ZERO WASTE SCOTLAND

Circular Steel in Scotland

Current landscape and opportunities
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WMG THE UNIVERSITY OF WARWICK

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Contents

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1 Executive summary

Steel is a strategically important material within the Scottish economy and is embodied within its stocks of buildings, infrastructure, and many different products.

As a highly recyclable material, steel has the potential to achieve high levels of circularity, and there is an active, global market for steel scrap. As a high-performance material (e.g., durable and strong), steel is expected to be in high demand to contribute to the building of renewables capacity as part of the energy transition. This report seeks to understand the current landscape for steel scrap generation in Scotland and its subsequent treatment, and to explore what opportunities there may be for increasing the circularity of the steel within Scotland.

It is important to note data used in this report were accurate at the time of writing, however, it is likely a number of figures may have changed at the time of reading. This includes a range of key input variables to the cost modelling (energy prices, scrap steel prices, finished steel prices etc.) which are highly variable by their very nature and susceptible to recent global events and economic forces.

The report is structured in three sections: the first section reviews the size and composition of the Scottish steel scrap market and was conducted based on a combination of desk-based research and stakeholder interviews (conducted in early 2022). This analysis estimates that between 620 and 930 kt of steel scrap is generated in Scotland each year, with key sources of scrap including: construction and demolition, agriculture, packaging, manufacturing, end-of-life vehicles, and municipal waste. Research finds that scrap steel generated within Scotland is currently exported for recycling, with approximately 73% destined for Europe, 25% exported to the rest of the UK (although this may subsequently be exported elsewhere), and 2% to the rest of the world.

The research identifies and maps the different actors within the steel recycling value chain, with a large network of steel processors consolidating, sorting, and fragmentising steel scrap within Scotland, before export for recycling.

The export destination for scrap shipments is influenced by a range of market factors, such as scrap price, steel mill demand, freight availability, and long-standing customer relationships.

The second section of this report provides a macro-economic assessment of the potential impacts and opportunities associated with the operation of an Electric Arc Furnace (EAF) steel recycling facility in Scotland. The report discusses a variety of issues that are deemed of significance in the business case for steel recycling in Scotland. These include locational considerations, employment impacts, profitability and gross value added.

A 'Technical Appendix' set outs all the input variables, factors and assumptions used in the modelling, while laying out how the calculations have been made, why certain assumptions have been used and recommends further testing that may be useful in future analysis. Three scenarios are considered: a 300 kt plant producing a construction grade ('low value') product (Scenario 1), a 300 kt plant producing a 'high value' product (Scenario 2), as well as a 1 Mt plant producing a construction grade product (Scenario 3).

The analysis finds that a 300 kt plant would likely create over 650 jobs in the Scottish economy (for both Scenario 1 & 2 which are assumed to be similarly labour intensive), while a 1 Mt plant could create upwards of 900 jobs. Total Gross value added (GVA) contributions (direct, indirect, and induced) are estimated to be around £9m, £389m, and £184m for scenario 1, 2, and 3, respectively. All headline findings are presented in Table 1 on the next page.

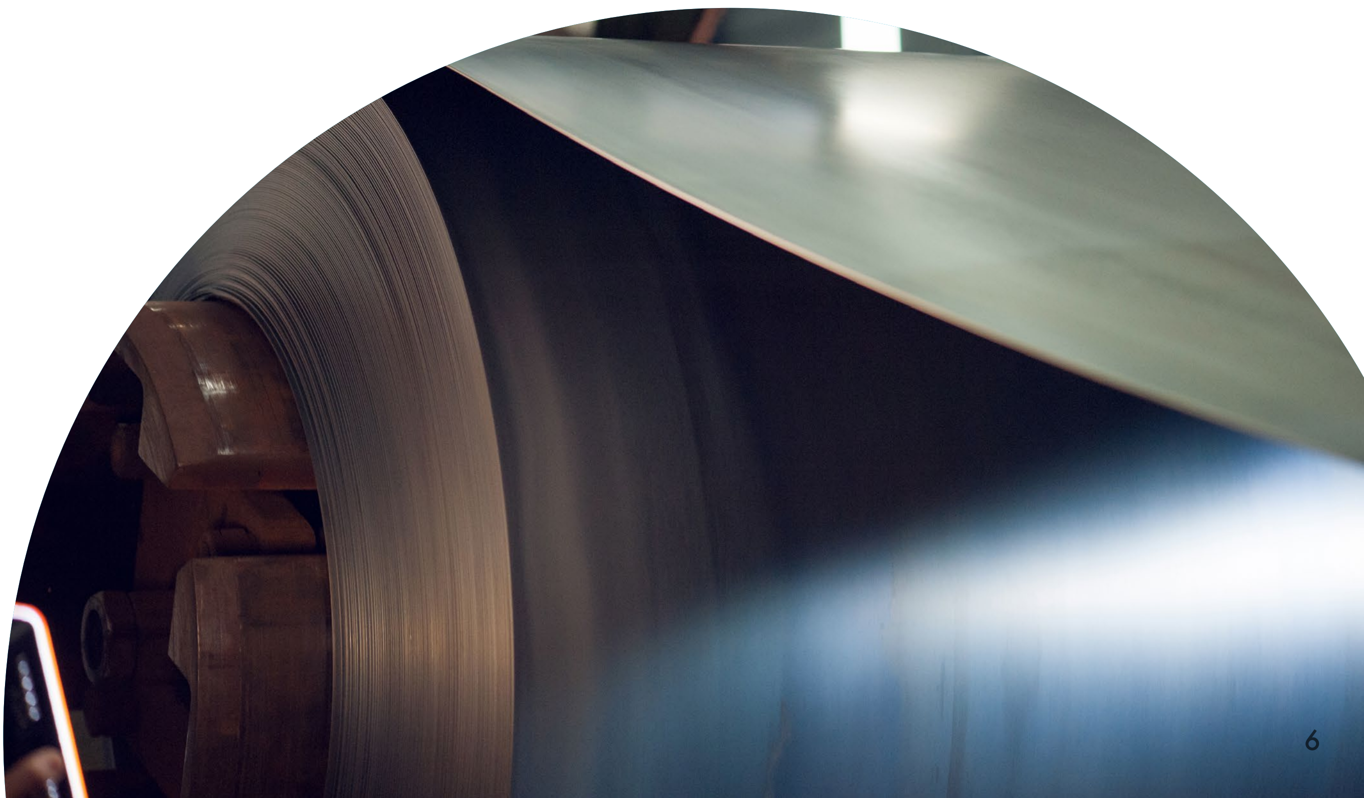


Table 1: **Key findings from the analysis**

Plant size	Direct EAF Employment	Indirect & Induced employment	Total employment	Direct GVA	Indirect and induced GVA (£m)	Total GVA (£m)	Profitability (£m)
300 kt – Construction grade (Scenario 1)	350	315	665	4.6	4.6	9.1	~ (-15.7)
300 kt – High value grade (Scenario 2)	350	315	665	194.7	194.7	389.4	~174.4
1 Mt – Construction grade (Scenario 3)	493	444	937	91.9	91.9	183.9	~48

The report identifies three key areas of uncertainty that could provide the greatest hindrance to the establishment of EAF steel recycling facilities in Scotland. These are:

- the price of scrap steel,
- the market price for finished steel products, and
- the cost of electricity.

