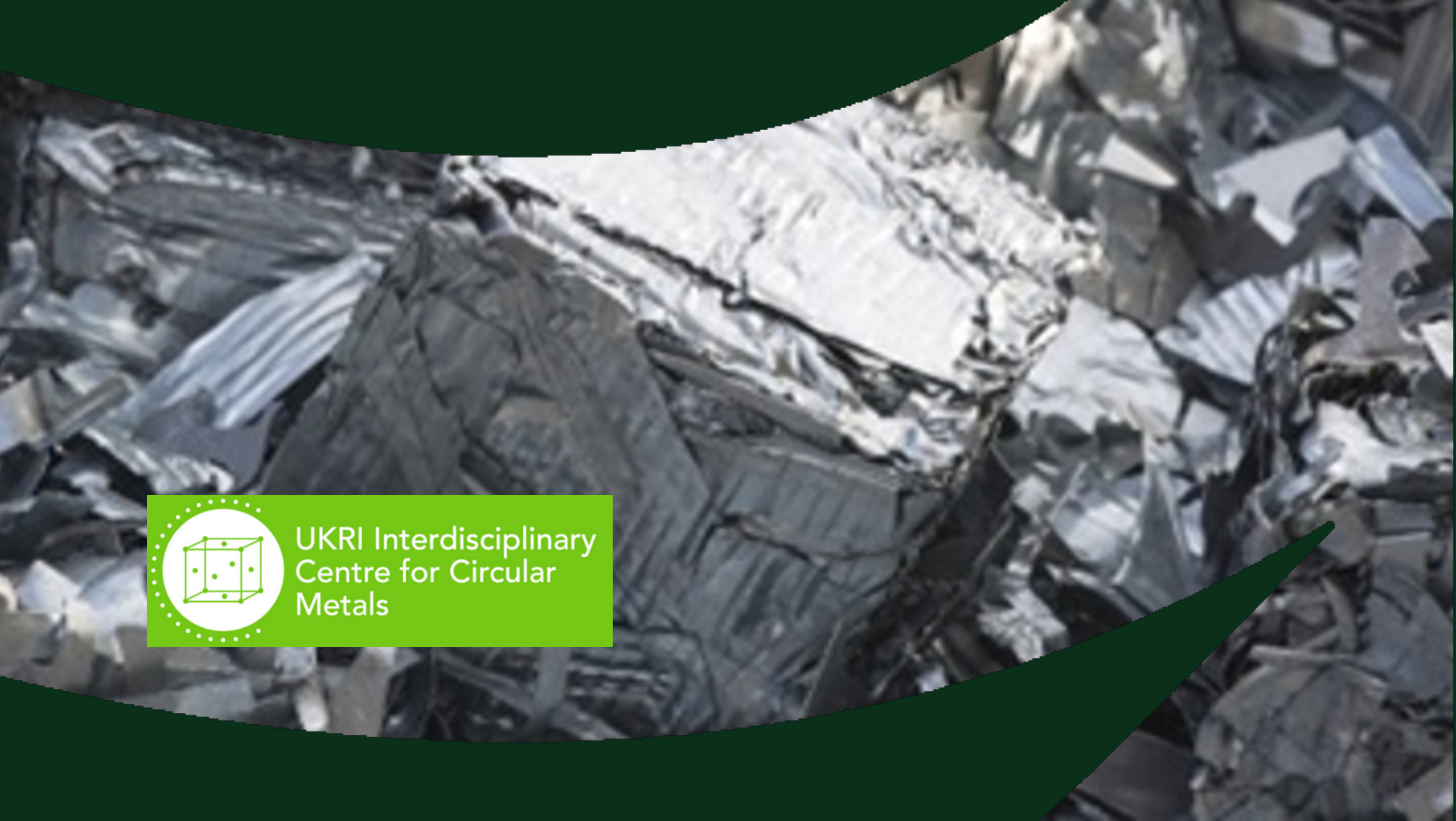
WRAP

Increasing UK Metal Recycling

A review of policy options for increasing UK recycling and delivering Net Zero commitments

Research date: 2021-2022
Publication date: 2024
Project code: POS105-004



About WRAP

WRAP is a global environmental action NGO transforming our product and food systems to create Circular Living. We examine sustainability challenges through the lens of people's day-to-day lives. We transform the systems that provide the products we consume. We catalyse action from policy makers, businesses, NGOs and citizens to make it happen.

Document reference
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WRAP (2024) Increasing UK Metal Recycling: Policy Options

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Front cover photography: Metal_cube_recycling_RM_0315_SS

Executive Summary

Transforming the metals industry from a current largely linear economy to a circular economy plays a critical role in delivering the government's strategy for clean growth and reaching net zero carbon emissions in 2050. The ambition of the Interdisciplinary Centre for Circular Metals is to make the UK the first country in the world to realise full metal circulation. This report considers a range of policy options for increasing recirculation of priority metals (steel and aluminium), identifying barriers and opportunities for metal recirculation in the UK.

Most metal collected for recycling in the UK is exported for recycling. This means that the UK is missing a key opportunity to reduce domestic greenhouse gas emissions, lower domestic energy demand and secure access to raw materials.

The steel and aluminium sectors are facing challenges associated with market volatility, raw material costs and energy supply and costs. The key issue identified for steel, is the need to invest in Electric Arc Furnaces which can incorporate a higher proportion of recycled feedstock than Blast Oxygen Furnaces, whilst also reducing energy demand. For aluminium, notable issues are contamination and separation of aluminium alloys from other materials or other aluminium alloys. At the current time, there is a substantial difference in the availability of different aluminium alloys, despite the overall availability of secondary aluminium in the UK. Contamination and separation can be addressed through further innovations in sorting technologies and whole-life planning. Such planning involves considering the materials used with aluminium (different alloys, coatings, other metals, etc.) during the initial production and the ability to separate these from aluminium at the end of the product's life.

The capital investment required for the steel-related innovations alone is estimated to be in excess of £3.6 billion. In September 2023, Tata Steel and the UK Government announced a joint investment in electric arc furnace steelmaking with a capital cost of £1.25 billion inclusive of a grant from the UK Government of up to £500 million. In November 2023 British Steel made a similar announcement contingent on securing government funding. Tata Steel subsequently closed their blast furnaces in Port Talbot in September 2024.

As is evidenced by the scale of this government investment, significant policies are required to change the market. A range of policy options are considered, but central to this is the need to facilitate investment in UK infrastructure.

Policies such as a Carbon Border Adjustment Mechanism can create incentives for investment, and Extended Producer Responsibility could raise funding to support investment in infrastructure transformation. However, there is no single intervention that will encourage more domestic recycling of domestically produced scrap metals, and a range of interventions will need to be pursued. These present a significant opportunity for the UK to lead in the production of net-zero or low carbon metals.

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1.0 Introduction

1.1 The aim of a circular economy is to transform our current throwaway society into one where we eliminate waste, circulate resources, and adopt nature positive, low carbon, resource-efficient systems and actions. Instead of using resources once and disposing of them in landfill, the aim is to gain the maximum benefit from them while reducing negative environmental impacts. Circularity offers the potential to 'build back better', bring new jobs, healthy lifestyles and green growth. The UKRI Interdisciplinary Centre on Circular Metals is aiming to make the UK the first country in the world to realise a fully circular use of metals. Circular metals are key to a green industrial revolution and to the UK's ambitions to double resource productivity and deliver net zero by 2050.

Steel is among the top three carbon-intensive products worldwide and is widely used in key sectors including construction and vehicle manufacturing. A more circular economy for metals is key to delivering the UK Governments Net Zero ambition, as is increased domestic sourcing more generally. UK steel production is associated with lower direct greenhouse gas emissions than the global average; UK ore-based producers are found to emit 16% less CO2e than the global average BOF producer and scrap-based producers emit 49% less CO2e than the global average EAF producer (Make UK, 2022). Hall et al (2021) suggest that recycled steel could save 86% of greenhouse gas emissions, 85% of energy, 76% of water pollution, and 40% of water consumption by using the electric arc furnace route of steel making, compared to the route of primary extraction and blast furnaces.

Primary aluminium production is energy intensive and, in 2013, was reported to be responsible for producing around 15% of global industrial GHG (Green House Gas) emissions (Gutowski, et al., 2013; Raabe, et al., 2022). However, secondary aluminium could be produced using 5% of the energy, with a 93% reduction in carbon footprint, based on the North American market (The Aluminum Association, 2022). Due to aluminium's relatively low-weight and long life, it could provide longer-lasting products for industries such as building construction, and reduced transport emissions if incorporated more into vehicle construction (AlFed, 2021b).

The primary environmental outcome which the Circular Metals Centre wishes the policies to deliver is to increase recycling rates. Secondary outcomes will include:

- Reduction in total waste (e.g. from mining, processing, households)
- Increase in levels of product reuse
- Increase in levels of product remanufacture
- Increase in levels of product repair
- Increase in recycled content

The review focusses on recycling, and supplementary to this will consider the other policy outcomes listed above. The review considers UK and Devolved Administration policy including the Resources and Waste Strategy[1] objectives on Resource Security, Transforming Foundation Industries[2], and the 2023 Powering Up Britain Strategy[3], which incorporates previous WRAP recommendations for the steel industry (WRAP, 2021). In particular, the options reviewed will be relevant to the commitment to develop Resource and Energy Efficiency (REEE) measures.

[1] https://www.gov.uk/government/publications/resources-and-waste-strategy-for-england
[2] https://www.ukri.org/our-work/our-main-funds/industrial-strategy-challenge-fund/clean-growth/transforming-foundation-industries-challenge/
[3] https://www.gov.uk/government/publications/powering-up-britain

2.0 UK Steel and Aluminium Markets

2.1 Current Market Size

Figure 2.1 shows the relative value of UK steel markets in 2018, based on Input Output analysis using Standard Industrial Classification (SIC) codes. However, the results should be viewed as indicative. Wieland et al (2021) note that both monetary and physical input-output tables "are generally underdetermined systems, that is, not all table elements are known or explicitly informed by primary data". It should also be noted that metals used in different applications have different specifications and characteristics, and therefore prices. This means that, for example, although the manufacture of air and spacecraft involves expenditure on steel similar to manufacture of machinery and equipment, the amount of steel involved can be different. Therefore, the results should be considered indicatory.

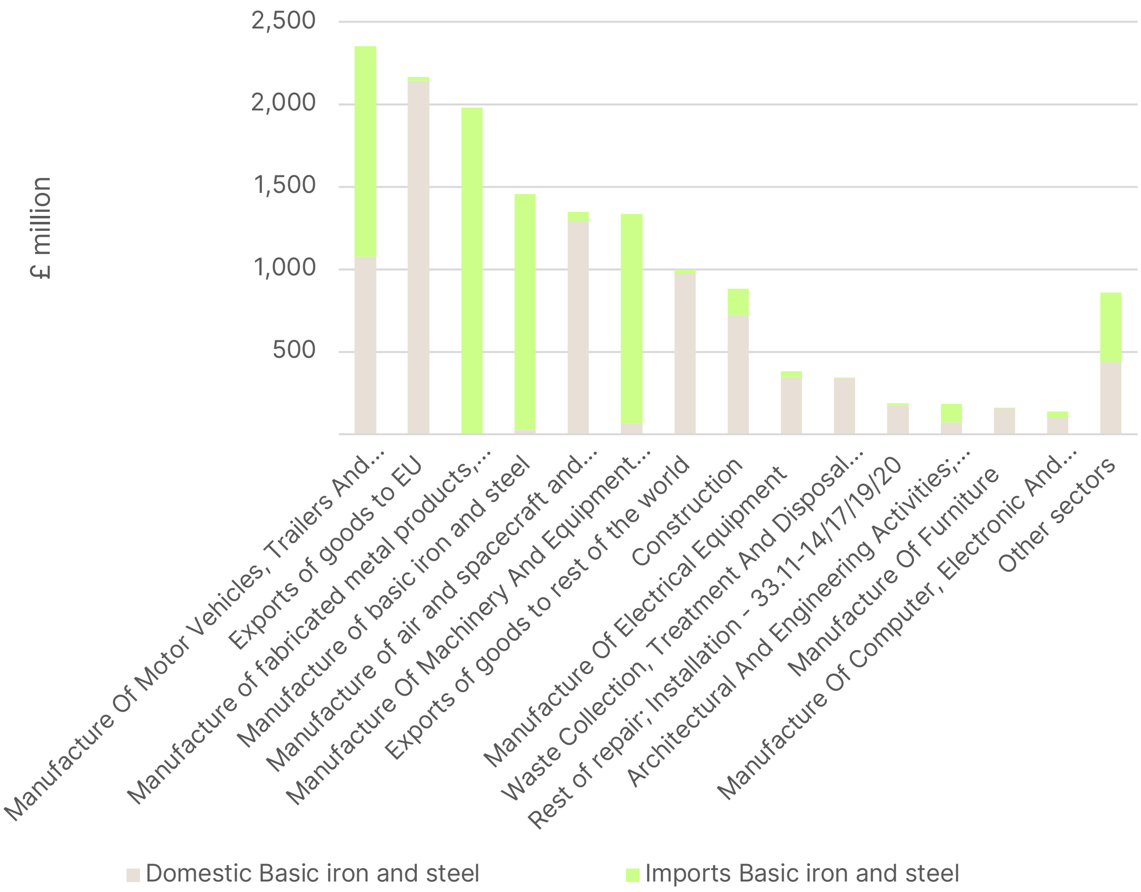

Figure 2.1 - UK basic iron and steel use table (product by SIC code) at basic prices, £ millions 2018 (Office for National Statistics, 2022)

The total use of basic iron and steel in the UK is estimated at £14 billion in 2018 prices. The United Kingdom Input-Output Analytical Tables suggest significant variations between sectors in their reliance on domestic or imported sources of iron and steel. Whereas most construction steel used in the UK is from UK production, automotive is split between imported and domestically produced steel. Packaging is not identified as a discrete category in the tables.

