.
- Developing *business models* for supply chain actors that will serve as a blueprint/guide for businesses interested in entering the market of steel reuse or improving their practices.

This document presents the literature review, which is the first outcome of this project. The mapping of supply chain actors involved in steel reuse will be published as well. The final case studies will be released closer to the end of the project along with the developed business models.

Find out more at: https://asbp.org.uk/disrupt.

LITERATURE REVIEW

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1. Introduction to steel reuse and the DISRUPT project

Steel is the world's most widely used material but also one of the most carbon-intensive ones. The production of a tonne of steel generates on average 1.85 tonnes of carbon dioxide (CO_2) emissions. The steel industry is responsible for between 7% and 9% of the world's CO_2 emissions (World Steel Association, 2021).

The construction sector is the largest consumer of steel products. Many buildings are currently demolished before the end of their technical lifetime, in particular commercial buildings that are often only used for 30 to 40 years compared to a technical lifetime of 75 years or more (IEA, 2020). While steel is widely recycled (circa 95% recycling rate in the UK), more benefits can be derived from reusing steel that avoids the high energy process of remelting.

Reuse is defined as the use of products or components more than once for the same, or other purposes, without reprocessing (ISO 20887, 2020). Steel is a highly reusable material; unless steel products have been subject to severe conditions such as fatigue or fire, their properties do not deteriorate over time. The use of reclaimed steel can save up to 96-97% of embodied carbon compared to new steel (Cleveland Steel and Tubes Ltd, 2018; EMR, 2022) and is generally preferable to recycling, which provides around 80% carbon savings compared to virgin steel (BCSA, 2022a).

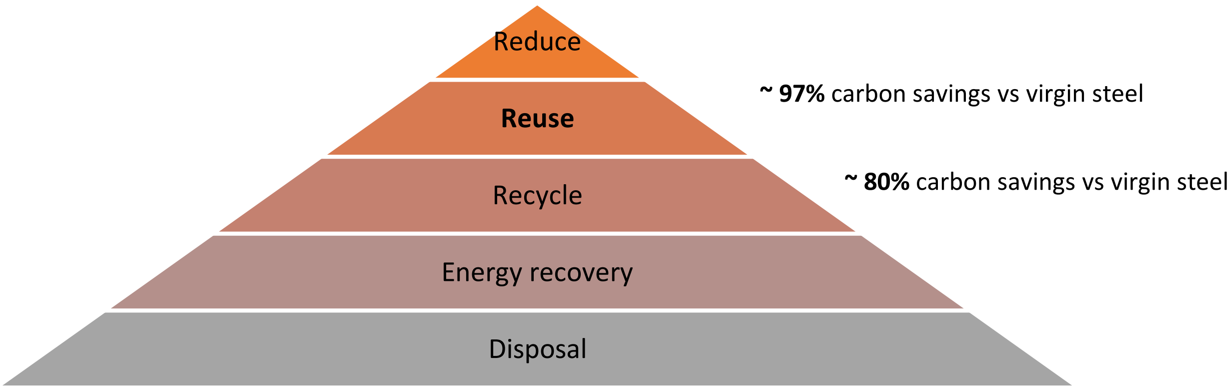


Figure 1 Waste hierarchy pyramid

Although not a new practice, steel reuse is experiencing a rebirth at the moment, with over a dozen large construction projects underway in London. The following sections of this report provide an overview of steel reuse rates (section 2), market conditions (section 3), key drivers (section 4), barriers (section 5), enablers (section 6), and processes required for steel reuse (section 7).

2. Steel reuse rates and steel reuse types

Steel reuse is not a new practice; it was more common 30-40 years ago but with the evolution of standards and the market's interpretation of them the reuse of steel sections in the UK reduced significantly by 2012 (Fishwick, 2022).

A survey of demolition contractors in the UK (Sansom and Avery, 2014) showed that around 5% of steel products on average from demolished buildings were reused in 2012 in the UK (Table 1); for structural steel, this was estimated at around 7%.

Table 1 Reuse and recycling rates of steel from a typical building demolition site in 2012 in the UK (Sansom and Avery, 2014)

Product	% Reused	% Recycled	% Lost
Heavy structural sections/tubes	7	93	0
Rebar (in concrete superstructure)	0	98	2
Rebar (in concrete substructure or foundations)	2	95	3
Steel piles (sheet or bearing)	15	71	14
Light structural steel (e.g. galvanised purlin, supports, etc.)	5	93	2
Profiled sheet cladding (roof/façade)	10	89	1
Internal light steel (e.g. plaster profiles, door frames)	0	94	6
Other (e.g. stainless steel – if different from above)	3	96	1
Average (across all products)	5	91	4

An earlier survey conducted by SCI in 2000 showed that 13% of structural steel was reused (Sansom and Avery, 2014).

Driven by low carbon targets, steel reuse has gained momentum recently, with more actors in the supply chain calling for a collaborative approach to encourage steel reuse in construction projects. Some demolition contractors have been reusing steel in their temporary works, for example, Erith Group has been using recovered steel from a building in propping works (Leversha et al., 2022).

Some steel products are harder to reuse than others. For example, composite materials are difficult to segregate, and so are rarely reused, such as reinforcing bars embedded in the concrete or composite floor systems made of profiled steel decking with reinforced concrete. Overall, longer steel sections are more likely to be reused than shorter ones because they have a higher residual value and can be cut further (Allwood et al., 2010).

Around 25% of the steel in typical buildings is in structural sections, mainly hot rolled sections but also some welded plate. The remaining 44% is in rebars and 31% is in sheet products such as cold-formed purlins for portal frame buildings and as exterior cladding (Alwood, 2002). Steel-framed buildings are assembled from sections, including the beams (horizontals) and columns (verticals) of the building frame. Structural steel sections are inert, robust and dimensionally stable elements particularly suitable for reclamation and reuse. Figure 2 shows a distribution of steel within a typical office building.

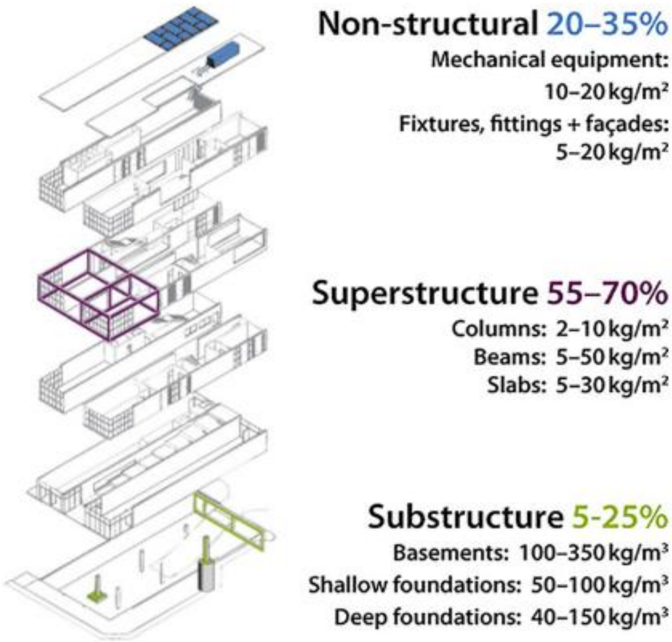


Figure 2 Distribution of steel within a typical office building (Alwood, 2002; Spooner et al., 2020)

Structural steelwork accounts for about 70% of multi-storey building frames built in the UK (Building, 2011).

There are some exceptions for structural steel reuse. A protocol for steel reuse (P427) by Steel Construction Institute does not recommend reusing steel from:

- *Structures erected before 1970* (because older buildings use steel with a different composition, which hinders to use of Eurocode rules. Also, the use of red lead to prevent corrosion is an issue as it is carcinogenic).
- Structures that have been *subject to fatigue,* e.g., reclaimed from bridges.
- Structures that have been *subject to significant strains*, e.g., plastic hinges.
- Structures with significant *loss of section due to corrosion*.
- Structures that have been *exposed to fire* (SCI, 2019).

In addition, structures that have been subject to *radioactivity* are not recommended for reuse.