The sensitivity analysis assesses market variations for these input variables, finding that GVA could vary by up to 1500% because of likely market volatilities. These uncertainties depict considerable risks associated with EAF steel recycling for any private company. Government assistance or intervention in the steel recycling market may be required to de-risk investment.

The third section of this report outlines an assessment of the steel required to fulfil Scotland's medium-term offshore wind ambitions. The assessment includes the volumes and types of steel required for future wind farm projects, how much steel could be available to be recycled from decommissioning North Sea oil and gas platforms, the potential types of environmental impact from domestic steel production, and the supply chains that would be required to produce steel and steel components for wind turbines in Scotland.

The assessment considers whether there is enough scrap steel in Scotland, if domestic scrap and decommissioning scrap sources are included, to recycle through EAF facilities into construction steel for offshore wind turbine manufacturing. The ScotWind Round 1 and INTOG projects are used as a baseline for steel mass requirements, with analysis showing that over 8 Mt of construction steel alone is required to meet the anticipated steel demand for these sites.

This analysis shows that it is technically possible to recycle Scottish scrap steel to manufacture steel for offshore wind energy projects in the future, with the upper bound scrap generation projections indicating that there could be sufficient scrap from domestic and decommissioning to meet this demand. However, it is not currently practically achievable to implement this – the required supply chains and infrastructure do not currently exist in Scotland to recycle steel and manufacture wind turbines. Steel supply from oil and gas decommissioning alone would not supply enough steel for operation of new steelmaking plant in Scotland and it would need to operate in tandem with another scrap steel source.

To take this opportunity forward, further investigation into a full Scottish supply chain for wind turbine manufacture (e.g., sites, economics, and related infrastructure) would be required as there are currently no large wind turbine components or assemblies manufactured in Scotland or the UK. Manufacture of wind turbines in Scotland using recycled steel would require development of an almost completely new supply chain involving scaling up of oil and gas decommissioning, building new electric arc furnace steel plant(s) and any associated infrastructure, heavy manufacturing facilities for substructures, monopiles, towers, large castings, and large assemblies.

In conclusion, while Scotland's steel scrap is currently recycled and recirculated at a global level, there remains an opportunity to tighten this loop and increase circularity through developing domestic steel recycling and manufacturing capability. This opportunity is primarily driven by the anticipated demand for steel to fulfil Scotland's renewable energy ambitions, and potential access to low carbon electricity via existing renewables capacity. There is also concern that the global race to decarbonise may lead to constraints on the supply of crucial materials[1], which could be alleviated, at least in part, through domestic reuse and recycling. However, the road to implementing a domestic steel value chain would likely be challenging, with current market economics stacked against UK steel production[a], and would need to represent a strategic decision at a governmental level and necessitate considered intervention.

[a]At the time of writing, LIBERTY Steel UK, announced that they would be reducing EAF output at their Rotherham EAFs due to "the UK steel industry's severe competitiveness issues", LIBERTY Steel UK to forge a viable way forward for its businesses and workforce (2023). Available at : Link

2 Scotland and steel

Steel is a strategically important material embodied in many of the products (e.g., cars, packaging, and domestic appliances) and civil engineering projects (e.g., bridges, wind turbines, and buildings) we interact with, or rely on, every day.

It is the mostly widely used and manufactured metal in the world[?], and the most widely recycled material by weight. A thriving global commodity market for scrap steel has developed due to its inherent recyclability, global steel demand far outstripping the supply of scrap, and UK market prices of up to £255/tonne in October 2022[3] making it highly valuable.

Out of the UK's total consumption of 15 Mt steel in finished goods per year, only one sixth is comprised of steel produced in the UK[2], making the UK reliant on steel imports. However, with central government infrastructure projects set to demand 6.5 Mt of steel in the next five years[4], resilient supply chains giving access to a secure supply of steel is of critical importance.
This section reports on the current market and outlook for the steel scrap market in Scotland to provide the context for the subsequent analysis in this study, which looks at ways in which production of Scottish steel could bring greater environmental, economic, and social benefits.

Data used in this report were accurate at the time of writing, however, it is likely a number of figures may have changed at the time of reading. This includes a range of key input variables to the cost modelling (energy prices, scrap steel prices, finished steel prices etc.) which are highly variable by their very nature and susceptible to recent global events and economic forces.

Analysis has been conducted utilising a combination of desk-based research, semi-structured interviews, and correspondence with stakeholders from across the value chain. During this project we spoke to 12 organisations with the following activities:

1	4	2	3	1	1
Scrap processing and brokering	Scrap processing and exporting	Oil and gas decommissioning	Steelmaking	Trade association	Technology innovation and research

The project delivery team consulted with stakeholders from within their networks as well as via the British Metals Recycling Association (BMRA). A range of stakeholders also provided feedback on the study during presentation sessions with Zero Waste Scotland. As this study incorporates perspectives and experiences from a range of stakeholders, these opinions may not therefore be shared by all actors and may have changed since the interviews were conducted (early 2022).

2.1 Scotland's iron and steel history

From its Celtic roots and the beginnings of a nascent industry in the 17th Century, the rise of the Scottish iron and steel industries was catalysed by the discovery of Black Band ironstone in North Lanarkshire, Ayrshire, and Stirlingshire, and the development of a hot-blast process at the Clyde Iron Works near Glasgow, that could cost-effectively remove carbon and other impurities[5]. These developments in the early 19th Century, made Scottish steelmaking a viable and attractive prospect. Iron production grew rapidly in Scotland from 37.5kt in 1830 to 540kt in 1847, making up 27% of British output[5]. Another key point for Scotland's burgeoning iron and steel industry came in 1872, with the opening of the Dalzell Iron and Steel Works in Motherwell, which later expanded to the Clyde Iron Works site[6]. With these, and other plants, steel production expanded from less than 1.2kt in 1873, to 58.5kt in 1890[6].

The iron and steel industries were buoyed by domestic shipbuilding activities, particularly on the River Clyde, with Clydebridge Steelworks opening in 1887[5]. As the cost of producing steel reduced below that of producing wrought iron, steel demand rose, for both shipbuilding, and other projects, such as the Tay and Forth Bridges[6]. Both the First and Second World Wars initially contributed to increased demand for steel, but following each conflict, demand contracted drastically, and some plants were closed[5].

The commissioning of the integrated steelworks at Ravenscraig in North Lanarkshire in 1957 saw the site become the largest producer of hot-steel strip in Western Europe[5]. Along with strip, it produced steel slabs, which were then processed at the Dalzell plate mill to produce plate for shipbuilding and offshore oil platforms[5]. At its peak, 12,000 people were employed at Ravenscraig[6]. The post-war period saw significant political intervention in the iron and steel industries. The Iron and Steel Act of 1967 established the British Steel Corporation, which nationalised 90% of UK steelmaking, and included Ravenscraig[5].