Figure 2.2 suggests a similar picture for metals other than iron and steel, with the automotive sector reliant on imports and construction reliant on domestic production.

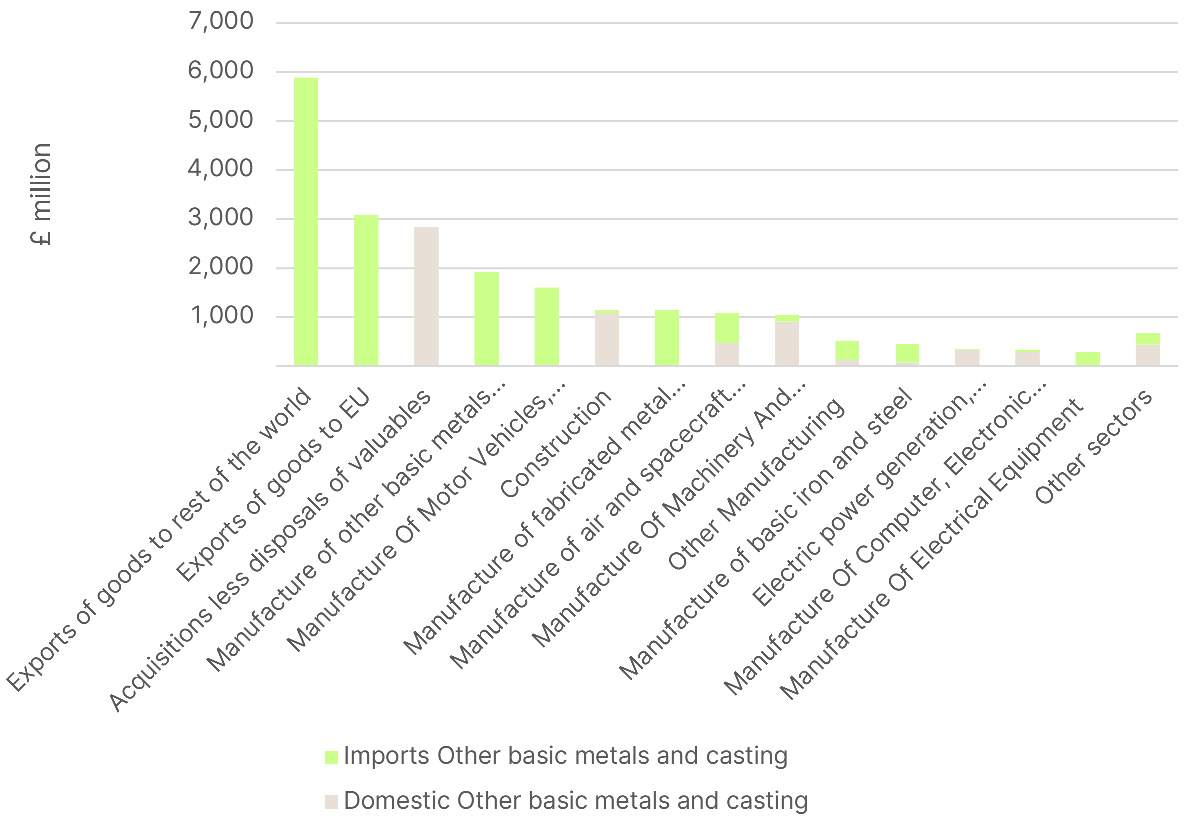

Figure 2.2 - UK other basic metals and castings use table (product by SIC code) at basic prices, £ millions 2018 (Office for National Statistics, 2022)

Similar data is not available for aluminium, although AlFed (2021a) identify the value of aluminium to the UK, the size of different markets is not identified. A report from the Fraser of Allander Institute (2020), estimated that aluminium directly contributes £2.9 billion to the UK economy, and the wider aluminium industry contributes £7.4 billion GVA. Hall et al., (2021) references IBISWorld (2020) stating that the UK major market segmentation for aluminium is: transport manufacturing industries (35.6%), construction industries (26.4%), equipment manufacturing industries (18.1%), packaging industries (15.0%) and others such as chemistry and pharmaceuticals (4.9%).

2.2 Existing UK market for secondary metals

Secondary metals can be divided into the categories of pre-consumer (production) waste, post-consumer waste in the form of products (such as those for the industrial, automotive and machinery, and building sectors), and packaging (such as drink cans).

Collections are through independents, scrap yards and local authorities. There are also a number of aggregators, which sell to yards where metals are sorted and graded and sometimes fragmented. These sorted and prepared streams are traded internationally in recognised grades at a global commodities price. The market is characterised by a combination of big multinationals, large regional players, and smaller independents. Primarily, all are private businesses. Recycled materials are recognised grades, traded internationally and making their way to smelters as co-feed to virgin ores. Pre-consumer aluminium is often sent directly from fabricators to be recycled in simpler process, this can be handled in such a way because the material is of known quality and neither coated nor contaminated (Alfed, undated).

Metals are sourced via bulking at scrap yards, from C&I skips and cars, waste electronics and from packaging. Metal waste is typically aggregated at facilities such as HHWRCs (Household Hazardous Waste Recycling Centres) and scrap merchants. At this point the material is unsorted and is then transferred to a transfer station or bulking station to be further concentrated. The material then travels to a processing facility where the material is sorted, shredded and decomposed into a purer waste stream. The processed raw material, that meets the specification for smelting, is transported to a smelting facility for recycling. The scrap metal collections sector is often informal, but one of the most established recycling sectors, with the majority of metals being exported (with the exception of lead).

The lack of domestic infrastructure for (re)processing of ferrous metals is an issue of concern according to stakeholders interviewed. Blast furnaces cannot handle as much recycled content as Electric Arc Furnaces (EAF) and the UK reprocessing infrastructure is dominated by the former. Some interviewees, such as those representing reprocessors, indicated they feel the key barriers are the proliferation of regulations, combined with the cost of compliance and lack of enforcement against illegal operations. Recent government investments will lead to a significant increase in the capacity for steel reprocessing in the UK, and further opportunities remain available.

Aluminium is collected via local authority recycling schemes (drink cans, foil packaging, etc.) and merchants, which may be specialised in collecting aluminium from specific sources - scrap vehicles or demolition sites, for example. Once identified, aluminium must be separated from non-metals and ferrous metals.

Metal separation in the UK is commonly done using magnetic technologies such as Eddy Current Separators to sort the non-magnetic aluminium from magnetic metals like steel. Depending on the source of the waste aluminium, there may be additional sorting by alloy, and, prior to remelting, the aluminium will be cleaned to remove as much contamination as possible at this point. The aluminium will then be shredded and sent to an appropriate furnace: Rotary furnaces can be used for smaller shredded pieces of aluminium, to reduce oxidation; reverb furnaces are used usually for clean (pre-consumer) aluminium; and a range of other furnaces combining different technologies furnaces are in use. Depending on the aluminium alloys added to the furnace, and any other additive, different aluminium alloys can be created. The molten aluminium alloy is then cast into large aluminium alloy ingots, suitable for transport and subsequent production. Different sources state that in the UK, demand for aluminium overall is outstripped by supply, however, demand varies depending on the aluminium alloy.

Re-use markets consist mainly of second-hand sales in the automotive and machinery sector (e.g. cars) and some re-use of re-conditioned materials (such as steel barrels or railway tracks). However, there is potential for market growth in some re-use sectors (for example steel section re-use in the building industry).

The re-use of prefabricated steel is commonplace throughout Europe and elsewhere, where interviewees suggested that CE Mark standards are applied more pragmatically than in the UK, where interviewees perceive that a more bureaucratic approach to certification is a current barrier. To create a substantial market shift in the UK, locally arising secondary metals would need to replace primary to a greater extent than at present with a reduction of imported secondary materials. To achieve this, pull mechanisms would be required to level the playing field for UK produced secondary metals.

Interviewees indicated that as the secondary commodities market flows straight into the primary materials market, it is an inherently circular industry. However, the global trading environment is still challenging, the high standards expected in the UK (combined with the various cost factors such as capital investment costs, energy costs and staff costs) are a competitive disadvantage in a global market.

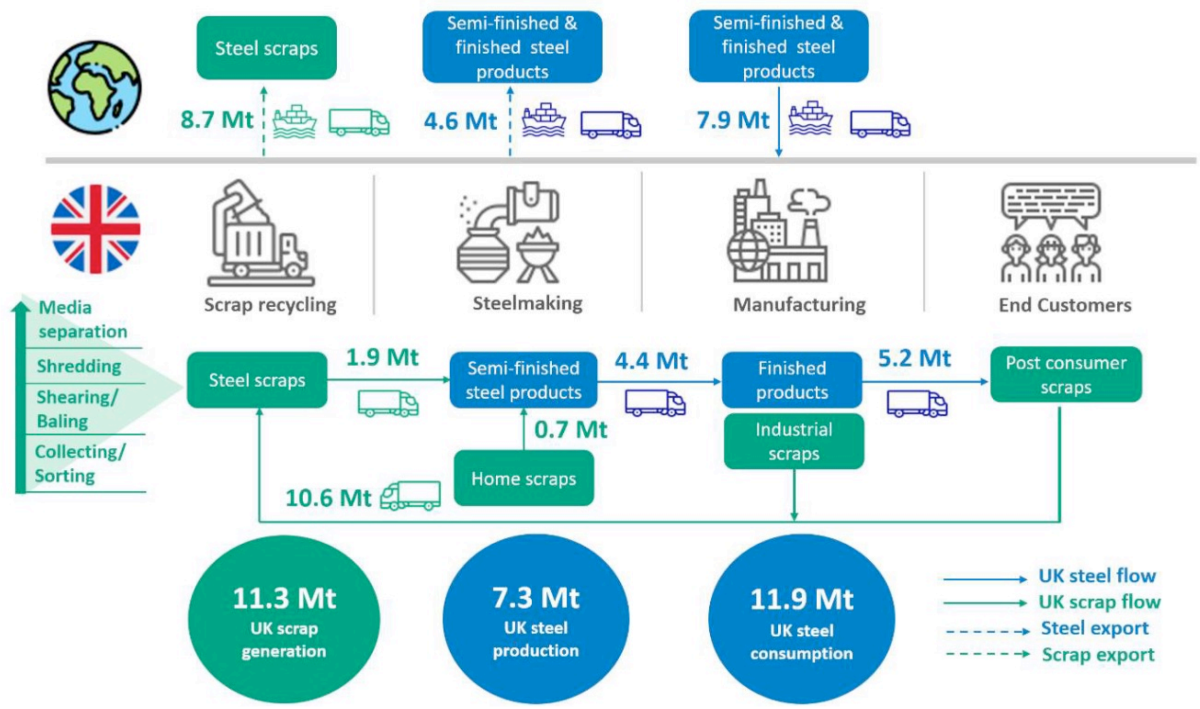

Figure 2.3 -Steel production and movement in the UK. Source: (Hall, et al., 2021)

Figure 2.3 shows the production, scrap generation, transportation, and consumption volumes for steel in the UK. In 2018 the UK steel industry (Rhodes, 2018) (World Steel Association, 2019)

- Produced 7.3 Mt of crude steel, out of which 5.7 Mt via Blast Furnace-Basic Oxygen Furnace (BF-BOF) and 1.6 Mt via Electric Arc Furnace (EAF) route
- Consumed 11.9 Mt of steel, a 4.6 Mt deficit between consumption and production (consumption figures are based on steel consumption per capita)
- Generated 11.3 Mt of scrap steel
    - 8.7 Mt of scrap steel was exported
    - 2.6 Mt of scrap steel was used in the manufacture of steel products in the UK, that is, the UK steel industry used 0.7 Mt internally generated scrap and 1.9 Mt purchased scrap. This was used in both EAF and BF-BOF.
- Exported 4.6 Mt of semi-finished and finished steel products
- Imported 7.9 Mt of semi-finished and finished steel products
- Steel manufacturers recycled approximately 0.7 Mt of internally generated scrap (home scrap).