Also, there are restrictions on where the reclaimed steel components can be reused. Steel products are not recommended to be reused in:

- Structures *subject to fatigue* (e.g., bridges) or in plastically analysed structures which rely on the formation of *plastic hinges.*
- In structures subject to *seismic actions*, unless the steel plays no part in resisting the seismic action, for example as a pin-ended floor beam.
- In *Consequence class 3 structures* (e.g., grandstands and public buildings where the consequences of failure are high such as a concert hall). This places additional requirements on the testing to determine material characteristics (SCI, 2019).

3. Market conditions for steel reuse

3.1 Steel and scrap steel market in the UK

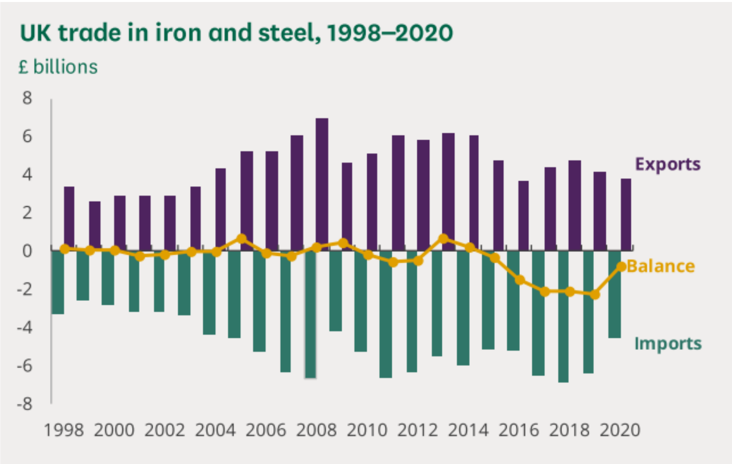
The UK steel industry contributed £2 billion to the UK economy in terms of gross value added (GVA) in 2020 with approximately 1,100 businesses involved in the industry supporting 33,400 jobs in the UK in 2019 (Hutton, 2021). More than half of all steel is used in construction. The steel industry makes intermediate products (such as plates, coils and bars of steel) that are then shaped, cut and assembled in the supply chains of manufacturing and construction into final products.

The major steel manufacturing companies in the UK are:

- British Steel Ltd (17.6% of the Iron & Steel Manufacturing industry in the UK)
- Tata Steel UK Limited (14.2%)
- Celsa (UK) Holdings Ltd (7.8%) (IBISWorld, 2018).

Steel is one of the world's most widely recycled materials. Around 91% of steel construction products from demolition were recycled in the UK in 2012 (Sansom & Avery, 2014). The major player in the UK steel scrap market is European Metal Recycling Ltd (£2.5 billion revenue). The company processes approximately 10 million tonnes of recycled commodities per year, including scrap vehicles, consumer products, industrial and commercial products and materials, and demolition scrap (IBISWorld, 2022).

The UK is a net importer of steel. In 2020, the UK exported 4.4 million and imported 5.3 million tonnes of steel, with a trade deficit of £0.8 billion for 1.1 million tonnes, see Figure 3. (Hutton, 2021).



Source: ONS, UK Trade, Series EHBT, EHAL, BQQE

Figure 3 UK trade in iron and steel (Hutton, 2021)

Around 80% of the scrap steel produced in the UK is exported. Out of 11.3 million tonnes of scrap steel produced in 2018, only 2.6 Mt was used in domestic steelmaking (which is a mixture of a Blast Furnace – Basic Oxygen Furnace (BF-BOF), and Electric Arc Furnace (EAF) production). The remaining 8.7 Mt was exported for recycling in other countries including Turkey, Pakistan, Egypt and India (Hall et al., 2021). The graph below shows the increased exports of scrap steel from the UK from 2009 to 2019.

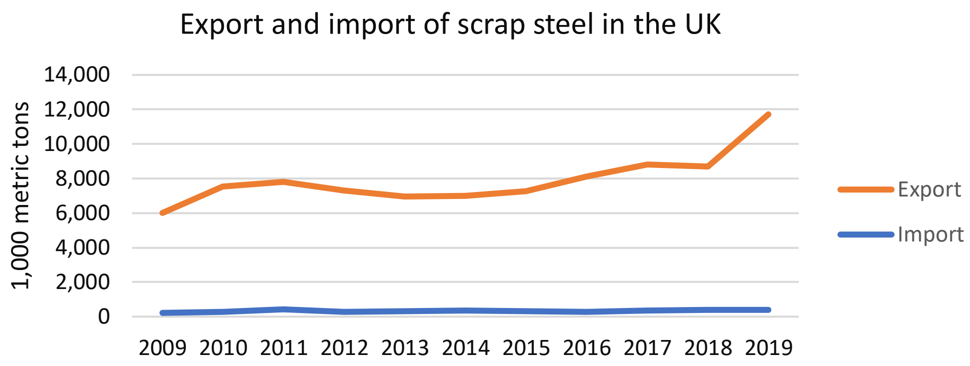


Figure 4 UK trade in scrap steel (Statista, 2021)

The UK is the largest exporter of steel scrap among the 28 countries that formerly made up the European Union (Letsrecycle.com, 2021).

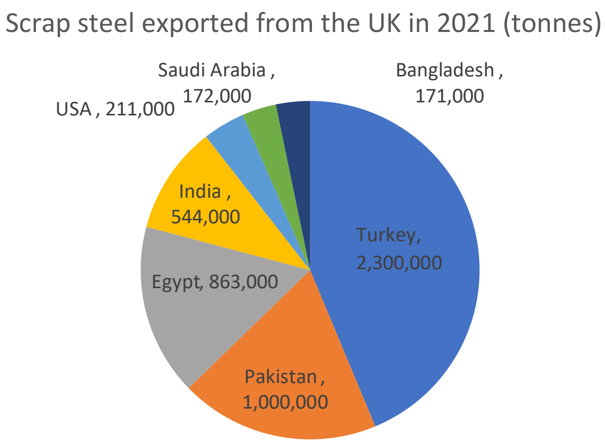


Figure 5 Scrap steel exports from the UK in 2021 (Letsrecycle.com, 2021)

The underlying reason for large exports of scrap steel is the limited domestic capacity to utilise it (Environmental Audit Committee, 2022). Around 80% of the steel produced in the UK is made via the BF-BOF, and 20% via electric arc furnace EAF routes (BCSA, 2022a). The UK's BOF steelmaking capacity (that uses nearly 20% of scrap in metallic charge) is approximately 8.5 Mt versus 2.5 Mt of EAF capacity (uses 100% scrap) (Hall et al., 2021).

The large export of scrap steel is a missed opportunity for the UK. Instead, some of it could be reused while bringing value locally (though generating jobs) and reducing the demand for steel production.

3.2 Environmental impact of the steel industry

Steel production is a carbon and energy-intensive process. The steel industry generates between 7% and 9% of the world's CO_2 emissions (World Steel Association, 2021). The UK steel industry was responsible for 12 million tonnes of CO_2 emissions in 2019 (including indirect emissions from power production) (as shown in Figure 6), which accounts for 11.5% of UK industrial emissions and 2.7% of all UK GHG emissions (UK Parliament Committees, 2020).

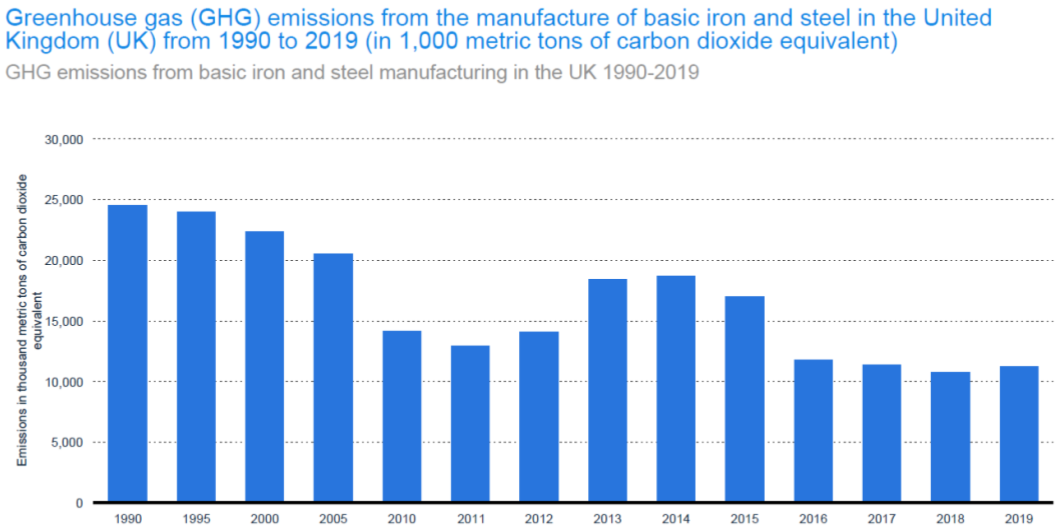


Figure 6 Carbon emissions from the manufacture of iron and steel in the UK (Statista, 2021)

The global steel demand is expected to continue, rising to 2.5 billion tonnes per annum by 2050 (from the current production levels of 1.8 billion tonnes) as demand for goods and services increases with economic and population growth, especially in the developing markets. Figure 7, shows differences in steel production and scrap consumption in leading markets in 2020.