In 1988, British Steel was privatised under Prime Minister Margaret Thatcher, and together with challenging market conditions, including high manufacturing costs, increased competition from imports, and a decline in key shipbuilding markets, Ravenscraig closed in the early 1990s[5]. British Steel itself became Corus in 1999, following a merger with Koninklijke Hoogovens, and Corus was subsequently acquired by Tata Steel in 2007 to form Tata Steel Europe[7]. In 2015, two of the most significant remaining steelworks in Scotland, Dalzell and Clydebridge, were mothballed by Tata Steel Europe but they were both purchased by Liberty House Group in 2016[8].

Today, LIBERTY Steel Dalzell and Clydebridge employs nearly 200 people, and the Dalzell plate mill has a production capacity of up to 300kt per year[9].

2.2 What is the size of the Scottish scrap steel market?

The Scottish scrap steel market encompasses a diverse range of stakeholders and actors, ranging from scrap processors, scrap brokers, exporters, municipal recycling facilities, decommissioning yards, and other essential elements of the supply chain. The route taken by scrap steel from arising as a waste to entering a furnace for recycling can vary widely in both complexity and geographical distance. Scrap steel can arise from a broad range of sources including:

Households

e.g., food cans, white goods, vehicles, demolition

Commercial

e.g., packaging, furniture, vehicles, demolition

Industrial

e.g., manufacturing scrap, yellow goods, industrial equipment decommissioning

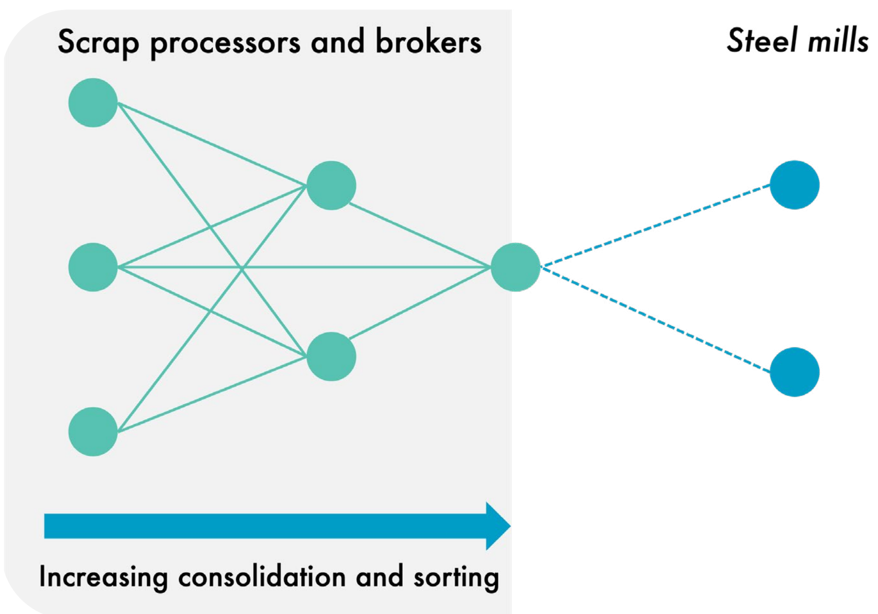
As steel scrap arisings are strongly connected to both population centres and industrial activity, scrap generation can be dispersed, highly variable in composition and quality, and low in density. This creates a limit on the distance from which it is economically viable to transport scrap by road (typically in distances of 30-100 miles[a]). The structure of the scrap industry has evolved to adapt to these challenges with a large network of intermediaries between scrap arising and remelting. As scrap is passed between actors in the chain, the scrap is consolidated, sorted, and fragmentised. These activities increase the value of the scrap, as it is then in a more useful form (e.g., in terms of geometry and degree of contamination) for the steel mills sourcing input materials for their processes. It is also higher density, which increases the efficiency and economy of transport logistics. At the top of the chain, there are a handful of companies that have access to sufficient volumes to broker the movement of that scrap to steel mills, both in the UK and abroad.

Stakeholders involved in the movement and processing of steel scrap must be registered with SEPA as waste sites. In 2021, the year for which most recent data are available, 114 operational sites were registered as having activity that included "metal recycling"[10]. The registered annual waste capacity of these sites was over 3,054,401 tonnes[b] with recorded waste outputs from these sites in 2021 of nearly 1.2 million tonnes (an increase from 1.4 million tonnes in 2018). Not all the metal handled would be steel, with other metals like copper and aluminium also being processed.

Additionally, the networked structure of the scrap processing industry creates challenges in monitoring the volume of scrap arisings from waste site data, as the scrap will most likely pass through more than one waste site between generation and a steel mill. Therefore, relying on waste site data could lead to double counting.

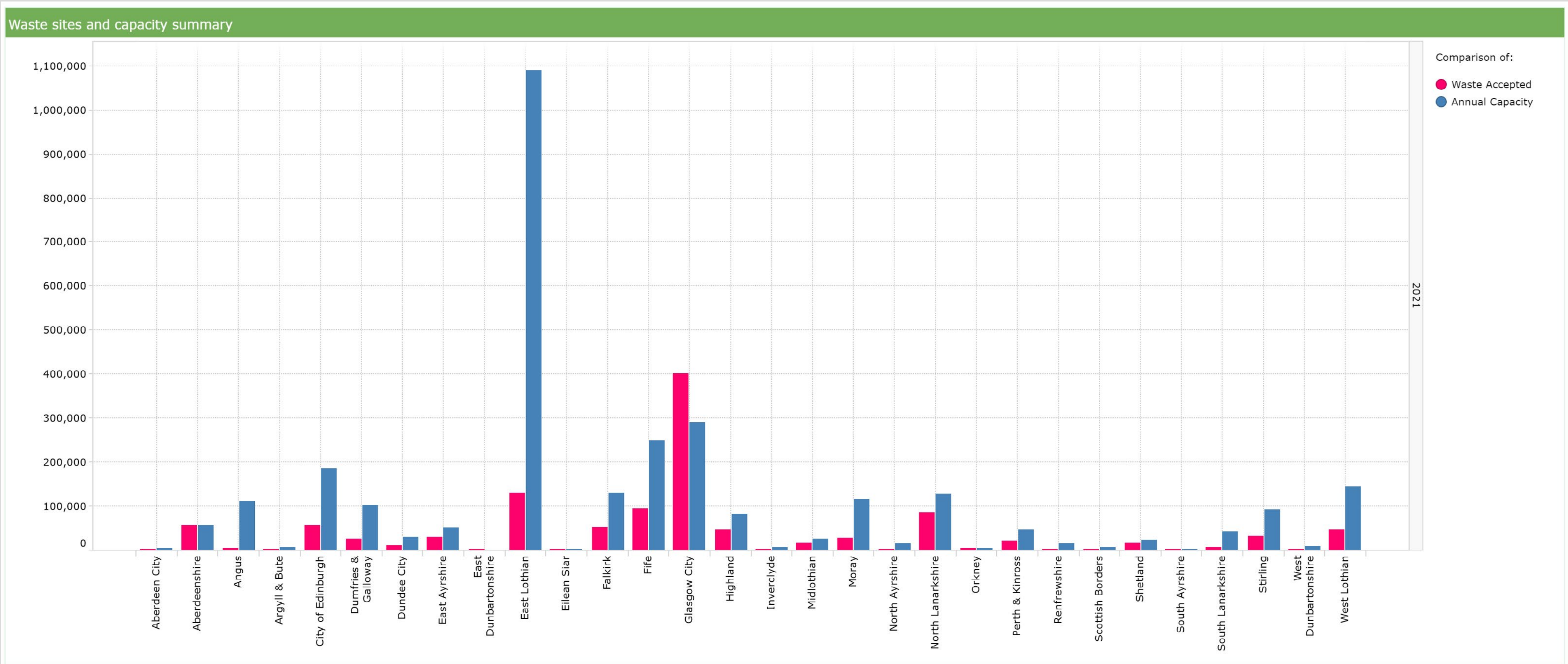
It is difficult to map the geographic location of steel scrap arisings from waste statistics - by the time the scrap is documented, it has already travelled to a waste site. However, SEPA data on waste sites does give us some information on the general location of scrap arisings through the location of metal recyclers. The graph below shows the regional distribution of waste sites in 2021 that include "metal recycler" as one of their activities and reports the licensed annual capacity and accepted waste tonnagess[10].