- Employed 32,000 people, with further employment in the supply chain
- Contributed £1.6 bn to the UK economy (Hall, et al., 2021)

However, this does not cover the full extent of UK exports of metals. For example, through a Freedom of Information (FDI) request to the Driver and Vehicle Licensing Agency (DVLA), the British Independent Motor Trade Association (BIMTA) found that a total of 430,937 used vehicles had been permanently exported from the UK between April 2017 and March 2018 (Automotive Management Online, 2018). In calendar years 2019 and 2020 the number of permanently exported used vehicles was recorded as 309,099 and 244,078 respectively (data received through a freedom of information request dated 28/02/2022). Looking at this data the number of vehicles being permanently exported seems to be decreasing, this could be a short-term impact of the Covid-19 pandemic or as a knock-on effect of Britain's exit from the EU, further research would be needed to confirm. Diverting these used vehicles to be recycled in the UK instead of being exported could help increase circularity.

Scrap steel is available in abundance in the UK however, the large majority of this is exported and typically downgraded (Bleischwitz, et al., 2021). If the UK were to recycle all of the scrap steel that it produced it would nearly be able to satisfy the country's steel demand (Hall, et al., 2021).

In 2019, the annual UK import bill for iron and steel was $7.4bn (The Royal Institute of International Affairs, n.d). (Hall, et al., 2021) suggest that as well as reducing import costs, recycling and reuse of steel would support areas such as power generation, sustainable construction & refurbishments, e-mobility, and engineering as well as strengthening resilience for direct jobs in the steel industry.

Hall et al (2021) identify that total aluminium recycled in the UK was 800,000 tonnes in 2019, "additionally 450,000 tonnes of unsorted scrap aluminium were exported to outside Europe. Meanwhile, ~150,000 tonnes of scrap aluminium were also imported into the UK, which is high purity scrap for specific use". This may be due to the fact that not all aluminium alloy grades are readily available on the secondary metals market, with potential for more sorting taking place in the UK. Hall et al project that the recycling opportunity could increase to 1.6 Mt in 2030 (*ibid.*), though the key challenge is the mismatch between UK production capacity and the amount of aluminium available for recycling.

Currently around 76% of aluminium ever made is still in use and recycling scrap aluminium can save 95% of energy consumption compared to primary aluminium production, significantly reducing the industry carbon footprint. If the energy is from renewable sources, the UK has a big opportunity to establish a net zero green aluminium industry. Further adaptation, like decreasing the thickness of aluminium packaging (without affecting function), increasing aluminium use in cars (to lighten weight), and incorporating more aluminium into construction, can increase the positive environmental impact of aluminium use (AlFed, 2021b).

2.3 Electric Arc Furnaces

Steel can be produced in two ways: using a blast furnace, which turns iron ore and coal into primary steel, or by electric arc furnace. Electric Arc Furnaces (EAF) are steel making plants that melt iron sources using electric energy. The UK mostly uses blast furnaces, for which it imports 12.3 million tonnes of iron ore (UK Steel, 2016). Despite the domestic availability of highly recyclable scrap steel, the UK exports most of this material (7.3 million tonnes) and only recycles two million tonnes domestically, primarily through electric arc furnaces (*ibid.*).

Establishing an effective secondary market to expand high value recycled steel production using electric arc furnaces could be an opportunity to revitalise the UK steel industry. A main difference between EAFs and BF-BOF is the latter needing energy-intensive processes of iron ore extraction and coal both as a reductant and as a source of thermal energy, while EAF uses scrap and electricity benefitting from renewable energy supply (Bleischwitz, et al., 2021). EAF can also process Direct Reduced Iron.

EAF steel production could have structurally lower capital costs and would benefit from plentiful domestic scrap steel (expected to treble by 2050 (Pauliuk, et al., 2013)), which is currently exported at minimum value (Serrenho, et al., 2016) .. Given their operational flexibility, compared to blast furnaces, electric arc furnaces would be well suited to meeting demand for the smaller product volumes required by UK manufacturers (BEIS, 2017). Though it may not be suitable for all grades of steel, a batch production approach could also allow producers to benefit from low-cost energy at times when renewable power is plentiful.

Importantly, although steel produced using electric arc furnace is not always cheaper than that from blast furnace, electric arc furnaces can make complex and specialist steels that are worth more than standard steel. Yet despite this, a number of barriers exist to changing industrial infrastructure in the UK.

3.0 Barriers and opportunities for increasing metal circulation

In order to identify the policy options for increasing recirculation of metal, it is necessary to understand the barriers and opportunities, and how policy can bring about the necessary changes.

In July 1998 the DETR established the Market Development Group to examine ways in which the markets for recycled goods and materials might be expanded. In 1999 the Group published a more detailed assessment of secondary material markets for materials including steel and aluminium (DETR, 1999). The Group included representation from central and local Government, waste and processing industries (including material organisations and compliance schemes) and the community sector. The barriers identified are summarised in figure 3.1.

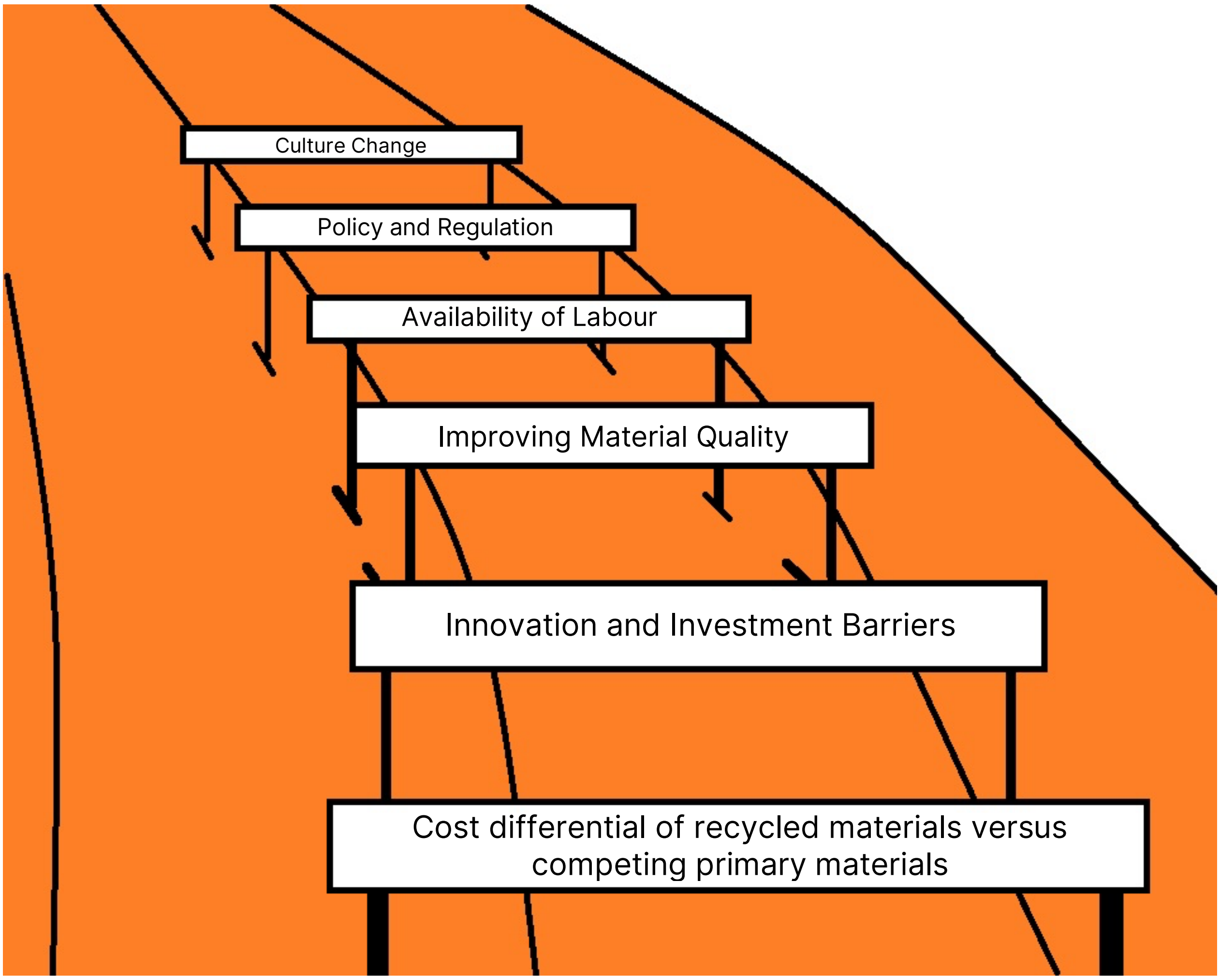

Figure 3.1 - barriers to increasing recycling in the UK

The recommendations of the group to overcome these barriers included the development of improved quality and standards for recycled materials, action to stabilise markets and to reduce price volatility, the use of public procurement policy to support demand and the introduction of economic instruments to increase demand for the recycled content in products. The need to address the lack of consumer awareness and poor public perception about recycled goods and materials was also highlighted.

Twenty years later, these long standing systemic barriers are still considered relevant by industry. In 2018 WRAP commissioned a series of stakeholder interviews with those supplying metals for recycling, as well as those using recycled metals. This included Alupro, Clearpoint Recycling, Cleveland Steel and Tubes, Coca-Cola European Partners, Duncan Baker-Brown, Foresight Group, Kier, Novelis, REB Market Intelligence, Suez, Tata Steel, Veolia and Viridor. These confirmed that the barriers identified in the Market Development Report were still relevant. Interviewees indicated that, where there is potential to increase some forms of re-use and processing (recycling) on shore, this will be driven by tariffs, quality requirements and the price of virgin metals (which scrap is used to co-feed). Key barriers are considered further below.

3.1 Cost differential

Whilst the scrap steel price is consistently lower than the primary steel price, the differential between the two is variable. Furthermore, the lower price of scrap steel does not mean that UK steel producers can necessarily purchase more because of limitations on the amount of scrap they can incorporate into their processes.

The Net Zero Steel Pathway Methodology Report (Responsible Steel, 2021) identifies that “scrap is a globally traded commodity with limited ability to increase supply due to finite availability, even where collection rates of what becomes available are high. Therefore, scrap will flow to regions of highest demand”. UK steel and scrap compete with materials from China, Turkey, Eastern Europe and other countries in a global marketplace.

In interviews carried out in 2018, health and safety standards, land use and labour were all considered to be more expensive here than these other locations. As the commodity price is global, interviewees considered that the UK is disadvantaged.

3.2 Investment

There are a number of conflicting issues which affect investment in infrastructure to enable recycling. Whilst policy (e.g. Powering Up Britain 2023) clearly sets the agenda for decarbonisation, there is little economic incentive to invest with such tight margins (Atradius, 2017). Global expansion in Electric Arc Furnaces which can create higher margins for producers and utilise higher proportions of scrap could put UK producers using Blast Furnaces at a disadvantage (S&P Global, 2021).

Conversely, there are industry concerns that switching to Electric Arc Furnaces could make the UK steel sector less competitive due to a combination of fuel and raw material costs (Make UK, 2021). However, MakeUK (2022) note that this is "dependent on global market developments and is unlikely to be influenced by UK specific policy" (see Policy and Regulation).

Make UK (2022) also notes that the Capital expenditure (CAPEX) "of an electric arc furnace varies depending on size, but a likely CAPEX would be closer to £400m for a plant with 1Mt capacity for existing ore-based sites. If the current 9Mt of ore-based production capacity were replaced by scrap-based production and electrified, the required CAPEX would be around £3.6bn". Operational expenditure costs for EAF and BOF are considered comparable in this report.

3.3 Improving Material Quality

A number of options exist to improve the quality of scrap to support an increase in recycling. Scrap steel may contain a range of residual elements, of which the most significant are copper and tin (Kenichi Nakajima, 2011) which can be present in the final product. The quality of the scrap and scrap segregation is therefore critical to the EAF steelmaking process.

Scrap aluminium is comprised of many different alloys, each with different properties. Sorting different alloys/grades from one another poses a challenge - even aluminium drink cans, which are recycled at a high-rate (90-95%) (AlFed, 2021b) in the UK, can be made from two different alloys. With the number of grades currently in use, mixing alloys and producing a pure product with known properties is challenging. As well as alloy mixing, products may be contaminated by other materials or paints, which adds more levels of separation or contamination of future products (Raabe, et al., 2022).

3.4 Improving Feedstock

Make UK (2022) call for "additional funding for scrap sorting techniques to improve processing, identification, and separation. This should also include R&D support for removing problematic elements from the scrap pool and new casting technologies, which could produce higher-quality products from less controlled steel compositions".

Raabe et al.'s (2022) review, proposes a reduction in the number of aluminium alloys and/or the creation of alloys with properties that are less affected by the presence of contaminants. This could potentially simplify the recycling process significantly and alleviate issues around mixing scrap aluminium. Whole-of-life design is also proposed in the review, with particular relevance to vehicle manufacture and making components that can be easily separated at the end of their usable life.

3.5 Changes to standards

Interviewees involved in the re-use and recycling sectors indicated that the standards applied in the UK are high in comparison to those of other countries outside of Europe, which make up the bulk of the competition from a global perspective. Whilst some standards are obviously necessary, the feeling was that at times these create an undue barrier for UK industry. The most extreme example was in the steel re-use sector, where interviewees considered that the UK had implemented the European CE marking standards in an overly bureaucratic way, severely inhibited the UK steel re-use sector, in turn limiting circular economy opportunities through the inflexible approach taken. The use of the mark was seen as a barrier in that it was being used as a minimum specification without consideration of whether that standard was appropriate for the use.