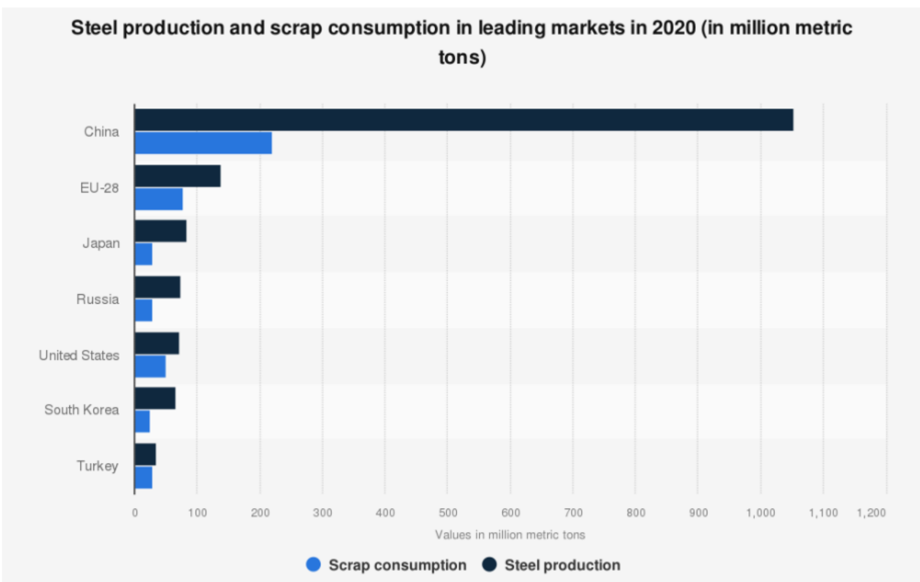
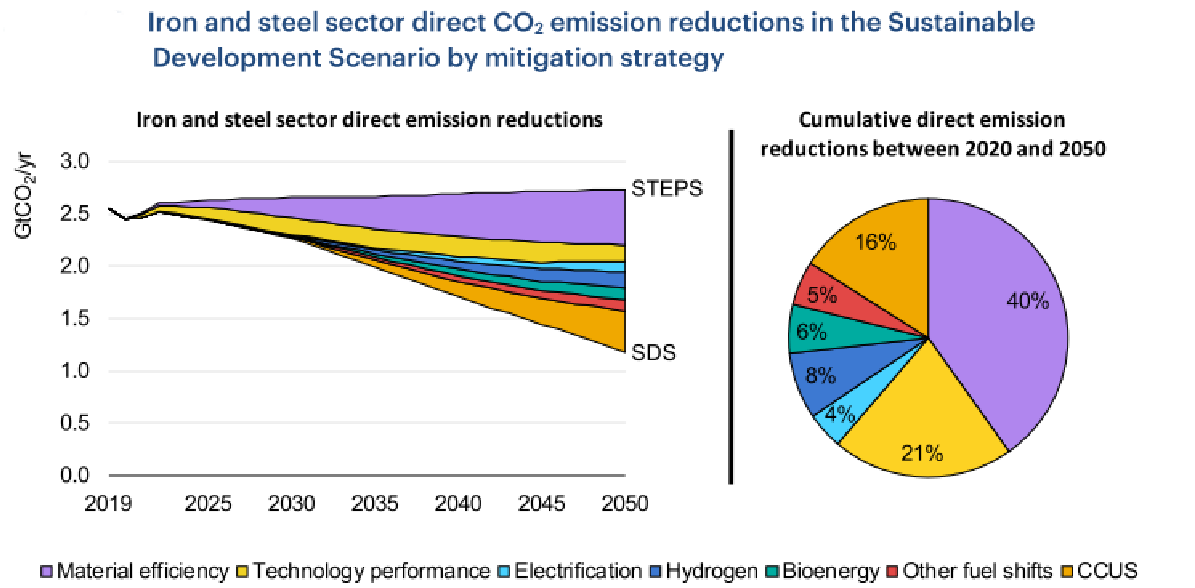


Figure 7 Steel production and scrap consumption gap in leading markets in 2020 (Statista, 2021)

To decarbonise steelmaking lots of attention is directed at improving the technology of steel production, such as using more recycled materials in EAFs, switching from coking coal to low-carbon hydrogen as the chemical reducing agent, and using Carbon Capture and Storage (CCS) and Carbon

Capture and Utilisation (CCU) solutions (Hutton, 2021). Adopting technological solutions alone is not sufficient to reach net-zero targets according to a recent study by Garvey et al. (2022). Material efficiency will also be necessary considering the growing demand for steel production worldwide. A roadmap to decarbonise steel produced by the International Energy Agency suggests that, cumulatively, more efficient use of materials will reduce carbon emissions between 2020 and 2050 by 40% – far more than any other approach, including a switch to electricity, hydrogen and biofuels, which could account for 18%, and CCS which could account for a 16% reduction (IEA, 2020), as shown by Figure 8.



Note: STEPS = Stated Policies Scenario, SDS = Sustainable Development Scenario. Emission reductions are measured relative to the Stated Policies Scenario; as such, the proportion of improvements relative to today that occurs in both scenarios is not represented (e.g. a significant share of increases in scrap-based production). Material efficiency here refers specifically to demand reduction. Electrification here includes only direct electrification, primarily via conventional technologies, including shifts towards secondary production in EFs and electrification of ancillary process equipment like preheaters and boilers. Hydrogen here refers specifically to electrolytic hydrogen, while so-called blue hydrogen (via natural gas-based DRI with CCUS) is included under CCUS. Other fuel shifts include primarily coal to natural gas switching.

Figure 8 The impact of material efficiency strategy on carbon emission reductions in the iron and steel sector in comparison with technology solutions (IEA, 2020)

Resource efficiency in the construction sector offers a great opportunity to cut carbon emissions. ***Estimates suggest that 22.3 MtCO2e of GHG emissions could be saved over 9 years by increasing the reuse of construction products to 35%*** (CIE-MAP, 2018).

3.3 Steel prices fluctuations

Steel is a commodity material traded globally and as such, subject to fluctuations depending on market activity. Steel prices reflect the immediate balance of supply and demand. Supply is constrained by the current global capacity. Prices rise if demand increases ahead of capacity, but when demand falls, prices fall below their long-run levels until sufficient steelmaking plants close (Allwood et al., 2019).

Global steel prices have risen over the past five years owing to high demand from China and other emerging markets, as well as supply shortages. The economic fallout from the COVID-19 outbreak initially limited demand for metals from the construction, automotive and manufacturing sectors. However, rising business confidence over 2021-22 is expected to support a recovery in these markets (IBISWorld, 2018). Historical steel prices are provided in Figures 9 and 10.