Figure 1: Schematic of steel scrap value chain



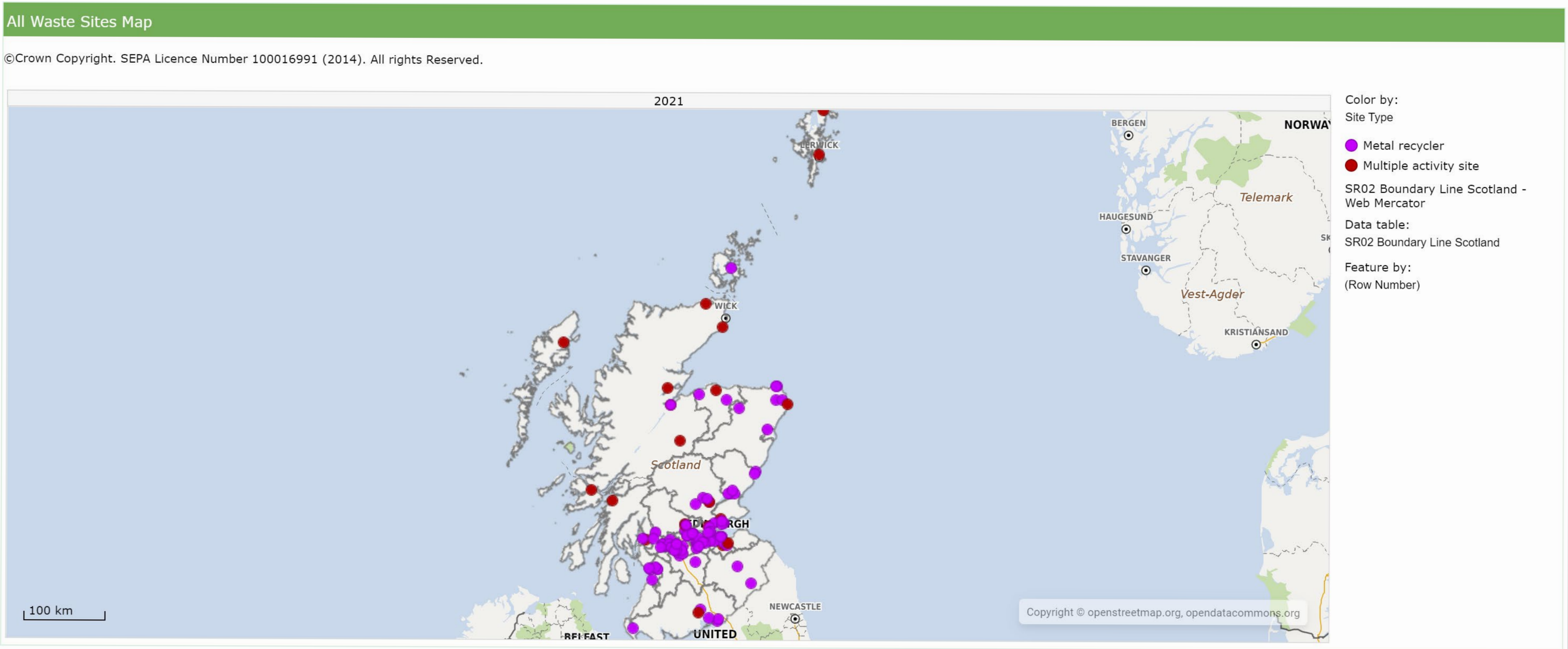
[a] From stakeholder interviews
[b] This excludes a reported permitted waste capacity of over 1 Mt, which is assumed to be an error

Figure 2: **Regional distribution of metal recyclers in Scotland in 2021, Source: SEPA**



The map on the next page illustrates the location of licensed metal recyclers in Scotland for 2021, based on the same SEPA data[10]. The map demonstrates a similar clustering of activity around population and industrial centres to scrap arisings (as identified from our stakeholder interviews).

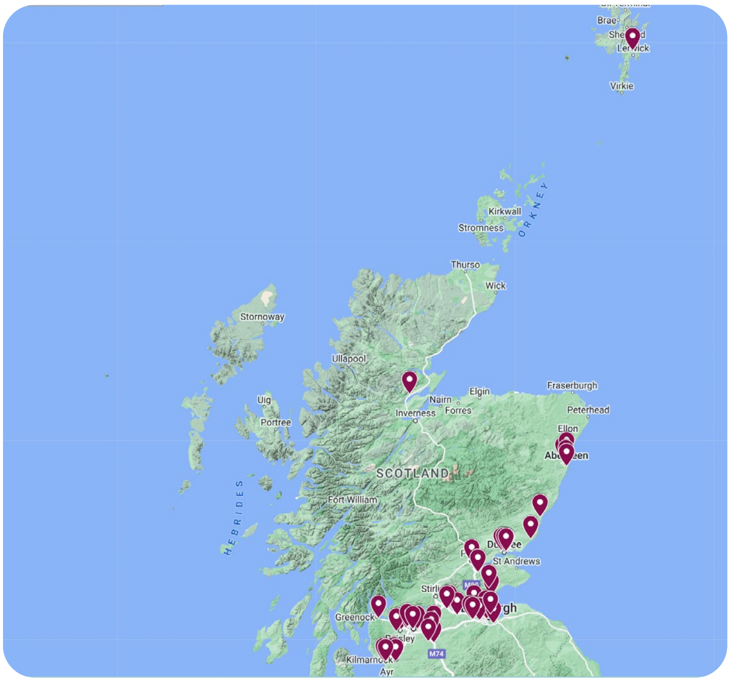
Figure 3: Geographical distribution of metal recycling facilities in Scotland in 2021, Souce: SEPA



The British Metals Recycling Association (BMRA) also maintains a directory of registered scrap collection sites. At the time of publication, the BMRA listed 47 sites in Scotland, of which 39 sites handled one or more of the following metals: heavy iron, light iron, steel, ferrous or stainless steel. The map below, from the BMRA website[11], shows the location of these sites and demonstrates a similar clustering of activity around population and industrial centres to scrap arisings to the SEPA dataset.