3.6 Policy and Regulation

3.6.1. Carbon legislation

The 2021 Industrial Decarbonisation Strategy (BEIS, 2021) commits the UK Government to considering the Climate Change Committee recommendation that the ore-based steelmaking sites be near-zero emissions by 2035. Make UK (2021) identify that the steel sector will need to invest in new production methods to deliver this, including use of Electric Arc Furnaces (EAF), and hydrogen-based steelmaking. Make UK (ibid) estimate that a switch to Electric Arc Furnaces would result in grid electricity demand for the steel sector increasing from 2.5TWh per year to 5.5TWh, whereas hydrogen-based steel production could increase electricity demand to over 8.3TWh. The relative cost of electricity in different countries, and the cost of electricity relative to coal and gas, is therefore a key influence on the relative competitiveness of BF-BOF and EAF in the UK and other countries.

Powering Up Britain (DESNZ, 2023) already predicts a potential 60% increase in electricity demand by the middle of the next decade resulting from the electrification in transport and heat. In order to supply this increase whilst also aligning with the Government's commitment to fully decarbonised electricity by 2035, the plan includes a commitment to 24GW nuclear capacity by 2050, 50GW of offshore wind by 2030 and at least one power Carbon Capture and Storage (CCUS) plant by the mid-2020s. The reports also contain commitments to fund the development of hydrogen and electrolytic hydrogen production as well as targets to accelerate transmission network deployment.

In their 2021 Low-Carbon Roadmap, British Steel outlined their commitment to achieving net-zero status through

- "Assessing and adopting several technology options such as Carbon Capture and Storage, hydrogen, increasing scrap utilisation and Electric Arc Furnace steelmaking
- Steel product innovation to promote the material benefits to end users, for example through light weighting and life extension
- Supporting recycling and reuse, for instance using increased levels of scrap in its steelmaking process and encouraging re-use of steel products at the end of life, where appropriate"
- Deploying circular economy and material efficiency methodologies (British Steel, 2021)

This highlights that the industry recognises the link between more circular production methods and meeting climate targets. However, other barriers remain. In 2018, interviewees identified the following interventions they felt were necessary to remove barriers and encourage market growth:

3.7 Other changes to regulations and standards

Interviewees indicated that changes in regulations and enforcement are necessary. In particular, waste definitions and the opportunity for VAT incentives. Strong focus was given by WRAP interviewees to the need for uniform enforcement of regulation, such as the Scrap Metal Dealers Act 2013.

Make UK (2022) highlight the potential for the Secretary of State to use the powers within the Environment Act 2021 to prevent steel scrap waste from being exported to economies with lower environmental standards than the UK. This could create a market signal to invest in UK infrastructure.

3.7.1. Efficient eco-design

Interviewees indicated efficient eco-design could make deconstruction or dismantling more cost and time efficient. It also creates opportunity for innovation, light-weighting, reducing embodied carbon and promoting circular economy. This would also require a change in contracts for demolition and practices to enable products to be recovered in a condition suitable for reuse or repair.

3.7.2. Scaling and pull mechanisms

A common comment from interviewees was around the need for government to support development of UK secondary commodity markets at scale. This included leveraging public procurement and easing the cost burden to stimulate investment.

The 2022 Steel procurement pipeline (BEIS, 2022) shows how the government plans to use 8.4 million tonnes of steel over the next decade on infrastructure projects such as High Speed 2 (HS2) and the construction of schools and hospitals. As a significant procurer of steel, the government is in a strong position to influence the steel market.

The UK Government recently updated its guidance on the public procurement of steel (ibid) which details how the public sector can design major projects in a manner that delivers best value for public money by taking into account the broader social and environmental impacts of their purchasing decisions. This includes a requirement that “steel used shall have a high recycled content. As a minimum this should be 70%, but higher recycled content rates are expected”. HS2 Limited is also working with the steel sector UK industry in pursuit of the SteelZero initiative to speed up the transition to a net zero steel industry (ibid).

Through pursuit of net zero ambition, sectors reliant on steel and aluminium may also increase the demand for recycled materials. For example, to hit net zero ambitions, the automotive sector could increasingly stipulate use of recycled materials.

Technology may also enable new business models which facilitate a change in markets. For example, traceability software around "buildings as material banks" could change models of material ownership in a way which provides an economic incentive to be able to reprocess materials.

4.0 Policy Options

A range of policy options can support the increased recycling of metals in the UK. These could influence all stages of the product life cycle, in the UK and countries from which we import. This section considers some of the key policy options available.

4.1 Eco-design regulations

Design for disassembly and new quality standards for reclaimed/ repaired/ remanufactured properties

Rationale

In 2018 WRAP held a series of stakeholder interviews with the metals sector. As stated in the section above, interviewees indicated efficient eco-design could make deconstruction or dismantling more cost and time efficient. It also creates opportunity for innovation, light-weighting, reducing embodied carbon and promoting circular economy.

Figure 4.2 shows different options for diverting products from landfill and how they are connected to each of the steps in the value chain. Whilst recycling is preferable to landfill, recycled materials displace raw materials in the value chain and still require significant processing before they can be reused. However, currently many products are not repaired due to the high dismantling costs (Abuzied, et al., 2020). Design for disassembly allows for extended usable life for product and the components. This creates a purpose for components preventing waste or being broken down into raw materials again. It further reduces the time and cost of disassembly therefore making recycling and reusing components more attractive to manufacturers, promoting a shift in thinking towards circular economics.

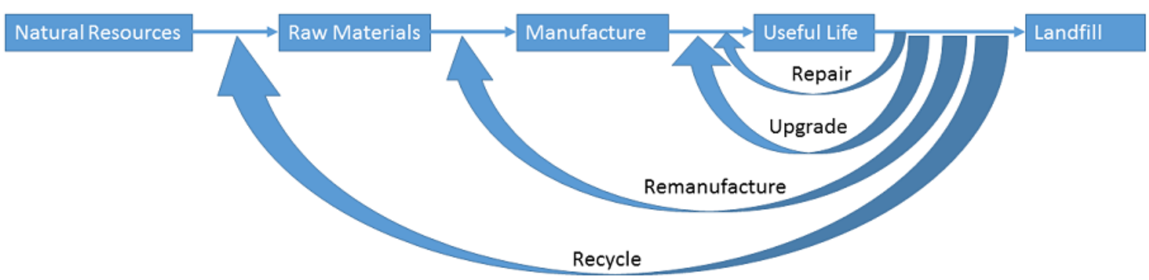

Figure 4.1 – adapted from Nurul (2016)

Remanufacturing is an industrial process by which used, or end-of-life products can be awarded a similar warranty period and are restored to their previous quality and functionality. A wide array of operational aspects of remanufacturing has been studied, including product design, material recovery planning and supply chain management. The largest car manufacturer in Sweden is home to remanufacturing operations which currently cover 15% of vehicle spare parts supply. It reports that in 2017 it saved 3,000 tonnes of carbon dioxide emissions and saved 542 tonnes of steel and 265 tonnes of aluminium.

Benefits

- Remanufactured spare parts have some benefits to consumers, including material and energy savings, quicker production lead times, and job opportunities.
- Designing for dismantling would significantly reduce deconstruction costs therefore encouraging a transition towards more structural steel re-use.

Drawbacks

- Consumer perception that remanufactured goods are of lower quality, and this perception might be made up by the lower price of second-hand goods.
- Consumers are less aware of remanufacturing and thus are more likely to buy new products.
- Consumers' concern about the quality of remanufactured goods is the major reason for their lower acceptance and willingness to buy. Therefore, warranties and technical documentation are needed to boost consumer confidence in these types of sales.
- Where innovation is required to meet eco-design regulations (e.g., for some specific technologies), small companies are unlikely to be able to make the necessary investments and are more likely to be those who leave the market.

Case Study

Milios and Matsumoto (2019) investigated factors affecting consumer purchasing intention of remanufactured auto parts, including consumer knowledge, benefit, and risk perceptions. The study was conducted on the Swedish market and the sample included non-probability aspects. A survey gathered opinions of 203 Swedish consumers. Knowledge of remanufactured auto parts positively influences purchase intention, and perceived benefit positively influences the purchase intention. Information about eco-labelling, certification schemes, and standards can potentially assist consumers in their decision-making process.

However, consumers tend to make decisions without being able to verify the product themselves, which leads to a higher risk perception.

A regression model was formulated to account for the personal characteristics of the respondents, along with the product knowledge, perceived benefit, and perceived risk of the respondents. Among the respondents, 58.6% have never heard of or bought remanufactured auto parts. Moreover, 14.8% of respondents would replace faulty car parts with remanufactured parts.

In the case of Sweden, the perceived risk of remanufactured auto parts in consumers' purchase intention is low because the level of trust in Swedish society is high and the expectation of an honest and trustworthy transaction between parties is high.

Swedish consumers are more willing to purchase quality certified remanufactured auto parts than uncertified ones. In the case of mandatory policy interventions for repairing older cars exclusively with remanufactured auto parts, the Swedish consumer is less willing to purchase remanufactured auto parts. Milios and Matsumoto conclude that consumers trust a remanufacturing industry association more than a governmental or public organization to set standards for remanufactured parts.

Policy in Practise

Japan is moving towards a highly efficient circular economy thanks primarily to the pioneering Law for the Promotion of Efficient Utilization of Resources, passed in 2000. The law, which treats materials as circular goods, covers products' entire lifespans. Manufacturers are legally required to also run disassembly plants, with material recovery legally mandated as well. This incentivises manufacturers to make their products easier to disassemble and recycle. By 2014, 98% of metals and 77% of plastics were recovered (Braw, 2014). By implementing a similar policy, the government would encourage UK manufacturers to design products for disassembly, make them easier to recycle and therefore increase metal circularity.

Reviewing certifications for remanufactured items could lead to an increase in consumer trust. To ensure the highest levels of trust from consumers, the literature identified suggests that this should be carried out by a remanufacturing industry association as opposed to a governmental or public organisation.

The new Ecodesign for Sustainable Products Regulation in the EU builds on the existing Ecodesign Direct and will introduce more extensive Ecodesign requirements for a wider range of product groups. The framework will allow for the setting of a wide range of requirements, with iron, steel and aluminium included in the list of prioritised materials for which a first working plan should be adopted within nine months of the new legislation coming into force (European Parliament, 2023). One of the ecodesign requirements relates to product remanufacturing and recycling, with the proposal for regulation including example parameters “ease of upgrading, re-use, remanufacturing and refurbishment” including through the “ease of non-destructive disassembly and re-assembly” (European Commission, 2022).

4.2 Material Passports / Digital Product Passports

Rationale

The aim of material passports is to be a ‘one stop shop’ for material information, they provide sets of data describing defined characteristics of materials in products that give them value for recovery and reuse this can include recycling potential and environmental impact of the materials embedded (e.g. in buildings or cars). Honic et al. (2021) state that material passports could serve as valuable documentation for a transition to a circular economy.

BAMB have developed electronic material passports **and** are supporting their use in the building sector (BAMB, n.d.), they list the main aims as (Heinrich, et al., 2019):

- Increase the value or keep the value of materials, products, and components over time
- Create incentives for suppliers to produce healthy, sustainable and circular materials
- Support material choices in Reversible Building Design projects.
- Enable circular product design, material recovery and chain of possession partnerships
- Make it easier for developers, managers and renovators to choose sustainable and circular materials
- Facilitate reversed logistics and take back of products, materials, and components
- Eliminate waste and reduce the use of virgin resources
- Reduce costs by managing resources rather than managing waste

Smeets et al. (2019) investigates how data services like BAMB Material Passports can facilitate structural steel re-use in the UK by lowering financial barriers. While steel re-use has the potential of saving up to 96% of environmental impacts compared to new steel, re-used steel is estimated to be about 8-10% more expensive than new steel, taking into account all required reconditioning processes. The study found that providing relevant data has the potential to reduce costs in sourcing, testing, reconditioning and fabrication, ranging from 150-1000 £/t. The study concluded that their core value proposition is cost reduction, including sourcing, testing, reconditioning and certain fabrication costs. The highest added value will be achieved in direct re-use, instead of remanufacturing.

Benefits

- Trial projects have shown success including the reuse of 80% of materials from a building redevelopment of an office in Duiven in 2015 (Kaminski, 2019).
- The data provided in material passports has the potential to reduce costs in sourcing, testing, reconditioning and fabrication, ranging from 150-1000 £/t (Smeets et al., 2019).
- On a large scale material passports have the potential to create detailed understanding of what materials are available in a city, this information would make it easier for municipalities and developers to use existing materials from demolished or dismantled buildings. Demolition could be matched to building and development through a thorough understanding of available materials and their status, this would ensure materials were being used to their highest possible value.

Drawbacks

- The infrastructure to support material passports is in its infancy.
- The passport database would require maintenance to be kept up to date, it's currently unclear how intensive this work would be.
- The passports would need to be standardised to be most effective.