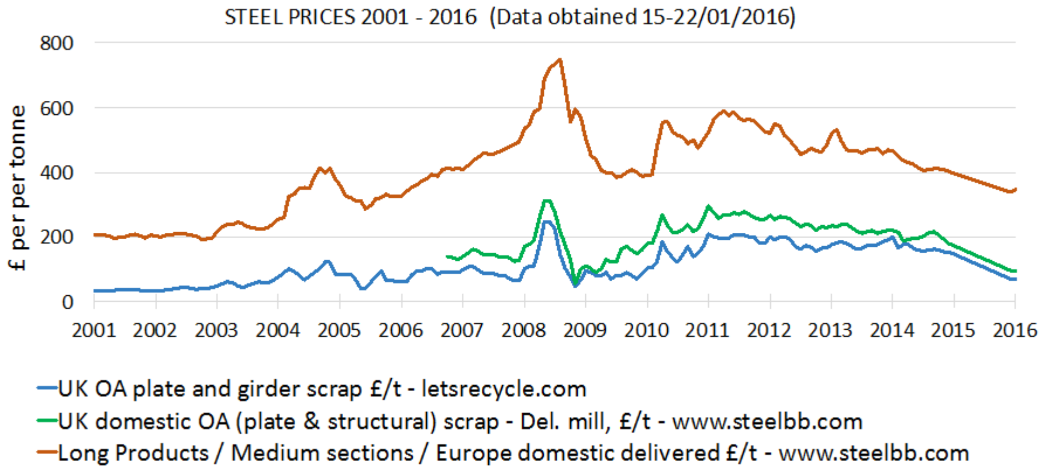


Figure 9 Prices of new and scrap steel from 2011 to 2016 (Dunant et al., 2018)

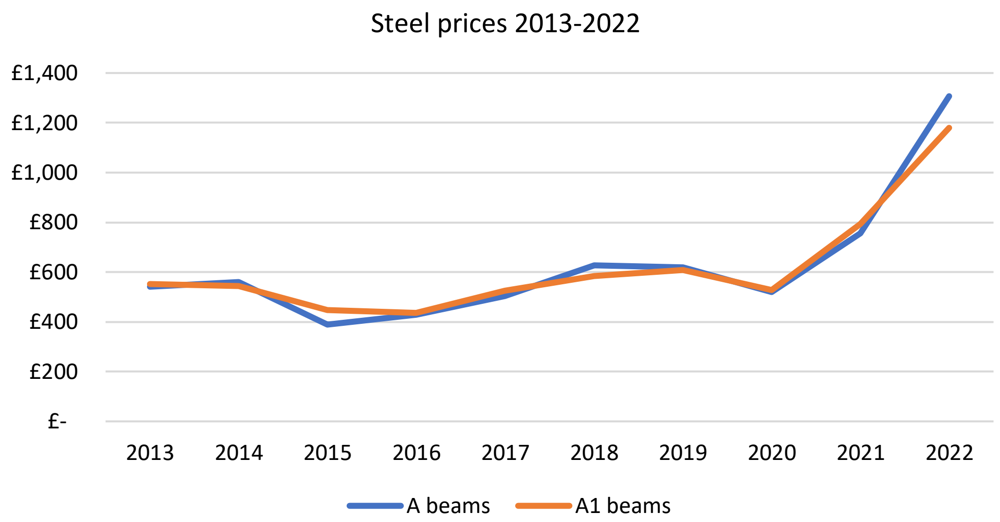


Figure 10 Prices of steel beams from 2013 to 2022 (Data was provided by Cleveland Steel and Tubes)

The cost of steel has gone up increasingly for both new steel and scrap steel. The average cost of new steel has undergone a 205% increase from £428 in 2016 to £1,307 in 2022 (see Figure 10). The average cost of scrap steel grade OA has gone up from £65 per tonne in 2016 to £350 per tonne in 2022, which is a 438% increase (see Figure 11).

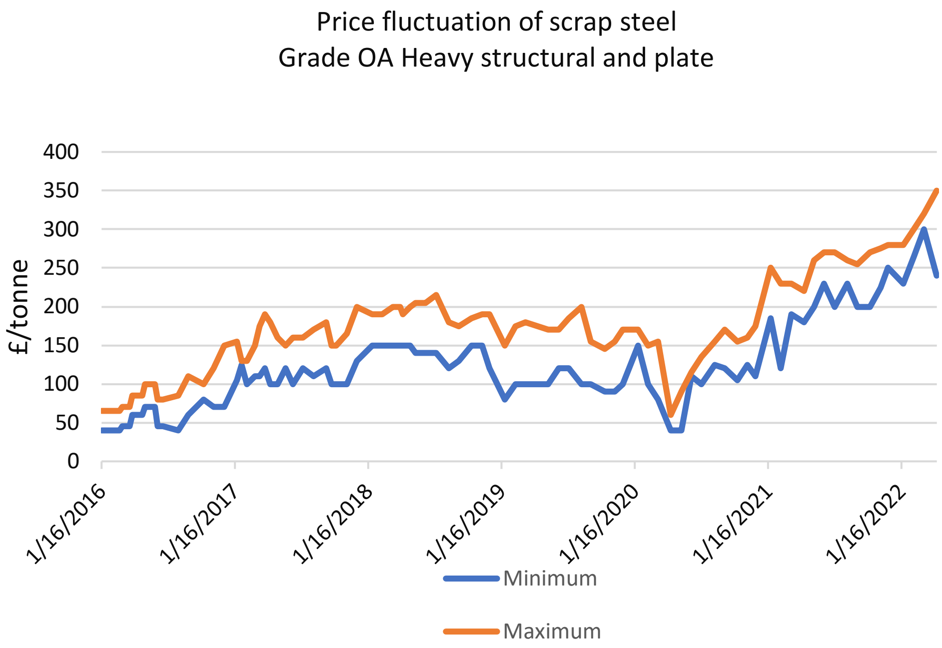


Figure 11 Scrap steel prices (MRW, 2022)

Although new steel and scrap steel prices are volatile, there has been a consistent price differential between new and scrap steel, which represents a profit opportunity for steel reuse.

3.4 Potential supply of scrap structural steel for reuse

Many buildings are currently demolished before the end of their technical lifetime, in particular commercial buildings that are often only used for 30 to 40 years compared to a technical lifetime of 75 years or more (IEA, 2020).

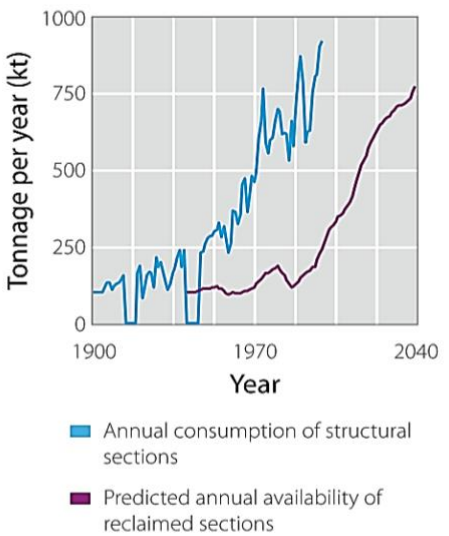


Figure 12 Forecast availability of scrap structural sections in the UK (Allwood et al., 2012)

The graph (Figure 12) shows an estimated history of construction steel used in the UK, and the second line, smoothed and shifted forwards by 40 years, is an indicator of the upcoming availability of structural steel in buildings reaching their end-of-life (Allwood et al., 2012).

4. Key drivers for steel reuse

4.1 Environmental advantages of steel reuse

Reusing steel can provide significant environmental benefits. The use of reclaimed steel products reduces the demand for virgin materials resulting in lower energy use and GHG emissions.

According to European Metal Recycling (EMR), reusable steel is responsible for only 15 kg of carbon emissions per tonne (EMR, 2022). This is significantly lower than primary steelmaking routes, see Figure 13.