To better understand the size of the steel scrap market in Scotland, we have explored three different approaches to evaluating the volume of scrap arisings: of scrap arisings:

Figure 4: Map of BMRA registered sites in Scotland



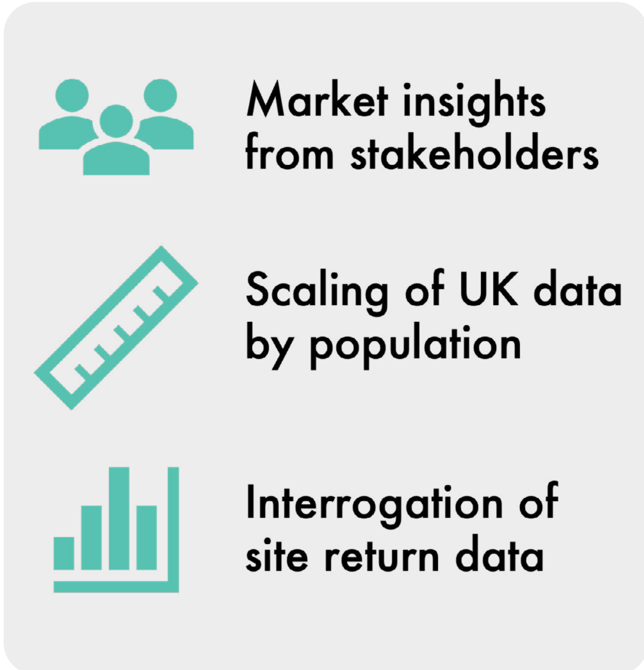
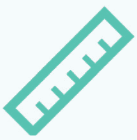


Table 2: Estimates of size of steel scrap market in Scotland

Approach	Estimated market size (year)	Details
	500 – 800 kt (2021)	Stakeholders were asked to estimate the size of the steel scrap market during interview. Responses ranged from 500 to 800 kt. From SEPA site return data, the stakeholders interviewed as part of this research reported site returns of nearly 530 kt of ferrous, non-ferrous, metals and mixed metals in 2019 in total.
	930 kt (2019)	Several stakeholders indicated during interview that scrap arisings were strongly correlated to population and that scaling UK scrap arisings data from previous research by population was an approach they used for estimating markets. Using UK scrap arisings and UK/Scottish population data for 2019 gives an estimated market size of 930 kt.
	At least 623 kt (2018)	Site return data from SEPA indicates that over 623 kt of "metallic waste, ferrous" was recycled in 2018. However, this likely represents a lower bound as a further 138 kt of "metallic wastes, mixed ferrous and non-ferrous" was also reported to be recycled. Further analysis of the 2021 SEPA site return data is now available. However, analysis and outputs relating to 2018 data will continue to be used in this paper I.e. noting that some output data could vary as a result of the use of up-to-date figures.

For the purposes of subsequent modelling of the market and recognising the uncertainty and variability in the scrap arisings data, we will investigate the impacts of scrap availability using rounded values ranging from 620 kt (lower bound from SEPA data) to 930 kt (upper bound from scaling of UK data) from this point on.

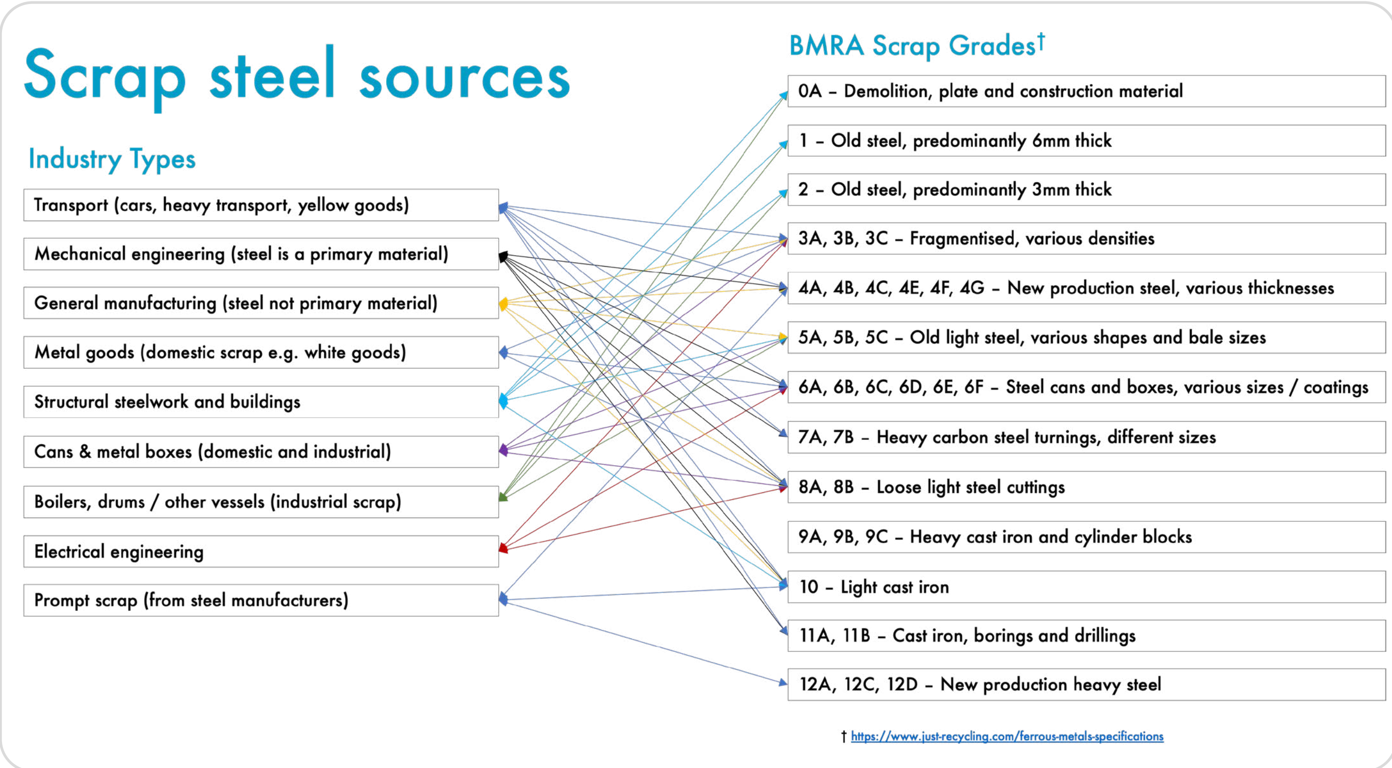
2.3 What are the main sources of scrap steel in Scotland?