Case Study

Maersk Line – Cradle to Cradle Passport (Ellen Macarthur Foundation, n..d.)

Maersk Line provide trade and transport solutions, for which a reliable supply of low-cost steel is extremely important. Maersk is exploring how to prepare ships for quality recycling in the design phase and has developed a Cradle-to-Cradle Passport. The aim is to gain greater control over the materials they use, and ultimately make new ships from old.

Previously, when the trade-offs between maintenance and technological improvements are no longer practical or viable, and a Maersk ship was decommissioned, it was taken to a shipbreaking yard in China. Here, the vessel underwent a safe and certified recycling procedure. However, due to scale of the product and the vast number of different component suppliers, until now it hasn't been possible to identify different material types and grades during this traditional disassembly process, so the mixed recyclate loses the quality, properties, and value of its previous state. Steel that had been found in seven different grades becomes a low-grade, low-price material.

By creating a resource that is flexible, manageable, and can be maintained throughout the 30-year lifetime of a ship, Maersk Line gains an improved understanding of the composition of the vessel that enters the recycling yard. As a result, the materials – including the 60,000 tonnes of steel per ship – can be sorted and processed more effectively, maintaining their inherent properties and hopefully commanding a better price when re-sold. The vision is to be able to manufacture a new hull from old, but in the meantime, this process will make the company more resilient to fluctuating steel prices. In addition, the sale of higher quality scrap metal that is not re-used in Maersk Line vessels can be a source of revenue, offering a hedge against rising steel and fuel costs.

London Metal Exchange (Jamasmie, 2021)

The London Metal Exchange (LME), the world's biggest industrial metals market, has launched a digital register to store sustainability credentials and other characteristics of metals trading on its platform, beginning with aluminium. The digital credential, known as the LMEpassport, stores electronic Certificates of Analysis (CoAs) or quality assurance documents based on a metal's size, shape, purity and other characteristics. It also allows users to disclose information on Environmental, Social and Governance (ESG) credentials, including carbon footprint, water use and social impact.

The LME has also launched a spot trading platform for lower carbon aluminium, made using renewable power. Disclosure of sustainability data will at first be voluntary, but the exchange will work with and liaise with the market to "monitor take-up and decide next steps as appropriate."

Aluminium producers have been able to use the register from October 1st 2021, and other metal producers followed from January 1st 2022. From 2023, all LME metals requiring a CoA had to use a LMEpassport. And by January 1, 2024, producers of all LME-listed brands will be required to directly register new metal production details into the register.

Policy in Practise

As Heisel and Rau-Oberhuber (2019) found in their study, documentation is one of the most important cornerstones of the transition from a linear to a circular economy, accordingly Material Passports show great potential.

Material Passports could be introduced at first on a voluntary basis like the LMEpassport in order to develop the system and highlight any potential issues before becoming a legal requirement. However, Smeets et al. (2019) state that data alone is not sufficient to overcome re-use barriers, material passports will be most effective when used in conjunction with other policy measures such as design for disassembly. It's believed that this would be a game changer in the transition towards more structural steel re-use since it can significantly reduce deconstruction costs.

The EU Ecodesign for Sustainable Products Regulation answers this need by establishing a framework for setting design requirements – including for ease of remanufacturing and recycling – in combination with new digital product passports for a wide range of products (European Commission, 2023). The Digital Product Passport will provide information about products' environmental sustainability, including the durability and repairability, with the intention of facilitating repairs and recycling.

4.3 Ecolabelling

Rationale

Ecolabelling is the process of assigning labels with sustainability information focused on the environmental impacts of a product. The purpose is to guide consumers in making environmentally friendly decisions. Eco-labels have grown in popularity in recent years and are now used in a wide range of industries. In the construction industry they have been used to quantify the sustainable properties of different materials that are predominantly manufactured artificially (Dutil, et al., 2011). The production of construction materials can be an extremely energy intensive process, but the sustainability of building materials presents the extra challenge of quantifying the environmental impacts associated with their performance e.g., effectiveness as an insulator and durability. Amani (2011) put forward an eco-labelling method that takes into account economic, environmental, and social factors at play, this is shown below in figure 4.2.

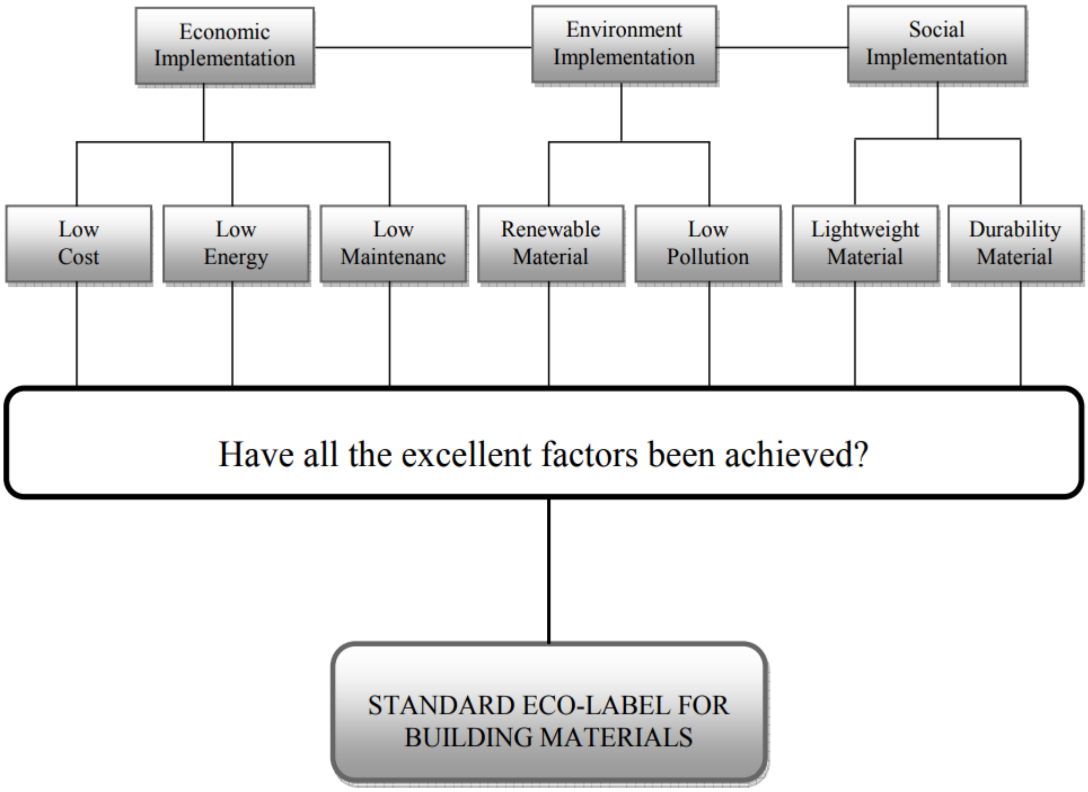

Figure 4.2 -Framework for a standard eco-label building material. Source: Amani (2011)

Due to its high strength and durability steel is a very common material used in construction. Basu and Bidanda (2014) argues that the high demand for steel combined with the fact that it can be recycled completely and used indefinitely creates a special need for sustainable steel and eco-labelling. Sustainable practices can take place in different stages of steel production therefore ecolabels could focus on different areas. For example, to encourage circularity an ecolabel focussed on the use of recycled content in making steel could be used.

Benefits

- Approximately 42 percent of the EU Ecolabel Licence holders declared that the EU Ecolabel helped them in setting targets for environmental improvements of their products/services for all or most areas, and this was thanks to a better and deeper knowledge of the environmental impact of their products/services.
- A key benefit for businesses choosing to use ecolabels is that it strengthens their brand. Having a third-party certification such as an ecolabel can help draw in investors while also satisfying pressure groups and displaying good practices.

Drawbacks

- The EVER study (2006) found that the main obstacles that Licence holders faced with the EU Ecolabel were associated with aspects such as “red tape/documentation” and “costs of complying with criteria”. Tata Steel's Graeme Peacock has said "In the construction sector, most ecolabels are national or regional, so for global companies like ourselves, they act as barriers to trade." (Seifert, 2012).
- Ecolabelling schemes, whose primary function is that of being communication tools, aim to close the information gap between operators providing environmentally friendly products/services and consumers making purchasing choices on the market, the potential for ecolabels in industrial markets such as construction may be limited.
- Companies choose to use Ecolabels driven by the fact that they see an opportunity to add value to existing products, expand their reach in existing markets, or maintain market share in a competitive environment. Literature does not provide much quantitative or qualitative research on the economic and environmental benefits really achieved by companies that are awarded an Ecolabel.

Policy in Practise

The Independent Review of Net Zero included the suggestion that the government should pursue ecolabelling by 2025 (Skidmore, 2022). In response, the government stated that they are “exploring eco-labelling for the embodied emissions of industrial products” and “consulting on how labelling could support demand for low carbon products” (HM Government, 2023). This was repeated in the Net Zero Strategy but the only direct commitment to eco-labelling was for a mandatory methodology for the food and drink sector (DESNZ, 2023). Defra, DESNZ and DfT have since commissioned an evidence review of ecolabels which found that there were some positive effects associated with ecolabels, but that price remained more important to consumers and that credibility or third-party verification influenced willingness to pay (Defra, 2023). However, the review acknowledged a lack of evidence and need for further research in most of the sectors examined. The review also focused on consumer-facing labels which may not be as relevant to industrial markets, as mentioned in the previous section.

4.4 Extended Producer Responsibility

Rationale

The original concept of EPR-based recycling policy aims for a shift in financial responsibility of waste treatment from local governments to producers called Producer Responsibility Organizations (PROs), which are mostly not-for-profit organisations, and in some countries, government-led systems that substitute PROs exist. Policy also aims for a shift in physical responsibility of the products in the post-consumption stage, to generate incentives for producers to promote design for environment and to reduce costs for environmentally sound management of post-consumer products.

The idea of making manufacturers play a significant role in the after-use stage of products is not a new intervention, it dates back to the early 1970s (Chung, et al., 2009). Although it was not until the 1990s that the term Extended Producer Responsibility was widely discussed as a governmental policy principle. Developed countries have experienced a rapid increase in the collection of secondary materials due to successful implementation of EPR-based legislation, as well as zero landfill industrial strategies (Hotta & Elder, 2009). Existing product-orientated extended producer responsibility approaches with mass-based recycling quotas do not create adequate incentives to supply waste materials containing precious metals to a high-quality recycling and should be amended by aspects of a material stewardship (Wilts, et al., 2011).

The Environment Act 2021 confers power on the relevant national authority in each UK nation to make regulations requiring the payment of sums in respect of the costs of disposing of products and materials. It sets out that Producer Responsibility schemes may "be made only for the purpose of—

(a) preventing a product or material becoming waste, or reducing the amount of a product or material that becomes waste;

(b) sustaining a minimum level of, or promoting or securing an increase in, the re-use, redistribution, recovery or recycling of products or materials.

The regulations may make provision about targets to be achieved in relation to the proportion of products or materials (by weight, volume or otherwise) to be re-used, redistributed, recovered or recycled (either generally or in a specified way)."

The Resources and Waste Strategy for England, 2018[4], identifies that Government will review and consult on measures such as Extended Producer Responsibility and product standards for five new waste streams, including certain construction

[4] Resources and waste strategy for England - GOV.UK (www.gov.uk)

and demolition materials and bulky waste (e.g. large electrical items) and packaging. The 2021 Beyond Recycling Strategy[5] makes similar commitments in Wales, and the Scottish Government and Northern Ireland Executive are also engaged in these. Alongside the existing scheme for End-of-Life Vehicles and waste electrical and electronic equipment, this would mean that the majority of products placed on the UK market containing steel and aluminium would be covered.

Policies to recover packaging and household items for recycling are also addressed through two other policies. DEFRA (2021) analysis indicates that an 'all in' deposit return scheme for England, Wales and Northern Ireland (Scotland have already announced a separate scheme) and the introduction of recycling consistency proposals in England could lead to a total UK packaging recycling rate by 2030 of 78%, with the estimated recycling rates for each material exceeding those set in the European Union. The recycling rates for glass (96%), card (86%) and steel (93%) are ambitious and close to the maximum likely to be achievable. The recycling rates estimated for aluminium of 69% and plastics 62% are lower, but expected to increase once the collection and recycling of other aluminium packaging and plastic film and flexibles is included in analysis.

To create the same level of funding as a tax or carbon border adjustment (see below), fees raised would have to be set at a similar level and for a similar range of products.

Benefits

- Extended Producer Responsibility schemes are a widely used environmental policy with a history of proven success. The Environment Act enables the introduction of Extended Producer Responsibility schemes.
- The system of producer responsibility for packaging has been in place in the UK since 1997 and has helped to increase recycling of packaging waste from 25%, 20 years ago to 63.9% in 2017 (DEFRA, 2021).