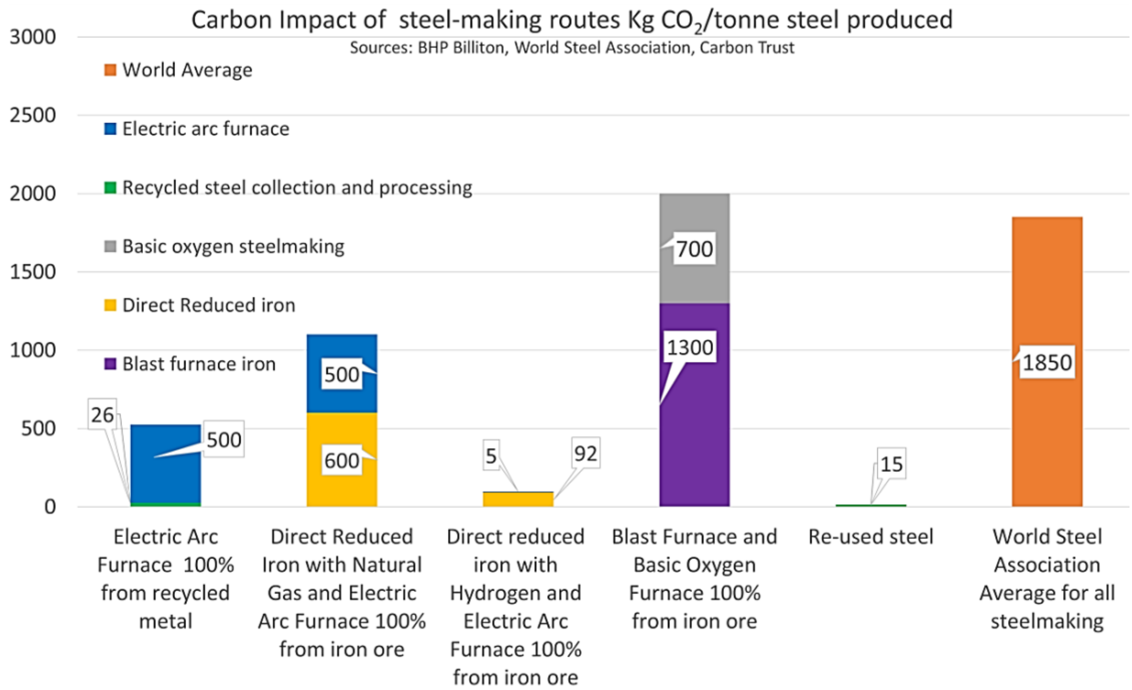


Figure 13 Carbon impact of steel reuse in comparison with other steelmaking routes (European Metal Recycling Ltd, 2022)

The Environmental Product Declaration (EPD) developed by EMR shows that their reusable steel is responsible for as little as 46.6 kg of CO_2e per tonne. This includes A1 raw material (25.5 kg/ CO_2e/t), A2 upstream transportation (13.4 kg/ CO_2e/t) and A3 manufacturing (7.7 kg/ CO_2e/t).

In comparison, embodied carbon of virgin steel (hot rolled sections) shows 1740 kg of CO_2e per tonne considering A1 module only, according to BCSA and SCI (NSC, 2021).

The use of reclaimed steel sections is estimated by BRE as having 96% lower environmental impact across various categories in contrast to using new steel (Figure 14).

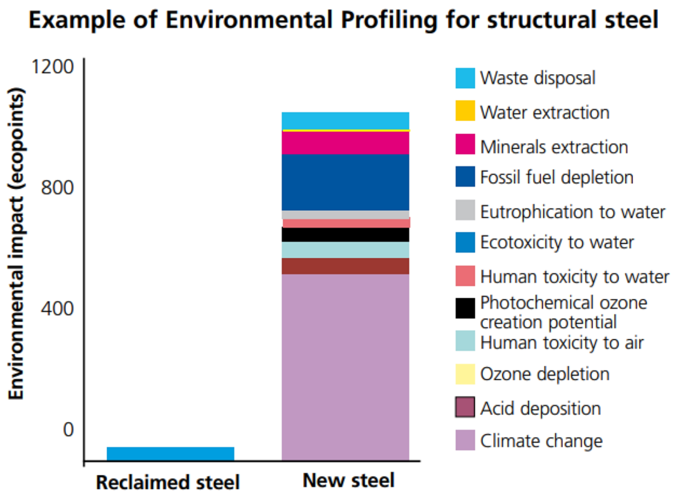


Figure 14 Life Cycle Assessment of reclaimed and new steel (BioRegional, 2002)

Cleveland Steel and Tubes Ltd commissioned a Life Cycle Assessment for their recovered and refurbished coated steel tubes from the steel, oil and gas industry. The assessment revealed 96% greenhouse gas emissions savings compared to buying new steel. The other environmental benefits include an 84% reduction in acidification, 63% in eutrophication, 96% in photochemical oxidation, 95% in abiotic depletion and 99% in water savings. The life cycle analysis considered a range of factors, including material processing, logistics, and disposal of any generated waste (Cleveland Steel and Tubes Ltd, 2018).

4.2 Environmental policies and client demand for ESG as a driver for steel reuse

The construction sector, similar to other sectors is experiencing growing pressure to reduce its carbon footprint, material consumption and waste.

Decarbonisation of the steel industry is an important part of reaching the Government's target to achieve net-zero greenhouse gas emissions in the UK by 2050. Earlier this year, the Environmental Audit Committee launched an inquiry looking for solutions to decarbonise UK steel production that includes improving material efficiency in the sector (Environmental Audit Committee, 2022). Steel reuse was mentioned as an approach to reduce the demand for steel production, lowering carbon emissions (see Appendix).

Circular economy concepts are being promoted, particularly at the EU level, with a roadmap developed to support a shift towards a resource-efficient, low-carbon European economy (SCI, 2019). In the UK, there are planning requirements for referable developments to the Greater London Authority to undertake a circular economy statement. In undertaking this retention the reuse of materials should be considered. Other local authorities are starting to ask for these types of Statements. There is also ad river for whole life carbon assessments and targets, which are being carried out more so; reusing steel, as already discussed is a key strategy to reduce embodied carbon on developments (Greater London Authority, 2022).

Strengthening policies around environmental issues impact developers who are looking for low carbon circular economy solutions. For example, Grosvenor Group has engaged in a number of steel reuse projects, including the Holbein Gardens project, Fabrix has enabled steel reuse at the 55 Suffolk Street project, and Delancey at Elephant and Castle town centre redevelopment project. (Case studies with steel reuse will be published closer to the end of this project.)

A list of strategies and initiatives around steel sector decarbonisation and resource efficiency in the UK is compiled in Table 2.

Table 2 Strategies, policies and initiatives around steel sector decarbonisation and waste reduction in the UK

Strategy/Policy/Initiative	Owner	Target
Government and agency publications		
Climate Change Act of 2008	The UK Government	To reduce 68% of carbon emissions by 2030 and 78% by 2035, compared to 1990 (which equates to a 67% reduction compared to 2018 levels); and net zero by 2050
Iron and Steel Technology Roadmap, 2020	International Energy Agency	The analysis of strategies required to reduce carbon emissions in the iron and steel industry concluded that: - when examining emission reductions cumulatively during 2020-50, the largest roles are played by **material efficiency (40%)**, technology performance (21%) and improvements for carbon capture, use and storage (CCUS) 16%. - Within this, direct steel reuse accounts for 15% of the cumulative reductions in demand for crude steel.
Net Zero Strategy: Build Back Greener, 2021	HM Government	To increase **resource efficiency.** Resource efficiency and material substitution measures could save 9 MtCO2e per annum in the industry within the UK by 2050. Resource efficiency measures reduce emissions from industrial processes by keeping products and materials in circulation for longer by way of **reuse,** repair, remanufacture and recycling as well as reducing material usage. These activities enable the retention of value, and in some cases the creation of new value for both the producer and customer, at a much-reduced environmental impact.
Industrial Decarbonisation Strategy, 2021	HM Government	Carbon emissions reduction by at least two-thirds by 2035 need to fall

Strategy/Policy/Initiative	Owner	Target
		by around two-thirds by 2035, with 3 MtCO2 captured through Carbon Capture, Usage and Storage (CCUS) and around 20 TWh switching to low carbon fuels by 2030
Steel Procurement Taskforce Final Report 2022 (Explored how the steel sector can best position itself to compete for major public projects)	The Steel Procurement Taskforce network consisted of representatives from the UK steel industry and from across the government including the Department for Business, Energy & Industrial Strategy (BEIS)	- The UK steel industry should develop a digital products library, collaborating with the Government as necessary. - HMG should restate the importance of early engagement with the steel supply chain, drawing on best practices set out in the Construction Playbook. - HMG should set a requirement for all new qualifying contracts, where steel may be purchased directly or via any sub-contract, for the origin of this steel to be recorded and reported.
Technological Innovations and Climate Change inquiry: Green Steel, 2022	Environmental Audit Committee (EAC)	- The Committee is concerned with increased dependency on imported steel in future. - Most of the scrap steel in the UK is exported. There is a potential to make better use of domestic scrap. (more details in Appendix)
The London Plan 2021	Greater London Authority	**Policy SI 7 Reducing waste and supporting the circular economy** encourages waste minimisation and waste prevention through the **reuse of materials** and using fewer resources in the production and distribution of products and sets the folowing targets: - To meet or exceed **95% reuse**/ recycling/ recovery targets for construction and demolition - To submit Circular Economy Statements for major developments in London demonstrating **how all materials arising from demolition and remediation works will be re-used** and/or recycled
Our Waste, Our Resources: A Strategy For England	Department for Environment, Food & Rural Affairs (DEFRA)	**To increase the reuse of materials and products** and **address barriers to reuse.**