Scrap steel is generated from a broad range of end-of-life products (e.g., cars, washing machines, and machinery) and industrial activities (e.g., demolition, decommissioning, and manufacturing). One of the challenges of monitoring scrap arisings is the way in which scrap is categorised within and outside of the industry. Within the industry, several references exist for classifying scrap grades, notably the BMRA scrap grades and Institute of Scrap Recycling Industries (ISRI) grades.

For some of the grades in the BMRA classification system, there is an indication of the product or activity that generated the scrap (e.g., OA – demolition, plate, and construction material). However, for most of the grades it is the composition and geometry that are most useful to distinguish as these are the features most relevant to steel mills when procuring scrap inputs. Similarly, the ISRI categories define two heavy melting scrap grades, along with shredded scrap and turnings – categories driven by the interests of the steel mill.

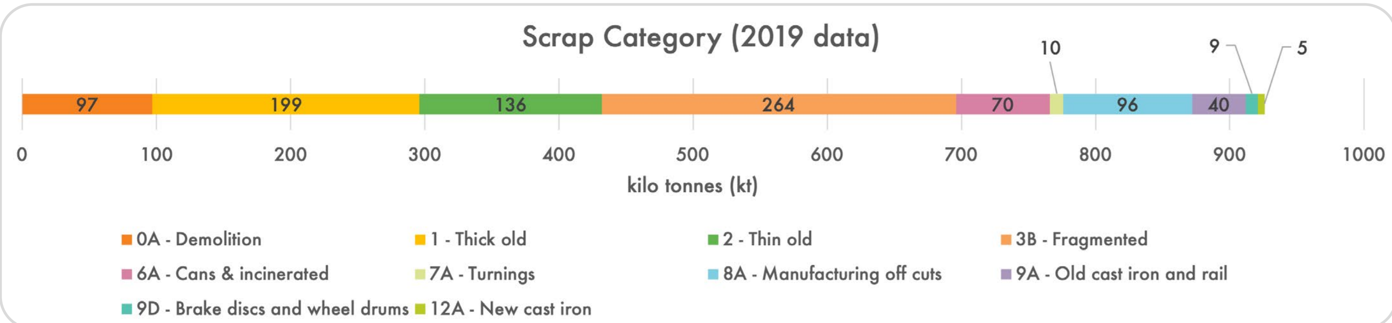
The following diagram maps different scrap steel sources (from a product basis) to the likely BMRA scrap grades and illustrates the wide variety of scrap sources and grades in circulation. While there is some information and analysis of scrap trade and arisings using the BMRA grades, there is no equivalent dataset for scrap arisings by source.

Figure 5: **Mapping of scrap steel sources to BMRA scrap grades, Source: Author analysis; †BMRA scrap grades[13]**



The following chart illustrates the estimated breakdown of Scottish steel scrap arisings by BMRA category, based on scaling UK data (2019). For most scrap categories, this is a reasonable approximation, due to the correlation between scrap arisings and population, as identified during stakeholder interviews. However, for categories related to manufacturing scrap, e.g., 8A and 12A, generation is less likely to be related to population, but rather to manufacturing activity, marginally reducing the accuracy of the scaling for those categories[a].

Figure 6: **Estimated breakdown of Scottish scrap by BMRA grade, Source: Author analysis**



Site return data is collected from authorised waste sites in Scotland by SEPA and the classification system used is the European Waste Catalogue (EWC) codes. In comparison to BMRA and ISRI codes, these codes focus more on the source of waste. The table on the following page summarises the EWC codes of most relevance to the scrap steel market[14]:

[a]The population of Scotland made up 8.2% of the UK population in 2019 (ONS data). By contrast, manufacturing output in Scotland in 2019 (calculated as number of manufacturing jobs multiplied by output (£) per jobs using ONS data) made up 8.1% of UK manufacturing output. This suggests the approximation of scaling scrap arisings by population for all scrap categories is unlikely to induce a significant error on manufacturing scrap arisings.

Table 3: EWC codes relevant to the steel scrap market, Source: Eurostat[14]

EWC codes	Details
Metallic wastes, ferrous	
10 02 10	Wastes from thermal processes > Wastes from the iron and steel industry > Mill scales (N.B. no data is available for this category in 2018 SEPA statistics)
10 12 06	Wastes from thermal processes > Wastes from manufacture of ceramic goods, bricks, tiles and construction products > Discarded moulds (N.B. no data is available for this category in 2018 SEPA statistics)
12 01 01	Shaping/Physical Treatment of Metals/Plastic > wastes from shaping and physical and mechanical surface treatment of metals and plastics > ferrous metal fillings and turnings
12 01 02	Shaping/Physical Treatment of Metals/Plastic > wastes from shaping and physical and mechanical surface treatment of metals and plastics > ferrous metal dust and particles
16 01 17	Other wastes from industrial processes > end-of-life vehicles from different means of transport (including off-road machinery) and wastes from dismantling of end-of-life vehicles and vehicle maintenance > ferrous metals
17 04 05	Construction and demolition waste > metals (including their alloys) > iron and steel
19 01 02	Materials from Waste and Water Treatment > Wastes from incineration or pyrolysis of waste > Ferrous materials removed from bottom ash
19 10 01	Materials from Waste and Water Treatment > Shredding of metal-containing wastes > iron and steel waste
19 12 02	Materials from Waste and Water Treatment > Mechanical treatment of waste (for example sorting – crushing – compacting – pelletising) not otherwise specified > ferrous metal
Metallic wastes, mixed ferrous and non-ferrous	
02 01 10	Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing, food preparation and processing > Wastes from agriculture, horticulture, aquaculture, forestry, hunting and fishing > Waste metal
15 01 04	Waste packaging; absorbents, wiping cloths, filter materials and protective clothing not otherwise specified > Packaging (including separately collected municipal packaging waste) > Metallic packaging
17 04 07	Construction and demolition waste > metals (including their alloys) > Mixed metals
20 01 40	Municipal Wastes (Household Waste and Similar Commercial, Industrial and Institutional Wastes) Including Separately Collected Fractions > Separately collected fractions > Metals

From 2018 SEPA data, we can further unpick the possible sources of steel scrap arisings by interrogating the reported site return data for the above EWC codes, as shown in the diagram below (Figure 7). Tonnages from EWC codes 19 10 01 and 19 12 02[a] are not included in the diagram as we anticipate that a significant fraction of waste from the other codes listed would subsequently be processed by shredding or other mechanical treatments and as such, would

[a] 573 kt of ferrous scrap was reported under EWC codes 19 10 01 and 19 12 02 in 2018

represent double counting. However, as some shredded and processed scrap from these two EWC codes may not be captured as arising in other categories, the breakdown of scrap by category below should not be considered a comprehensive summary of scrap arisings. It is rather an indicative breakdown of the relative sizes of waste arising categories, i.e., the sum of the tonnages per EWC code do not equal the total metallic wastes reported as recycled in 2018[b].