Drawbacks

- The approach of an extended producer responsibility is undermined by the current exports of used and waste products.
- There is the possibility of public hesitation or industry resistance.
- The success of EPR will be contingent upon the willingness and capacity to invest in this policy and its enforcement. EPR will only be able to achieve its

[5] Beyond recycling | GOV.WALES

theoretical potential to the extent that producers efficiently fulfil their obligations in order to help relieve the social, economic, and environmental burdens of waste.

Case Study

Japan’s End-of-life (ELV) EPR Scheme

In the recycling process, auto dismantlers first recover engine parts, body components and electrical components, which account for about 20 to 30 percent of the weight per used vehicle, to be reused as valuable parts. About 50 to 55 percent of parts (by weight) per vehicle are non-reusable, including some engine components as well as catalysts, non-ferrous metals, and tires; these are recycled as raw materials. Overall, 75 to 80 percent of parts (by weight) per vehicle are reused or recycled.

The remaining parts, equivalent to 20 to 25 percent of vehicle weight, used to be shredded and buried as automobile shredder residue (ASR). In recent years, however, there has been a greater need to reduce the volume of ASR, as industrial waste landfill sites are approaching full capacity.

Owners are required to take their ELVs to registered ELV-collecting businesses, which deliver them to registered fluorocarbon-recovery businesses and licensed auto-dismantling businesses. The latter remove airbags and other recyclable items from the vehicles. The remaining vehicle shells are delivered to auto dismantlers and processed into ASR. Authorized automakers receive ASR, collected fluorocarbons and airbags, and pay collection fees.

The fees for recycling are paid by owners of vehicles, generally at the time of purchase. For vehicles purchased prior to the date the law entered into force, fees shall be paid at the first vehicle inspection or when on-premises vehicles (for which neither registration nor official inspection is required) are turned over to ELV-collecting companies. Although the recycling fees are determined and announced by automakers, the government will issue a recommendation or order when fees are considered inappropriate. Recycling fees are managed by a third-party fund management institution.

Currently, ELVs are recycled by 85,000 vehicle collecting companies, 22,000 fluorocarbon recovery companies, 5,800 dismantling companies, and 1,200 shredding companies. Recycling fees depend on the type of vehicle and are the sum of fees for processing fluorocarbons, airbags and ASR, and those for fund management and information handling, amounting to 6,000 to 18,000 yen (about U.S.$51-153).

4.5 Economic Instruments

4.5.1. Tax on Virgin Materials

Rationale

Recycling policies often rely on price signals and economic incentives, e.g., surcharges on the disposal of recyclable products, tradable recycling credit schemes, subsidies to recycling programs, and virgin material taxes (Finnveden, et al., 2013). A materials tax is a tax levied on producers for using virgin materials, or materials that are difficult to recycle, or toxic materials, to create incentives for using secondary (recycled) or less toxic materials. Ideally, the tax is set at a level where it meets the treatment costs. The tax is used for the collection, sorting, and treatment of post-consumer products.

Söderholm and Ekvall (2020) modelled the impact of imposing a virgin material tax on the production a sample of primary materials. The tax leads to a higher long-run material consumer market price and at this price, additional secondary material production become more profitable. The tax on primary materials production induces a substitution of secondary materials for virgin materials. The virgin material tax represents a policy that increases the demand for secondary materials. However, due to the low own-price elasticity of secondary material supply, the impacts on actual use may be low unless the tax on primary materials is very high.

Benefits

- Increases demand for secondary materials by increasing costs of virgin material production.
- While urban mining of e-waste is becoming more cost-effective than virgin mining (Zeng, et al., 2018), it has also been shown by Li and Tee (2012) that in the production of electronics recycled materials save more energy than virgin materials with aluminium saving 95% more energy and copper saving 85% more energy. This has already led to a large move away from virgin materials by suppliers such as Apple and Electrolux and so a further taxing of virgin materials would only help this shift across the rest of the sector.

Drawbacks

- Due to the low own-price elasticity of secondary material supply, the impacts on actual use may be low unless the tax on primary materials is very high.

- A tax on virgin raw materials in one country may induce higher imports of recycled materials from other countries where such a policy is absent.

Case Study

The Danish Tax on Raw Materials (Söderholm, 2011)

From 1977 to 1990 a tax on raw material extraction existed in Denmark at rates from DKK 0.35 (US$ 0.06) per m^3 (1977-83) to DKK 0.5 (US$ 0.08) per m^3 (1983-1990). In 1990 a new tax on raw materials was introduced. The new tax is set at DKK 5 (US$ 0.8) per m^3 for selected extracted raw materials. The Danish tax is levied on raw materials that are commercially extracted and consumed in Denmark or commercially imported (Nordic Council of Ministers, 2002). The Danish tax is designed so that imports are taxed, while no tax is levied on exports. The raw materials tax was introduced in close junction with the waste tax. The latter was introduced in 1987, with a tax of DKK 40 (US$ 6) per tonne of waste landfilled or incinerated. In 1993 the tax was differentiated and for landfill it increased substantially to DKK 335 (US$ 42) and in 1998 to DKK 375 (US$ 47) (European Environment Agency, 2008). The main intention of the two taxes in combination is to reduce the use of the above resources and encourage substitution to recycled materials (e.g., construction and demolition waste).

It is difficult to evaluate to what extent the Danish tax on raw materials has lowered consumption of virgin materials and encouraged substitution to recycled materials. When introducing the tax in 1990 the Danish government expected the effects on consumption to be modest. The tax burden is primarily transferred from producers to end consumers with prices increasing between 3-33 percent depending on material. The tax costs for these consumers (primarily construction and infrastructure companies) are however small in relative values, and their raw material demand is highly own-price inelastic.

Figure 4.3, which shows the development of raw materials extraction in Denmark over the period 1989-2009, confirms this view. Extraction levels decreased between 1989 and 1993, but then increased during the latter half of the 1990s. After 1999 the trend was downwards again. Overall total extraction of raw materials has declined slightly over this twenty-year period. The significant downturn in 2009 can primarily be explained by the economic crises (e.g., implying few construction and infrastructure projects), and should not be attributed to the raw materials tax. The above confirms the conclusion made in ECOTEC (2001), namely that the tax has had small impacts on raw materials extraction in Denmark.

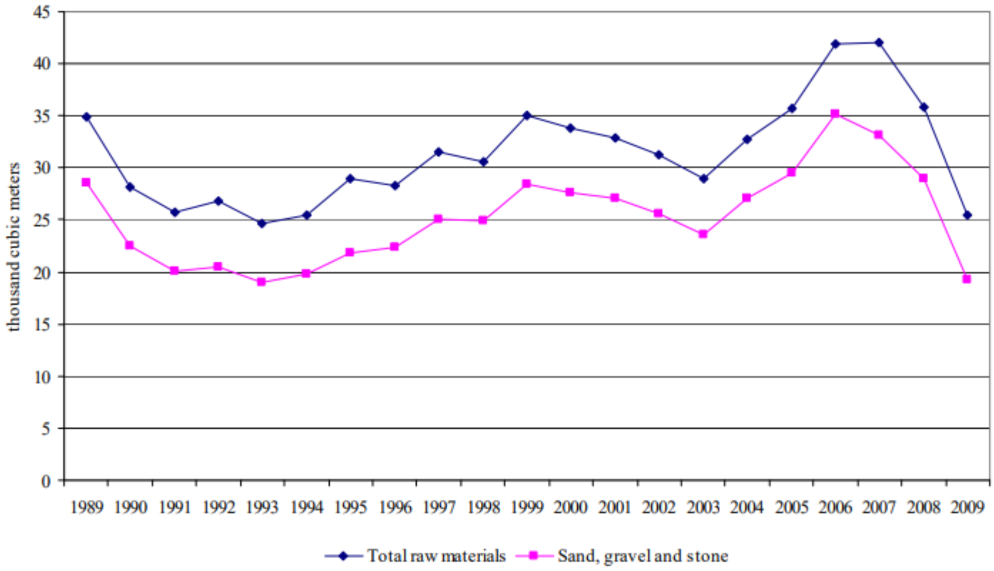

Figure 4.3 - Extraction of Raw Materials in Denmark, 1989-2009. Source: Statistikbanken (2010).

The two taxes have in combination induced a marked increase in recycling, in particular of construction and demolition waste. In 1985, 82 percent of the construction and demolition waste was landfilled and only 12 percent recycled, but in 2004 the recycling rate had increased to 94 percent (European Environment Agency, 2008).

Policy in Practise

Introducing a virgin material tax on steel and aluminium could lead to an increase in demand for secondary material and already has precedent in UK policy. In the March 2020 budget, the government announced a tax on plastic packaging to take effect in April 2022. A £200/t tax is now levied on plastic packaging with less than 30% recycled plastic content. The tax will be levied on UK users of plastic packaging, with an exemption for producers and imports of small quantities (less than 10 kt of plastic p.a.). While the tax represents additional tax revenue in the short to medium term, the goal is to encourage the use of recycled plastic packaging and other sustainable options. Tax revenues are expected to fall as switching from virgin plastic packaging increases. If the plastic packaging tax is successful, this opens the door for further virgin material taxes. If the tax were set at the same level for steel, it could raise up to £2 billion per year depending on the products to which it was applied.

Taxing primary materials output would raise the overall long-run consumer price of the material and induce a reduction in aggregate material demand, something that in turn will dampen the price increase following the tax. For instance, in Sweden, the tax on natural gravel has primarily led to a substitution of crushed rock for natural gravel, while the increase in the use of recycled material has been much more limited (Ministry of Finance, 2003). Similar impacts have been reported in the UK and the country's aggregates tax (Legg, 2007). For this reason, unless additional policies that increase the supply of recycled material, e.g., waste sorting requirements, are implemented, supply may not increase much even in the presence of a high demand. A tax on virgin raw materials in one country may also induce higher imports of recycled materials from other countries where such a policy is absent.

4.5.2. Carbon Tax / Carbon Border Adjustment

Rationale

There are several opportunities that can be exploited to encourage further domestic recycling of UK generated scrap steel. Larger market shares in domestic markets would serve to increase the amount of steel that UK steelmakers could sell, and this could be driven at a government level with steel for major infrastructure projects. Import and export tariffs could be considered as an option to protect the UK steelmaking market, however evidence from other countries where this has been tried suggests while it may help the steel industry it may be detrimental to wider domestic manufacturing supply chains.

In 2022, the Environmental Audit Committee published their report on Greening Imports (Environmental Audit Committee, 2022). This calls for a UK carbon border adjustment mechanism to ensure an equivalent carbon price is applied to imports as is applied to domestic production, as part of a co-ordinated set of policies, including product standards.

Many G7 nations and the EU are currently developing plans for Carbon Border Adjustment Mechanisms, with Canada consulting on a scheme in 2019, and the EU intending to introduce a scheme in 2023. The EU scheme would include certain aluminium, steel and iron products. Under the proposal, from 2026, following a three-year transition period, EU importers would purchase CBAM certificates closely mirroring the EU Emissions Trading System (ETS) price, to bring the carbon price on imports in line with the carbon price paid by EU producers. As shown in figures 1 and 2, the UK exports significant quantities of metals to the EU, and there is the potential that the EU carbon border adjustment would create an incentive to invest in low carbon technologies in the UK.

A UK Carbon Border Adjustment Mechanism could create further incentives for investment. Following the consultation Addressing carbon leakage risk to support decarbonisation (HM Treasury 2023), the government announced that it would introduce a CBAM from 1 January 2027 on imports of certain carbon intensive imported goods from the following sectors: aluminium; cement; ceramics; fertilisers; glass; hydrogen; and iron and steel. The UK Carbon Border Adjustment Mechanism should be designed to promote supply to the lowest carbon supply routes, which are often domestic.

At present, costs associated with greenhouse gas emissions for UK steelmakers are internalised through the UK emissions trading scheme (ETS), which caps the industry's emissions. The UK ETS is roughly in-line with the EU ETS and was designed to provide a seamless changeover in emissions taxes post Brexit. The UK ETS is a "cap and trade" scheme where a cap is set on the total amount of greenhouse gases that can be emitted, the cap is reduced over time, forcing overall emissions to fall.

Current carbon emission taxes are charged to individual companies, the taxes start at the point where a raw material enters a company site and stop at the point where a finished product exits a company's site. This is a simple and practical way of taxing companies as it makes emissions calculations relatively easy. As a means of measuring and taxing the actual emissions of a supply chain it misses some aspects of production.

A large portion of UK scrap steel is exported to Turkey, where it is recycled in EAF process into semifinished or finished product, and a significant portion of this is then exported to other countries where it is further processed into finished products. Turkey does not currently have a tax on carbon emissions, so has no incentive to control Turkish steel industry emissions (The World Bank, 2020).

A further addition of carbon emissions through the export of steel scrap is caused by international shipping. International shipping is a major source of carbon emissions, transporting 85,000 tons of scrap steel to Turkey emits approximately 9640 tons of CO2 (2.64 tCO2 / nautical mile). Transport emissions would be reduced by using road, or shorter coastal shipping for domestic recycling (Hall, et al., 2021).