Strategy/Policy/Initiative	Owner	Target
Waste Prevention Programme for England, 2021	Department for Environment, Food & Rural Affairs (DEFRA)	To reduce construction waste and increase the reuse of construction materials at their highest value. This means designing buildings for adaptability and deconstruction, increased reuse of components, **use of materials that can be reused** and recycled, and improved demolition systems.
Resource efficiency and waste reduction targets Detailed Evidence report, 2022	Department for Environment, Food & Rural Affairs (DEFRA)	To eliminate avoidable waste of all kinds by 2050.
	Industry networks	
Low Carbon Roadmap Pathways to a CO2-Neutral European Steel Industry, 2019	The European Steel Association (EUROFER)	A roadmap to transition to a low or carbon neutral European steel industry: • To achieve carbon emissions cuts of between 80-95% by 2050 • Total costs of production will rise by 35-100% per tonne of steel by 2050 as a result of the costs of using new technologies and more energy • Additional energy requirements will be about 400TWh of CO2-free electricity in 2050 – about seven times what the sector purchases currently.
SteelZero initiative, 2020	Climate Group and ResponsibleSteel	To join SteelZero, organisations must make a public commitment to procuring, specifying or stocking 100% net zero steel by 2050 and an interim commitment to procuring, specifying or stocking 50% of its steel requirement by 2030. Reuse is not specifically mentioned.
How should Scotland manage its scrap steel? The environmental assessment, 2021	ZeroWaste Scotland	To encourage local reuse of steel to reduce carbon footprint of steelmaking. A scenario is suggested where 16% of the steel scrap generated in Scotland is reused and the remaining 84% is recycled, which would result in 580 $kgCO_2e/t$. In comparison, 100% recycling is estimated at 641 $kgCO_2e/t$.
Maximising value: Positive Procurement of Steel. Guidance	Make UK	To contribute fully to those produced by

Strategy/Policy/Initiative	Owner	Target
for Signatories for the UK Steel Charter, 2021		the UK, Scottish and Welsh Governments. Sourcing products locally cuts down significantly on transport related carbon emissions. A tonne of steel transported within the UK produces less than 10kg CO2/tonne, on average. Compare this to steel imported from the EU at 160kg CO2/tonne or from China at 550kg CO2/tonne.
Roadmap to net zero for the manufacturing sector, 2022	Make UK and Inspired Energy	To achieve a 67% reduction in Scope 1 and 2 emissions by 2035, and net zero by 2050
Accelerating material re-use network, 2021	Grosvenor in collaboration with 120 built environment professionals representing the full lifecycle of a building	To build confidence in supplying and receiving materials on-site through enhancing knowledge and creating a network of progressive companies willing to trial new approaches.
UK structural steelwork: 2050 decarbonisation roadmap, 2022	BSCA	A roadmap for the UK structural steelwork sector decarbonisation. **Steel reuse** is featured as part of the circular economy strategy, which contributes 15% along with other strategies such as design efficiency, direct steelmaking emission reductions, decarbonisation of the electricity grid, carbon capture and use and storage, and steel transport, fabrication and erection. Reuse and remanufacture were given a Technology Readiness Levels (TRL) score of 7 (System prototype demonstration in operational environment).
	Steel companies	
Low-Carbon Roadmap, 2021	British Steel	To deliver CO2 reduction by 2030, 2035 and 2050 to align with UK net zero targets To **support recycling and reuse**, for instance using increased levels of scrap in its steelmaking process and encouraging **reuse of steel products at the end of life**, where appropriate

Strategy/Policy/Initiative	Owner	Target
Pathway to net zero carbon, 2021	CELSA Steel UK	To achieve a Net Zero Carbon emissions facility by 2030
Commitment to net zero, 2021	Tata Steel	To achieve 30% carbon reductions by 2030 and become carbon neutral by 2050
GREENSTEEL strategies, 2021	LIBERTY Steel Group	To recycle and upcycle the growing amount of scrap steel, using electric arc furnaces powered by renewable energy

4.3 Economic benefits of steel reuse

Reusing steel can provide significant cost savings. The profitability of steel reuse depends on the relative costs of new and scrap steel, and the costs of additional processes required for reclaimed products (including reconditioning, testing, transporting, storing, certification and deconstruction costs).

A research study by Dunant et al. (2018) showed that reclaimed steel products can be slightly (3 to 10%) more expensive than new steel depending on a number of factors. Figure 15 shows the cost comparison for reused and new steel.

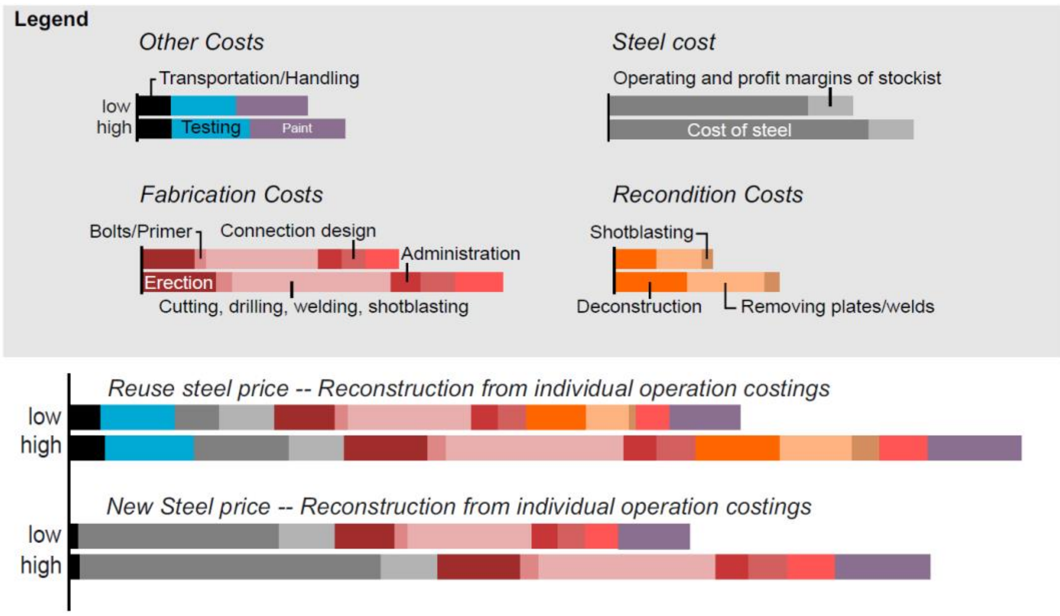


Figure 15 Comparison between reconstructed new steel prices, by summing individual costs, and from information about the overall structure. Reused steel prices are reconstructed only by summing the prices of individual operations (Dunant et al., 2018)

However, a review of case studies in the past showed many cases of gaining economic benefits from steel reuse. A summary of steel reuse projects in the UK completed between 2004 and 2012 is given in Table 3. The majority (75%) of steel reuse case studies were profitable.