Figure 7: Metallic waste arisings by key EWC codes (2018), Source: SEPA

Manufacturing and industrial waste
8,500 t fillings and turnings (12 01 01)
4 t metal dust and particles (12 01 02)

Agriculture
484 t mixed metal (02 01 10)

Packaging
7,060 t mixed metal (15 01 04)

ELVs
102,000 t ferrous metal (16 01 17)

Construction and demolition
209,000 t ferrous metal (17 04 05)
56,800 t mixed metal (17 04 07)

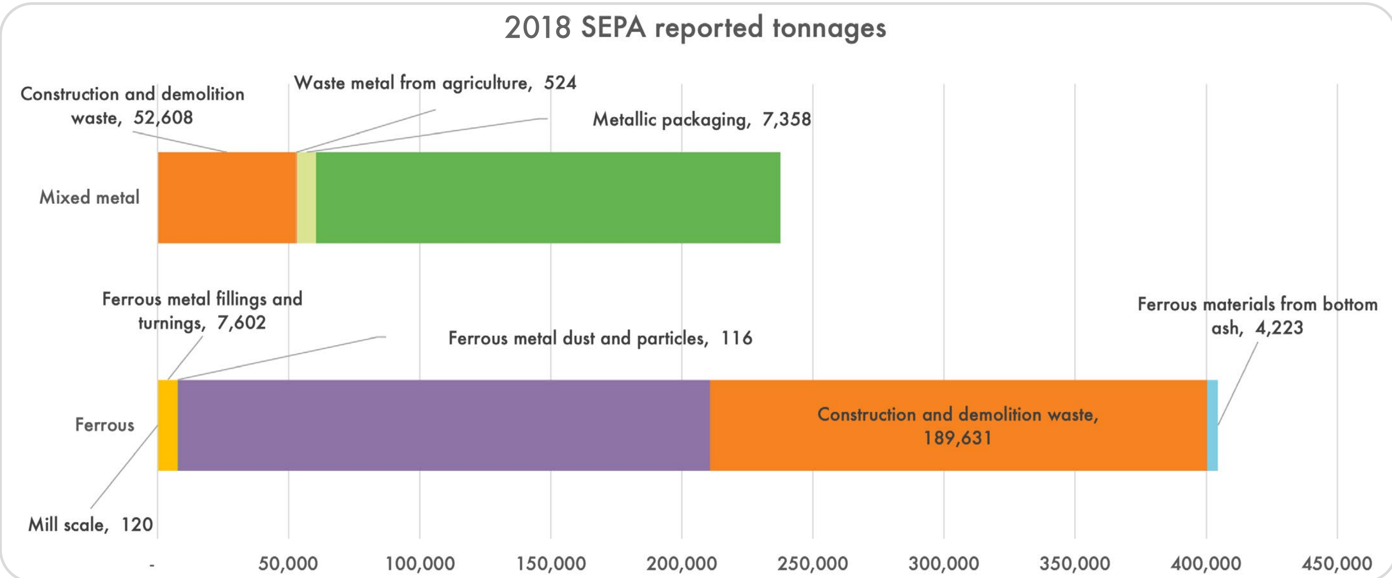
Waste processing
1,460 t ferrous materials from bottom ash (19 01 02)

Municipal waste
195,000 t mixed metal (20 01 40)

Metallic wastes, ferrous ~321 kt
Metallic wastes, mixed ferrous and non-ferrous ~260 kt

The relative size of these sources is shown in the chart below (Figure 8), distinguishing between ferrous sources and mixed ferrous and non-ferrous sources.

Figure 8: Site return data by EWC code for ferrous and mixed metal categories (2018), Source: Author analysis



[b] We present 2018 data for consistency throughout the report. However, 2019 reported site return data by EWC code is available and while total tonnage is slightly higher, the breakdown of arisings by EWC code is generally similar (within about 10%) except for mill scale (10 02 10), ferrous metal dust and particles (12 01 02) and ferrous materials from bottom ash (19 01 02) and ELVs (16 01 17). For the first three of these categories, while the relative year-on-year change is large, the absolute change in tonnages compared to total scrap arisings is small. For ELVs the change is more significant, with 203 kt of ferrous metal in 2019.

Our understanding is that decommissioning activities are classified under construction and demolition wastes, under NACE code 43 – Specialised Construction activities (43.1 Demolition and site preparation). As such, this is listed as a source branch for metallic wastes. No other references to decommissioning of refineries or oil rigs are found in the EWC catalogue. It is difficult to estimate the current volumes of steel scrap arising from decommissioning activities because of the lack of distinct EWC classification and the lack of granularity in data provided by stakeholders during interview.

However, it would likely represent a significant fraction of the 266 kt of ferrous and mixed metal construction and demolition waste reported in 2018. Additionally, stakeholders note that not all scrap arising from the decommissioning of oil and gas assets from the North Sea is processed in Scotland, or even the rest of the UK; this is discussed further later in this report.

2.4 How might scrap sources change in the future?

Stakeholder interviews, supported by other sources of information, raised a range of opinions as to how sources of steel scrap may change in the future. These insights (which may not reflect the views of all in the industry) included:

Manufacturing and industrial waste is expected to decrease

One stakeholder identified this potential trend based on an anticipated decrease in domestic manufacturing activities. Domestic manufacturing activities are reported to have decreased during the Covid-19 pandemic; however, it is not clear to what extent this activity may recover and whether a longer-term decrease is likely.

Scrap arisings are expected to remain connected to population

The population of Scotland is projected to continue increasing until around mid-2033, peaking at 5.53 million. It is then projected to fall by 0.6% to 5.49 million by 2045.[15]

Decommissioning volumes are expected to be volatile

While scrap may arise through decommissioning activities, arisings are expected to be “lumpy” based on the intermittent nature of decommissioning. Assuming current trends continue, it is also likely that not all the scrap will be processed in Scotland or the rest of the UK, with much scrap heading to other countries, like Norway, Denmark, the Netherlands, and beyond. However, in the Draft Energy Strategy and Just Transition Plan[16], Scottish Government has announced investment of £9m to develop an ultra-deep-water port in the Shetlands, to “increase the competitiveness of the decommissioning sector in Scotland”.
(**Source**: Draft Energy Strategy and Just Transition Plan)

Additional changes that may influence future arisings of steel scrap in Scotland that were not mentioned during interviews include:

Changes in vehicle composition: with the transition to low and zero-carbon powertrains further reinforcing the design priorities of vehicle lightweighting, the material composition of future vehicles may change. In the pursuit of weight reduction, conventional structural materials such as steel (which is relatively heavy) may be substituted with advanced high strength steels, aluminium, magnesium, composites, or even plastics. This would reduce the amount of steel scrap arising from end-of-life vehicles and may make efficient separation and sorting of scrap more difficult.