A future development opportunity for carbon border adjustment mechanisms or taxes would be to take into account their entire supply chain across international borders. This would ensure that carbon emissions from shipping and countries which have no or little carbon emission taxation are taken into account. It would make products that are manufactured in more carbon intensive supplies chains more expensive, and this cost difference could be enough to encourage more domestic recycling of scrap and would represent a more responsible approach to carbon emissions taxation.

In its first full year, HM Treasury (2024) suggest that the UK CBAM will raise £155 million, rising to £195 million in its second year. If the tax were hypothecated, this could facilitate significant investment in UK steel infrastructure.

Benefits

- If emissions taxation were to consider the environmental cost of different transportation modes, as well as including where materials were sourced, it could encourage more domestic production.

Drawbacks

- Emissions tax regimes are an investment burden when compared against steelmaking countries where there are no carbon taxes. A Carbon Border Adjustment Mechanism could mitigate this.
- Current taxation allows manufacturers to stop calculating carbon emissions at the end of their production processes, ignoring the emissions created further up and down the supply chain.
- Current taxation methods can lead to offshoring carbon – manufacturing is moved to a different country in order to reduce emissions that are more expensive in one country.

4.5.3. Direct Government Funding

UK Government has provided a range of direct funding to the metals industry to decarbonise. In 2019 the UK Government launched a £250 million Clean Steel Fund (BEIS, 2020) to support companies in switching to low-carbon steel production, with money due to be distributed in 2023. However, with an estimated cost for a £1 million capacity EAF of £400 million, the funding announced would need to be judiciously allocated in order to have significant impact on UK steel production.

In September 2023, Tata Steel and the UK Government announced a joint investment in electric arc furnace steelmaking with a capital cost of £1.25 billion inclusive of a grant from the UK Government of up to £500 million. In November 2023 British Steel made a similar announcement contingent on securing government funding.

To support further increases in use of recycled materials, ongoing direct funding or targeted funding which addresses limitations on recycling due to contaminants could support future private sector investment.

Further funding for capital investments in electric arc furnaces or recycling facility improvements could come from the UK Infrastructure Bank (UKIB), which was founded in 2021 “to drive regional and local economic growth or support tackling climate change” (UK Infrastructure Bank, 2022). The UKIB is wholly owned and backed by, but operationally independent from, HM Treasury and aims to deploy up to £3 billion of debt and equity and £2.5 billion of guarantees a year. Waste is one of the UKIB's five priority sectors and they specifically identify "proposals that increase the scale and sophistication of recycling infrastructure" as a key investment opportunity (ibid). However, of the 20 deals announced as of September 2023, none were related to recycling infrastructure. Investments this area could satisfy both the goals for regional or local economic growth and improvements in resource efficiency, as well as the UKIB's investment principles of delivering positive financial return and crowding in significant private capital over time. As part of the creation of a National Wealth Fund, the UK Government announced £7.3bn of additional funding allocated through the UK Infrastructure Bank in July 2024, focusing on further priority sectors and catalysing private investment at an even greater scale (HM Government 2024).

4.5.4. End of life Vehicle (ELV) Recycling

Electric arc furnaces can be used to recycle ELVs into scrap steel. The 'whole recycling method', in which an end-of-life vehicle (ELV) is pressed and transferred to an electric furnace or converter, simultaneously recycles iron, and treats automotive shredder residues. This contrasts with the usual practice of shredding ELVs to produce scrap. An advanced dismantling process is required to recycle pressed ELVs using a converter because the quality of scrap entering a converter is restricted (the copper content must be low). It provides significant GHG emission savings and successful recycling of vehicles which redirects waste from landfill but requires steep investments to ensure efficiency and sustainability.

Benefits

- Recycling a pressed ELV in a converter was found to cause GHG emissions approximately 320 kg-CO2e lower than caused by the recycling of the pressed ELV in an electric furnace. Approximately, 120 kg-CO2e less GHGs were emitted when recycling in a converter than when using the shredding method.

- EAF plants are smaller and less expensive to build than integrated steelmaking plants.

- EAFs are also cost-efficient at low production rates—e.g., 150,000 tons per year—while basic oxygen furnaces and their associated blast furnaces will not break even financially until over 2 million tons of liquid steel are produced within a year.

- EAFs can be operated intermittently, while a blast furnace is best operated at very constant rates.

- An EAF uses 0.67MWh per tonne of liquid steel produced from scrap, whereas blast furnaces use 3.68MWh per tonne of liquid steel (Vogl, 2018).

Drawbacks

- The amount of greenhouse gases reduced by a converter depends on the conditions used, such as the presence of a Linz–Donawitz converter gas recovery facility
- Whole recycling method of vehicles results in contaminants which must be reduced to ensure the quality of recycled steel scrap. Removal of these contaminant alloys such as copper cause increased costs and complications.
- To increase the electric arc furnace steel production capacity in the UK would require significant investment, estimated costs for an electric arc furnace steel manufacturing site could be over £400 million for a 1 million tonne capacity site depending on the scale, location and complexity of any downstream steel production required.

Policy in Practise

Currently recycled content in steel varies widely depending on the sector, with construction having an average of almost 40 per cent recycled content, compared to 16 per cent in automotive applications (Daehn, et al., 2017). Increasing recycled content across all manufacturing sectors could support demand for 3.1 million tonnes of additional recycled steel (from 3.4 million tonnes of scrap steel), a scale that would justify investment in new electric arc furnace facilities (Green Alliance, 2018). Introducing policies such as a virgin material tax would increase demand for recycled steel.

Scrap metal quality could be improved if automobile manufacturers are encouraged to design for disassembly, which in turn will incentivise recyclers to disassemble more ELV components. A policy such as eco-design standards may be beneficial in improving the efficiency and success of this scheme.

There is no single intervention that will encourage more domestic recycling of domestically produced scrap steel, and a range of interventions will need to be pursued. There is a significant opportunity for the UK to lead in the production of green, net-zero or low carbon steel if increased electric arc furnace steel production is pursued.

4.5.5. Policies on Electricity Prices

One of the barriers to building Electric Arc Furnaces identified by industry relates to high and instable electricity prices. Grubb et al (2022) identify electro-intensive, internationally trade-exposed industries as one of two priority groups for targeted support with energy prices in the wake of the recent energy crisis. Without this support, there is a risk that these industries migrate outside of the UK, with potentially negative impacts on global greenhouse gas emissions. The literature identifies a range of policy options to combat the instability and to make electricity prices more favourable for industry.

UK Steel (2021) suggest a range of options including exemption from Capacity Market costs; increasing the level of renewable levy exemptions from 85% aid intensity, to closer to the level of reliefs applied in Germany; and providing high exemptions to network charging (transmission, distribution, and balancing). These proposed policies aim to make electricity prices lower for the steel sector which can help provide confidence in EAFs.

Green Alliance (2022) propose contracts for difference (CfD) which provide stability to renewable energy generators. CfD can also help decarbonisation of energy-intensive sectors more widely by setting the price of a low-carbon product at a price comparable to the market rate. The price may be higher than the conventional equivalent initially, meaning the buyer initially loses money but then will make money once the technology pushes the price to competitive levels (BMWK, 2020). In the meantime, Green Alliance (2022) propose a government-backed “green power pool” to allow energy intensive industries “to access renewable electricity at prices far closer to CfD strike prices, through a mechanism similar to a centrally managed and bundled power purchase agreement.” Grubb et al (2022) note that a targeted green power pool for intensive industries should “be legitimate under EU and/or WTO rules”.

4.6 Overview

The barriers identified in the previous section can be addressed through a range of policies. An overview of the benefits and drawbacks of key policies considered in this section is provided in table 4.1.

Policy	Benefits	Drawbacks
Eco-design regulations Design for disassembly and new quality standards for reclaimed/ repaired/ remanufactured properties.	• Remanufactured spare parts have some benefits to consumers, including material and energy savings, quicker production lead times, and job opportunities. • Designing for dismantling would significantly reduce deconstruction costs therefore encouraging a transition towards more structural steel re-use.	• Consumers' concern about the quality of remanufactured goods is the major reason for their lower acceptance and willingness to buy. • Small companies are unlikely to be able to make the necessary investments and are more likely to be those who leave the market.
Material Passports / Digital Product Passports A 'one stop shop' for material information, that can give the value for recovery and reuse including recycling potential and environmental impact of the materials embedded.	• Trial projects have shown success including the reuse of 80% of materials from a building redevelopment of an office in Duiven in 2015 (Kaminski, 2019). • The data provided in material passports has the potential to reduce costs in sourcing, testing, reconditioning and fabrication, ranging from 150-1000 £/t (Smeets et al., 2019).	• The infrastructure to support material passports is in its infancy. • The passport database would require maintenance to be kept up to date, it's currently unclear how intensive this work would be. • The passports would need to be standardised to be most effective.

Policy	Benefits	Drawbacks
Ecolabelling Labels with sustainability information focused on the environmental impacts of a product.	• Approximately 42 percent of the EU Ecolabel Licence holders declared that the EU Ecolabel helped them in setting targets for environmental improvements of their products/services for all or most areas, and this was thanks to a better and deeper knowledge of the environmental impact of their products/services.	• Companies choose to use Ecolabels driven by the fact that they see an opportunity to add value to existing products, expand their reach in existing markets, or maintain market share in a competitive environment. Literature does not provide much quantitative or qualitative research on the economic and environmental benefits really achieved by companies that are awarded an Ecolabel.
Extended Producer Responsibility EPR-based recycling policy aims for a shift in financial responsibility of waste treatment from local governments to producers.	• Extended Producer Responsibility schemes are a widely used environmental policy with a history of proven success. • The system of producer responsibility for packaging has been in place in the UK since 1997 and has helped to increase recycling of packaging waste from 25%, 20 years ago to 63.9% in 2017 (DEFRA, 2021).	• The approach of an extended producer responsibility is undermined by the current exports of used and waste products. • The success of EPR will be contingent upon the willingness and capacity to invest in this policy and its enforcement. EPR will only be able to achieve its potential to the extent that producers efficiently

Policy	Benefits	Drawbacks
		fulfil their obligations.
Tax on Virgin Materials A tax levied on producers for using virgin materials, materials that are difficult to recycle, or toxic materials, to create incentives for using secondary (recycled) or less toxic materials	• Increases demand for secondary materials by increasing costs of virgin material production. • While urban mining of e-waste is becoming more cost-effective than virgin mining (Zeng, et al., 2018), it has also been shown by Li and Tee (2012) that in the production of electronics recycled materials save more energy than virgin materials with aluminium saving 95% more energy and copper saving 85% more energy.	• Due to the low own-price elasticity of secondary material supply, the impacts on actual use may be low unless the tax on primary materials is very high. • A tax on virgin raw materials in one country may induce higher imports of recycled materials from other countries where such a policy is absent.
Carbon Tax / Carbon Border Adjustment End-to-end supply chain carbon tax to promote supply to the lowest carbon supply routes which are often domestic.	• If emissions taxation were to consider the environmental cost of different transportation modes, as well as including where materials were sourced, it could encourage more domestic production. • If hypothecated, the tax or adjustment could fund investment in low carbon infrastructure.	• Emissions tax regimes are an investment burden when compared against steelmaking countries where there are no carbon taxes. • Current taxation allows manufacturers to stop calculating carbon emissions at the end of their production processes, ignoring the emissions created further up and down the supply chain.

Policy	Benefits	Drawbacks
Direct Government Funding	• Clear and precise intervention to deliver change in infrastructure.	• Funding is provided on a case by case basis.
End-of-life Vehicle Recycling Electric arc furnaces can be used to recycle ELVs into scrap steel. The 'whole recycling method', in which an end-of-life vehicle (ELV) is pressed and transferred to an electric furnace or converter, simultaneously recycles iron, and treats automotive shredder residues.	• Recycling a pressed ELV in a converter was found to cause GHG emissions approximately 320 kg-CO2e lower than caused by the recycling of the pressed ELV in an electric furnace. • EAF plants are smaller and less expensive to build than integrated steelmaking plants. • EAFs are also cost-efficient at low production rates. • EAFs can be operated intermittently, while a blast furnace is best operated at very constant rates.	• EAF power consumption is high. • The amount of greenhouse gases reduced by a converter depends on the conditions used, such as the presence of a Linz–Donawitz converter gas recovery facility • Whole recycling method of vehicles results in contaminants which must be reduced to ensure the quality of recycled steel scrap. Removal of these contaminant alloys such as copper increases costs and complications.
Policies on Electricity Prices	• Addresses significant proportion of cost associated with processing metals. • Reduces risk of "offshoring" energy intensive industries.	• Broad brush policy that does not specifically incentivise recycling

5.0 Conclusions

A substantial increase in UK metal recycling will require a step change in UK infrastructure. Whilst the UK currently captures a high proportion of steel and aluminium products at end of life, most of these are exported for recycling. The capability of UK metal producers to incorporate higher proportions of recycled content is constrained by current infrastructure for sorting and reprocessing.

Through direct investment, UK Government has already supported the steel sector in this transition, and further opportunities remain to transform the steel and aluminium sectors. The investment necessary to achieve greater levels of metal recycling could be partially funded through:

- Extended Producer Responsibility Schemes for products containing steel and aluminium – in particular construction products, automotive, packaging and electrical items.
- The National Wealth Fund, specifically the UK Infrastructure Bank (UKIB), which is backed by HM Treasury to deploy debt, equity, and guarantees to projects which support tackling climate change, with waste being one of its five priority sectors. Securing funding from the UKIB could also crowd in significant private capital over time.