Table 3 Profitability of steel reuse case studies in the UK between 2001 and 2014, compiled by (Dunant et al., 2018)

Case study	Profitability of steel reuse	Description
Guillemont Park Camberley 2004	No	Five, 3-storey buildings, grid 9×9m, 14,000m^2; 107 tonnes of the almost unspoilt floor beam available for reuse. The price of steel scrap was high so the proposed buyer price was not profitable for the demolition contractor.
Carrwood Park Doncaster 2008	Yes	1800m^2 portal-framed building constructed using 82 tonnes of reclaimed structural steel from an old warehouse. Refurbished.
Blue Steel Building Leeds 2005	Yes	14,500m^2, Poundstretcher facility refurbished and extended. Became a Carlsberg facility.
BedZed London, 2001 (BioRegional Development Group, 2002)	Yes	The structure of the workshop area of the building is made using steel sourced from temporary works at Brighton railway station. No testing, and material costs were neutral compared to new steel, second-hand steel price was 300 £/t.
Relocation of Leigh Rd, 9 Cambridge Ave. (Segro) Slough, 2015	Yes	Relocation of the building 1 mile away. Reused: steel structure, glazing, staircases, loading doors, precast beams, planks, curtain walling, fencing, lift, balustrades. Not reused: bricks, cladding, roof.
Sainsbury Mezzanine Kent, 2010	Yes	The roof was disassembled, and a new floor was added. Structure: shot blasted, not painted, not fire protected, only connections tested.
RHS Hyde Hall Essex, 2014	No	An option for reuse was developed and rejected based on costs.
Honda Central Swindon, 2005	Yes	Honda steel warehouse deconstruction, and storage (for 18 months). Re-erection in a different location (cladding not reused).

Under certain (project-dependent) circumstances steel reuse can bring cost savings if some of the costs are abolished or significantly lower, for example, when:

- Testing of individual elements is limited
- Transport costs are lower when the reused elements are available from a nearby site
- Sub-assemblies which are reused do not need to be re-fabricated
- Reused steel can be procured at low costs
- Fabrication costs for reclaimed steel are lower than for new steel (Dunant et al., 2018).

5. Barriers to steel reuse

Previous studies have shown that the major barriers to steel reuse include limited availability of reclaimed products, lack of traceability, economic barriers and time limitations, poor supply chain integration, and lack of incentives for steel reuse. Each of these barriers is described further in detail.

- **Limited availability of reclaimed products.** Given the low volume of steel sections currently reclaimed from UK demolition (estimated to be 7%), reclaimed steel members are not readily available, particularly in terms of the desired size, volume and the right location. This hinders procurement and affects lead times that are critical in construction projects.

- **Lack of traceability of reclaimed products.** Steel reuse might be hindered when little or no information is available about which building the reclaimed products come from, their mechanical and chemical properties and in-use history. Having such information is essential for deciding whether steel elements can be reused (e.g. steel from structures erected before the 1970s is not recommended for reuse by the protocol for steel reuse (P427)). Some properties of the material can be determined by tests, but this can increase costs and can be time-consuming. Having information on the provenance of reclaimed steel products is important for designers and steelwork contractors to design and fabricate reclaimed steel structures efficiently and safely (Tingley et al., 2017).

- **Insufficient time** within new development programmes **to allow for deconstruction** and recovery of the steel elements rather than demolition (BCSA, 2022b). Seel reuse being uncommon practice means more time on planning, coordinating and reassurance might be required. The impact of steel reuse on project timeliness is particularly important for the clients, main contractors and demolition contractors. This will be mitigated with more companies getting experience with steel reuse.

- **Lack of incentives.** Companies are not sufficiently incentivised to drive steel reuse from policy and legislative perspectives. Material reuse is not directly recognised/encouraged in the BREEAM sustainable building certification scheme (unlike in the LEED scheme where one or two points are awarded, respectively, if the project can demonstrate that 5% or 10% of the total monetary value of materials on the project is reclaimed, refurbished, or reused, and installed permanently in the final building (Winters-Downey, 2010)). Also, the reclamation of steel from demolition for reuse instead of recycling is not incentivised.

  Economic barriers and time limitations. Although case studies demonstrate that steel reuse can be profitable, it also entails economic risks. The profitability of steel reuse projects depends on a number of factors including relative prices of new and scrap steel. Steel prices have been highly volatile over the past five years; these pose risks and are difficult to forecast. There are also additional costs incurred as a consequence of using reclaimed steel: deconstruction/demolition, reconditioning, transportation, storage and testing costs. The costs of these activities are highly variable and project dependent.

- **Lack of supply chain integration.** Traditional construction supply chains are complex and highly fragmented. In most construction projects, the supply chain relations terminate at a building completion/handover or shortly after this. Following the building's useful life (which can be 50-100 years or more, though usually shorter for commercial buildings), a demolition contractor is engaged to demolish or deconstruct the building. Hence, designers and demolition contractors are disconnected. In the reuse model where steel is recovered from a demolished donor building and incorporated into a new recipient building, information sharing between designers and demolition contractors is beneficial for planning the reclamation of steel elements and design based on available steel elements (Tingley et al., 2017).

6. Enablers to steel reuse

The following enablers could help to overcome some of the barriers to steel reuse.

- **Digital tools including BIM and material passports**

  The application of digital tools and the BIM model could increase information sharing across the products supply chain, responding to the barriers of lack of traceability, supply chain integration and availability of reclaimed products.

  - For example, having a **BIM model** of a building could help to identify which materials have been used in a building, its properties, certificates and testing details. When the building is demolished/deconstructed, reclaimed steel products with known provenance and properties are easier to be reused in future, as some testing can be avoided.

  - A **permanent marking** on each steel product/section at regular intervals could specify its grade, property and product history. This enhances **the traceability** of products and facilitates decision-making on reusing products.

  - A **database** of suppliers could be created to link supply and demand. The database could show which products are available for purchase and their characteristics. This would facilitate the procurement of reclaimed products (Tingley et al., 2017).

    For instance, the Loopfront digital reuse platform launched in 2019 in Norway enables registering technical information on materials and inventory on existing buildings or those planned for demolition. The company connects building owners, construction companies and industrial actors and is currently working with several organisations, including municipalities in Norway and Sweden, and has plans to enter more countries in the EU market (Loopfront, 2022).

    In the UK, the London Borough of Enfield has set up an Excess Materials Exchange platform for the partners, contractors and consultants where construction materials can be uploaded and purchased to be reused in new projects (*Enfield*, 2022). Currently, Drumsheds are scheduled for disassembly or demolition, which can potentially be reused in new projects.

  - Furthermore, the introduction of **material passports** could facilitate the reuse of steel products. Material passports consist of a series of data describing the characteristics of the building's elements, including a complete description of all products, components, and raw materials that are present in the building to provide value for the recovery, recycling, and reuse of the mentioned parts after demolition/deconstruction (Bertino et al., 2021).

- **Design for reuse**

Some of the principles for design for reuse include simplicity in design, modular design, using standardised sizes, using longer beams, avoiding fabricated sections, and avoiding composite materials, such as composite steel floor decks. Also, the development of a disassembly plan could become part of the design process to encourage the reuse of materials and components.

- **Government policy and incentives**

  Government intervention could play a significant role to encourage supply (demolition contractors) and demand (clients and their professional advisers) to increase steel reuse.
    - The government could encourage demand through public sector procurement, specifying a percentage of steelwork to be reused.
    - Local authorities could incorporate design for deconstruction and future reuse into local planning regulations.
    - Fiscal incentives to support new business development around steel reuse could be provided, for example, subsidising the storage of reused steel (Tingley et al., 2017). Material pricing mechanisms such as virgin material taxes and material price stabilisation instruments could be applied (Garvey et al., 2022).
    - Softer initiatives might include establishing a registry for suppliers of reused steel, encouraging information sharing, awareness-raising and recognition for projects leading to steel reuse, for example through industry awards (Tingley et al., 2017).

- **Technologies for non-destructive testing, deconstruction and segregation**

  Improvements in infrastructure for steel reuse would facilitate its wider adoption. This includes:
    - Rapid *non-destructive testing* technologies enable fast low-cost assessment of the material properties of reclaimed steel members.
    - Technologies for remote *deconstruction* of buildings conforming to health and safety considerations.
    - Technologies that effectively *segregate* composite materials (Allwood et al., 2010).

7. Processes for steel reuse

Figure 16 shows a simplified model for the construction of a building with reused steel. Testing and certification of reclaimed steel are described in detail in the protocol for structural steel reuse (P427) developed by the Steel Construction Institute (SCI, 2019). Also, the British Constructional Steelwork Association (BCSA, 2022) has published a model specification that applies particularly to the contract between the stockholder and the purchasing steelwork contractor to provide confidence that steel sections meet performance requirements.