Whilst not a direct source of funding, Carbon Border Adjustment Mechanisms could also create incentives for investment. To maximise the benefits to the UK this should be combined with additional policies that increase the supply of recycled material, e.g., waste sorting requirements to ensure that supply of recycled materials can increase in line with demand.

In order to realise systemic change, additional supporting policies would also be required. The Law for the Promotion of Efficient Utilization of Resources in Japan creates a systemic framework and requires manufacturers to also run disassembly plants, with material recovery legally mandated as well. Emulating this in the UK would also create an incentive to design products for disassembly and for retention of information on materials present in products. It could also improve scrap quality.

Business alignment between metal manufacturers and scrap suppliers needs to be improved to enable a working and efficient industry. The standards used to sort scrap steel in the UK are currently insufficient to ensure that scrap steel received by steel manufacturers is the quality and consistency required to be easily recycled into high quality steel grades. Further investment in research and development to address contaminants is required. Policies supporting eco-design standards may be beneficial in improving the efficiency and success of this scheme.

There is no single intervention that will encourage more domestic recycling of domestically produced scrap metal, and a range of interventions will need to be pursued. Such interventions can also deliver reductions in greenhouse gas emissions, whilst supporting UK jobs. This presents a significant opportunity for the UK to lead in the production of net-zero or low carbon metals.

6.0 References

Abuzied, H., Senbel, H., Awad, M. & Abbas, A., 2020. A review of advances in design for disassembly with active disassembly applications. *Engineering Science and Technology, an International Journal,* 23(3), pp. 618-624.

AlFed, 2021a. *The Aluminium Industry In The UK 2021,* s.l.: s.n.

AlFed, 2021b. *UK Aluminium Sustainability Roadmap to 2050,* UK: AlFed.

Amani, N., 2011. Effective Factors on Eco Labeling Building-Construction, Materials and Components. *Advanced Materials Research,* pp. 374-377.

Atradius, 2017. *Market Monitor Steel 2017,* s.l.: s.n.

Automotive Management Online, 2018. *Global used car export demand driving up UK wholesale values.* [Online]
Available at: https://www.am-online.com/news/market-insight/2018/11/19/global-used-car-export-demand-driving-up-uk-wholesale-values

BAMB, n.d.. *Material Passports.* [Online]
Available at: https://www.bamb2020.eu/topics/materials-passports/

Basu, S. & Bidanda, B., 2014. Shortcomings of eco-labelling of construction and building materials. *Eco-efficient Construction and Building Materials,* pp. 151-165.

BEIS, 2017. *Future capacities and capabilities of the UK steel industry,* s.l.: s.n.

BEIS, 2020. *Clean Steel Fund Call For Evidence Summary of Responses,* s.l.: s.n.

BEIS, 2021. *Industrial decarbonisation strategy,* s.l.: UK Government.

BEIS, 2022. *Steel public procurement 2022,* s.l.: s.n.

Bleischwitz, R., Domenech, T. & Winning, M., 2021. *Remaking steel for a net zero carbon circular economy.* [Online]
Available at: https://www.ucl.ac.uk/bartlett/news/2021/sep/remaking-steel-net-zero-carbon-circular-economy

BMWK, 2020. *What actually are carbon contracts for difference?.* [Online]
Available at: https://www.bmwk-energiewende.de/EWD/Redaktion/EN/Newsletter/2020/11/Meldung/direkt-account.html
[Accessed 8 April 2024].

Braw, E., 2014. Five countries moving ahead of the pack on circular economy legislation. *The Guardian*, 29 October.

British Steel, 2021. *Low Carbon Roadmap,* s.l.: s.n.

Chung, S., Murakami-Suzuki, R. & Kojima, M., 2009. Application of EPR to Recycling Policies in Japan, Korea and Taiwan. In: *Extended Producer Responsibility Policy in East Asia.* s.l.:Institute for Global Environmental Strategies, pp. 13-36.

Daehn, K., Serrenho, A. C. & Allwood, J. M., 2017. How will copper contamination constrain future global steel recycling?. *Environmental Science & Technology,* 51(11), pp. 6599-6606.

DEFRA, 2021. *Extendted Producer Responsibility for Packaging: Consultation Document,* s.l.: Department for Environment, Food and Rural Affairs.

Defra, 2023. *The role of ecolabelling in the path to net zero: Evidence review and Theory of Change,* s.l.: s.n.

DESNZ, 2023. *Powering Up Britain: Net Zero Growth Plan,* s.l.: s.n.

DETR, 1999. *Report of the Market Development Report,* London: DETR.

Dutil, Y., Rousse, D. & Quesada, G., 2011. Sustainable Buildings: An Ever Evolving Target. *Sustainability,* Volume 3, pp. 443-464.

Ellen Macarthur Foundation, n..d.. *Using Product Passports to improve the recovery and reuse of shipping steel: Maersk Line.* [Online]
Available at: https://ellenmacarthurfoundation.org/circular-examples/using-product-passports-to-improve-the-recovery-and-reuse-of-shipping-steel

Environmental Audit Committee, 2022. *House of Commons Environmental Audit Committee Greening imports: a UK carbon border approach,* s.l.: House of Commons.

European Commission, 2022. *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC.* [Online]
Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022PC0142&qid=1686296281605
[Accessed 5 April 2024].

European Commission, 2023. *Ecodesign for Sustainable Products Regulation.* [Online] Available at: https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/sustainable-products/ecodesign-sustainable-products-

regulation_en
[Accessed 5 April 2024].

European Environment Agency, 2008. *Effectiveness of environmental taxes and charges for managing sand, gravel and rock extraction in selected EU countries.,* Copenhagen: EEA.

European Parliament, 2023. *Deal on new EU rules to make sustainable products the norm.* [Online]
Available at: https://www.europarl.europa.eu/news/en/press-room/20231204IPR15634/deal-on-new-eu-rules-to-make-sustainable-products-the-norm [Accessed 5 April 2024].

Finnveden, G. et al., 2013. Policy Instruments towards Sustainable Waste Management. *Sustainability,* 5(3), pp. 841-881.

Fraser of Allander Institute, 2020. *The Aluminium Industry in the UK,* Glasgow: Fraser of Allander Institute.

Green Alliance, 2018. *Completing the Circle: Creating effective UK markets for recovered resources,* s.l.: Green Alliance.

Green Alliance, 2022. *Building the future: A faster route to clean steel,* s.l.: s.n.

Gutowski, T. et al., 2013. The energy required to produce materials: constraints on energy-intensity improvements, parameters of demand. *Phil. Trans. R. Soc.,* 371(20120003).

Hall, R., Zhang, W. & Li, Z., 2021. *Domestic scrap steel recycling – economic, environmental and social opportunities (EV0490),* UK: DEFRA Science and Research Projects.

Heinrich, M., Lang , W. & BAMB, 2019. *Material Passports - Best Practice,* s.l.: The Technical University of Munich.

Heisel, F. & Oberhuber, S., 2019. Calculation and evaluation of circularity indicators for the built environment using the case studies of UMAR and Madaster. *Journal of Cleaner Production,* Volume 243.

HM Government, 2023. *Responding to the Independent Review of Net Zero's Recommendations,* s.l.: s.n.

HM Government, 2024. Boost for new National Wealth Fund to unlock private investment

Honic, M., Kovacic, I., Aschenbrenner, P. & Ragossnig, A., 2021. Material Passports for the end-of-life stage of buildings: Challenges and potentials. *Journal of Cleaner Production,* Volume 319.

Hotta, Y. & Elder, M., 2009. Internationalization of Waste and Recycling Related Issues and Its Implications for EPR-based Recycling Policy. In: *Extended Producer Responsibility Policy in East Asia.* s.l.:Institute for Global Environmental Strategies, pp. 115-130.

IBISWorld, 2020. *Alumnium production in the UK,* s.l.: s.n.

Jamasmie, C., 2021. *LME launches digital sustainability passport, begins with aluminum.* [Online]
Available at: https://www.mining.com/lme-launches-digital-sustainability-passport-for-aluminum-other-metals/

Kaminski, I., 2019. Material Passports: Finding Value in Rubble. *The Architects' Journal*, 8 August.

Kenichi Nakajima, O. T. T. M. K. M. a. T. N., 2011. Thermodynamic Analysis for the Controllability of Elements in the Recycling Process of Metals. *,Environmental Science & Technology,* 45(11), pp. 4929-4936.

Legg, D., 2007. *Effectiveness of environmental taxes and charges for managing sand, gravel, and rock extraction in selected EU countries: Sweden,* s.l.: European Topic Centre on Resource and Waste Management.

Li, R. & Tee, T., 2012. A Reverse Logistics Model for Recovery Options of E-Waste Considering the Intergration of the Formal and Informal Waste Sectors.. *Procedia - Social and Behavioral Sciences,* Issue 40, pp. 788-816.

Make UK, 2021. *A barrier to decarbonisation: Industrial electricity prices faced by UK steelmakers,* London: MakeUK.

Make UK, 2022. *Net Zero Steel - A Vision for the Future of UK Steel Production,* London: MakeUK.

Milios, L. & Matsumoto, M., 2019. Consumer Perception of Remanufactured Automotive Parts and Policy Implications for Transitioning to a Circular Economy in Sweden. *Sustainability,* 11(22).

Ministry of Finance, 2003. *The tax on natural gravel: Goal fulfilment and consequences,* Stockholm: s.n.

Office for National Statistics, 2022. *UK input-output analytical tables - product by product.* [Online]

Available at:
https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datalist?filter=datasets

Pauliuk, S., Milford, R. L., Muller, D. B. & Allwood, J. M., 2013. The Steel Scrap Age. *Environmental Science & Technology,* 47(7), pp. 3448-3454.

Raabe, D. et al., 2022. Making sustainable aluminum by recycling scrap: The science of “dirty” alloys. *Progress in Materials Science,* Volume 129.

Responsible Steel, 2021. *Net Zero Steel Pathway Methodology Report,* s.l.: Responsible Steel.

Rhodes, C., 2018. *UK steel industry: Statistics and policy,* s.l.: UK Government: House of Commons.

S&P Global, 2021. *Demand for aluminum, steel remains firm as scrap prices decline.* [Online]
Available at: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/energy-transition/091021-demand-for-aluminum-steel-remains-firm-as-scrap-prices-decline

Seifert, R. W., 2012. *Have ecolabels had their day?.* [Online]
Available at: https://www.imd.org/research-knowledge/articles/have-ecolabels-had-their-day/

Serrenho, A. C. et al., 2016. The influence of UK emissions reduction targets on the emissions of the global steel industry. *Recourses, Conservation and Recycling,* Volume 107, pp. 174-184.

Skidmore, C., 2022. *Mission Zero: Independent Review of Net Zero,* s.l.: BEIS.

Smeets, A., Wang, K. & Drewniok, M. P., 2019. Can Material Passports lower financial barriers for structural steel re-use?. *Earth and Environmental Science,* Volume 225.

Söderholm, P., 2011. Taxing Virgin Natural Resources: Lessons from Aggregates Taxation in Europe. *Resources, Conservation and Recycling,* 55(11), pp. 911-922.

Söderholm, P. & Ekvall, T., 2020. Metal markets and recycling policies: impacts and challenges. *Mineral Economics,* Volume 33, pp. 257-272.

The Aluminum Association, 2022. *The Environmental Footprint of Semi-Fabricated Products in North America,* USA: Aluminum Association.

The Aluminum Association, 2022. *The Environmental Footprint of Semi-Fabricated Products in North America.,* USA: The Aluminum Association.

The Royal Institute of International Affairs, n.d. [Online]
Available at:
https://resourcetrade.earth/?year=2019&importer=826&category=35&units=value&autozoom=1

The World Bank, 2020. *Carbon Pricing Dashboard.* [Online]
Available at: https://carbonpricingdashboard.worldbank.org/map_data

UK Infrastructure Bank, 2022. *Strategic Plan,* Leeds: s.n.

UK Steel, 2016. *Key Statistics 2016,* s.l.: s.n.

Vogl, V. Å. M. &. N. L. J., 2018. Assessment of hydrogen direct reduction for fossil-free steelmaking. *Journal of Cleaner Production,,* Issue 203, pp. 736-745.

Wilts, H. et al., 2011. Challenges of metal recycling and an international covenant as possible instrument of a globally extended producer responsibility. *Waste Management & Research: The Journal for a Sustainable Circular Economy,* 29(9), pp. 902-910.

World Steel Association, 2019. *Steel Statistical Yearbook 2019,* s.l.: s.n.

WRAP, 2021. *Net Zero Why Resource Efficiency Holds the Answers,* s.l.: WRAP.

Zeng, X., Mathews, J. & Li, J., 2018. Urban Mining of E-Waste is Becoming More Cost-Effective than Virgin Mining. *Environmental Science & Technology,* 52(8), pp. 4835-4841.