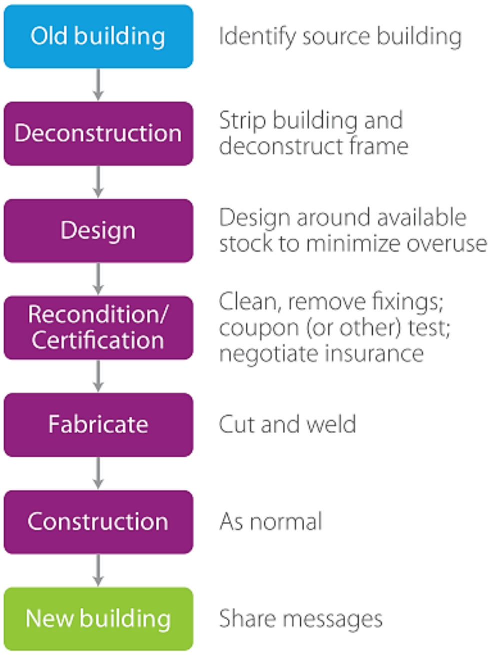


Figure 16 Process flow for building a new building with reused steel (Allwood et al., 2012)

The main processes required for steel reuse include the following.

- **Pre-demolition audit (also called preliminary assessment)** is conducted before the existing structure is demolished/deconstructed to collect information about potential qualities and quantities of steel. At this step, general information about the existing structure is collected, such as the description of the structure and its use, the location of the structure and the date of construction. The audit can help to define expected steel condition, quantities, recommendations for reclamation and ways to ensure safety during the process.

- **Reclamation of steel products** by demolition contractors from structures erected after 1970 that were not subject to fatigue, significant strains, loss of section due to corrosion, and other severe conditions such as fire.

- **Inspection** of reclaimed products after deconstruction (conducted by stockholders).
    - Steelwork is visually inspected for any significant (exceeding 5%) *loss of section due to corrosion*, signs of *damage* or *plastic strain*.
    - If existing connections are to be reused, the *condition of any welds* should be carefully inspected and tested.
    - Also, a stockholder should measure the sectional *dimensions* (cross-section and length) and assess *straightness* (against specified tolerances) to comply with the National Structural Steelwork Specification for Building Construction (NSSS) (SCI, 2019).

Reclaimed steel will be available in various conditions. Some steelwork will have been used in a building for years with plates welded and holes drilled through it. Some may have been stored outside for months and may appear ‘rusty’. Other steelwork is as good as new, coming from cancelled orders where the steel has already been fabricated for a new project - it has been certified and its provenance is known. To differentiate between various conditions of reclaimed steel, a grading system has been proposed by Penny Gowler from Elliott Wood and Roy Fishwick from Cleveland Steel and Tubes (Table 4).

Table 4 The proposed grading system for reclaimed steel (Gowler, 2022)

Grade A	**Grade B**	**Grade C**	**Grade D**	**Grade E**
Pre-owned clean steel, no holes, no fittings etc.	Second-hand steel, all existing holes repaired, all historic plates, connections etc. to be removed	Second-hand steel, some existing holes to be repaired (refer to drawings), historic plates, connections etc. to be removed	Second-hand steel, existing holes remain, historic plates, connections etc. can stay in place unless they clash with proposed connections	Not structurally compliant e.g. twisted, plastic deformation
				

- **Reconditioning (re-fabrication)** of reclaimed steel products (by stockholder) including:
  - removing *coatings*, particularly those containing toxic substances such as lead, cadmium, asbestos and surface scaling
  - removing redundant *welded fittings*, such as stiffeners or cleats
  - filling *bolt holes* (depending on location, size and other requirements)
  - Steel products should be free from *discontinuities (imperfections and defects*) resulting from the reclamation process; these can be rectified by the supplier.

- **Testing** and certification of reclaimed products. This is conducted by independent accredited testing bodies and coordinated by the stockholder. The following material properties are determined via testing:
  - *yield strength, ultimate strength* and *elongation* (determined by both destructive and non-destructive tests, based on which steel grade can be established)
  - *impact toughness* (if required, determined by destructive tests)
  - product analysis to determine *Carbon Equivalent Value (CEV)* (determined by non-destructive and destructive tests)

- *section dimensions* and *member straightness* (based on dimensional survey).

Reclaimed structural steelwork is subject to CE/UKCA Marking in accordance with BS EN 1090 in a similar way as with new steel products. For reclaimed steel, the declared material properties are consistent with those assumed in the design.

The following properties are mandatory to be declared:

- *strength* (yield and tensile),
- *elongation*,
- *tolerance on dimensions and shape*,
- *heat treatment delivery conditions*.
- If the steel is to be welded, information on *Carbon Equivalent Value (CEV)* should be provided.

In some cases, the following properties might also need to be declared:

- *stress reduction of area requirements (STRA),*
- *impact strength or toughness,*
- *through thickness requirements (Z-quality)* and
- *limits on internal discontinuities* or *cracks in zones to be welded.*

- **Transport** and **storage** of reclaimed products.

- **Data recording.** The following data should be recorded and linked with each structural member:

  - *Data on buildings* (from which steel products are reclaimed), i.e., building age and location, the form of construction and any related information such as drawings, modifications and records.

  - *Data on individual steel members,* i.e., section size, length, group, member individual identification, tolerance check (section dimensions and bow imperfections), comments such as stiffeners or fabricated features, coating type, coating thickness if determined, condition of coating, materials properties determined by tests and through conservative assumptions.

  - *Stockholder records,* i.e., stockholder details including name and other relevant data, internal report/documentation number (based on stockholder records) and other quality records such as testing laboratories, etc.

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Appendix

*Table 5 Written and oral evidence from the inquiry examining green steel in 2022 referring to steel reuse**

Document	Steel sector player	Target
Oral evidence: Liberty Steel and the future of the UK steel industry, HC 118 20 July 2021	Liberty Steel	*"We generate around 10 million tonnes of scrap steel. We use about a quarter of it and we use only 2.7 million tonnes of recycled steel scrap. The UK was the largest exporter of scrap steel in Europe in 2020." … "We need to focus on incentivising the use of scrap steel here in the UK"*
Oral evidence: Technological innovations and climate change: green steel, HC 1093 27 April 2022	British Metals Recycling Association	*"That* [**reuse** of steel in buildings] *will be down to health and safety in the main, depending on how a building is deconstructed. If it is done rapidly, the impact on the steel is going to be concerning. If the I-beams and the steel are taken apart carefully and they are measured and checked for wear and fatigue, I would assume they could be reused. However, in the main right now, because of those safety concerns, a lot of it is cut up."*
Oral evidence: Technological innovations and climate change: green steel, HC 1093	University of Oxford	*"we could **reuse** the products that we make for the construction sector—for instance, hollow sections, I-profiles and all these products that we currently use on a daily basis in our buildings and have used for the past 50 years. All these products are simply*

Document	Steel sector player	Target
20 April 2022		*discarded—they are simply shredded, used and re-melted. We could reuse those products … that could lead to massive reduction of our impacts."*
Written evidence submitted by the British Constructional Steelwork Association 30 March 2022	British Constructional Steelwork Association (BCSA)	*"BCSA has recently (November 2021) published its decarbonisation roadmap … This roadmap includes supply-side measures, including steel production and fabrication, and demand-side measures relating to design efficiency, use of higher strength steels,* ***reusing structural steelwork*** *and the circular economy."*
Written evidence submitted by European Metal Recycling Ltd 30 March 2022	European Metal Recycling Ltd	Recommendations include: *"Producers should be made responsible for sustainable design for* ***reuse*** *and recycling."* *"Support for R&D into design for recycling, enhancing* ***reuse****, and addressing challenges in processing recycles steel including, cleaning, chemistry and dealing with by-products."* *"Government can create a policy environment that will encourage private sector investment to decarbonise the sector through escalating carbon taxation, mandated carbon targets for construction and making producers responsible for eco design for* ***reuse*** *and recycling."*

** https://committees.parliament.uk/work/6512/technological-innovations-and-climate-change-green-steel/publications/written-evidence/*