Changes in product ownership business models: with the development of new business models inspired by Circular Economy principles, product design may adapt to support practices such as design for repair, design for remanufacture, design for longevity, and design for upgrade etc. The successful deployment of these design principles and business models would act to delay the generation of waste by extending the life of products and components, and reducing scrap from repair and maintenance activities, which would result in lower annual scrap arisings. These types of changes could have significant impacts if applied to vehicles (e.g., car-sharing models), buildings (e.g., retrofit over demolition) and white goods (e.g., pay-per-use schemes) and reduce the amount of steel scrap arising.

The impact these types of changes could have on the magnitude of future scrap arisings are uncertain, being based on the ambition and uptake of new business models and product designs. However, while these changes would reduce scrap availability, they would also contribute to a reduction in demand for new steel, and so would not be expected to have an overly disruptive impact on the scrap market or pricing. Additionally, the impacts of these changes would most likely be felt in the medium- to long-term – particularly those related to product life extension. For example, a vehicle put on the market today (2023), with a life span increased by 50% (e.g., to approximately 18 years), would not be available as scrap until 2041.

2.5 The changing scrap market

In addition to changes in the future arisings of steel scrap in Scotland, stakeholders were able to provide insights on the changing dynamics in the steel scrap market. These changes are summarised below:

Changes within Scotland

- The commissioning of a deep-sea port in Glasgow by European Metal Recycling (EMR) in 2022 created, for the first time, direct scrap export opportunities from Scotland, beyond Europe. This

may precipitate a recalibration of scrap prices as the industry responds to the difference in scrap prices EMR may be able to command as they ship much larger volumes of scrap.
- A new deep-water berth at Inchgreen, operated by Atlas Decommissioning, could expand their activities from ship breaking into exports.

Changes within the UK

- The operating costs for scrap processors are anticipated to rise due to the increase in energy costs and the end of the use of red diesel in the industry.
- Following launch at COP26, the UK co-leads the Clean Energy Ministerial Industrial Deep Decarbonisation Initiative, which aims to stimulate demand for low carbon industrial materials, including steel.

Changes beyond the UK

- The race to decarbonise steel production in Europe is picking up speed with numerous companies announcing investment in new low-carbon steel production facilities. The commissioning of these new facilities is anticipated to increase demand for steel scrap, and particularly high quality, shredded scrap.
- The consolidation of the supply chain is happening across national borders, with the recent announcement of the acquisition of John Lawrie Metals by Luxemburg-based steel producer, Arcelor Mittal.

The development of new low-carbon steel production facilities in Europe could have significant bearing on the future of the steel scrap market, including for scrap in Scotland by increasing demand for high quality scrap. The following map identifies some of the key facilities being commissioned, with numerous other facilities also being developed.

Figure 9: **Key European steel decarbonisation projects involving Electric Arc Furnaces (EAFs) with Direct Reduced Iron (DRI).**
Source: H2 Green Steel [17], SSAB[18], ArcelorMittal[19], [20], [21]

H2 Green Steel – Boden

- SEK 30m (~£2.3m) in funding from Swedish Environment Agency
- Conditions cited for location: "500 hectares of land permitted for industrial use in Svartbyn, ready access to energy from fossil-free energy sources, high-quality iron ore, a large port in Luleå, and a cluster of world-leading expertise in metallurgy and steel production."
- Production to start from 2024 and targeting 5Mt per annum by 2030
- Estimated to increase net export value by SEK 30bn (~£2.3bn)
- Series A funding round in 2021 raised $105m.

SSAB – Oxelösund

- *Conversion of BF to EAF and competition of HYBRIT demonstration plant in 2025*
- *Commercial steel production from 2026*
- *Support for HYBRIT from EU Innovation Fund*
- *Around 2030, facilities at Luleå and Raahe to be converted to EAF minimills*

ArcelorMittal – Hamburg

- *Demonstrator plant for hydrogen reduced DRI, and EAFs powered by renewables*
- *Production to start 2025 (100 kt DRI).*
- *By 2030 targeting 1Mt production per annum*
- *Federal government intending to fund €55 m of €110 m total capital expenditure requirements*

ArcelorMittal – Dunkirk and Fos-sur-Mer

- *€1.7bn to replace coal-fired blast furnaces with EAFs with support from the French Government (value of support not yet disclosed)*
- *Fos-sur-Mer: to become "a reference site for the production of low carbon, circular steel, made from recycled steel"*
- *Dunkirk: 2.5Mt DRI and two EAFs*
- *Facilities operational from 2027*

ArcelorMittal – Gijón

- 2.3Mt green hydrogen direct reduced iron (DRI) unit and 1.1 Mt hybrid electric arc furnace (EAF).
- Production to start before end of 2025.
- €1bn investment for the project.
- Spanish government to "provide maximum financial support for the project, in line with Spanish legislation and European Union regulations"

2.6 Decommissioning impacts on steel scrap arisings

This section highlights two important decommissioning activities that may influence steel scrap arisings in Scotland in the future. This is explored in further detail in section 4 of this report.

Oil and gas decommissioning

- Oil and gas decommissioning represents a significant potential source of steel scrap
- OEUK project 138 topsides and 132 substructures will be removed from the North Sea between 2022 and 2031, with a total tonnage of over 1.4 Mt[1].
- However, the timescales for this steel becoming available are:
- **Variable** – One year one platform may be available for decommissioning, another year, ten.
- **Uncertain** – Decommissioning timelines are affected by oil and gas prices, which may delay or accelerate planned decommissioning. They are also strongly dependent on the availability of vessels and heavy lift equipment to bring the assets to shore.
- Once on site, **decontamination, and preparation activities**, are required before any steel scrap can be removed.
- In a 12-month project, this could take between 2-3 months.
- Decommissioning companies most often supply scrap to processors who will broker export of the material. However, in some instances, decommissioning companies will themselves broker export of the scrap directly to steel mills in Europe, via short sea.
- Arranging export directly with the steel mill may allow the decommissioner to receive a higher price for the scrap, depending on market conditions.
- The disadvantages of exporting directly include the effect on cashflow (scrap would need to be stockpiled to fill a vessel), the risks of potential rejection if scrap is out of specification, additional administration from export paperwork, and the labour costs required for downsizing the scrap.
- Decommissioners indicate **direct export may become more common** in the future.
- Decommissioning markets and yards are **more mature in other countries**, such as Norway, Denmark, and Spain.
- The UK has **4 to 5 docks** suitable for decommissioning activities, two of which are in Scotland.
- Stakeholders estimated that the UK wins about **10%** of current decommissioning activity as contracts are determined based on lowest cost. However, recent analysis of figures from the North Sea Transition Authority and stakeholder insights by Energy Voice suggests that 26 of the 39 oil and gas assets removed from the UK North Sea between 2018 and 2021 were in fact dismantled in the UK[2].
- Other countries take a more strategic approach and require domestic decommissioning. Stakeholders indicate the Oil and Gas Authority is looking to introduce an equivalent requirement.

1 OEUK Link; 2 Energy Voice Link; all additional insights from stakeholder interviews

Wind turbine decommissioning

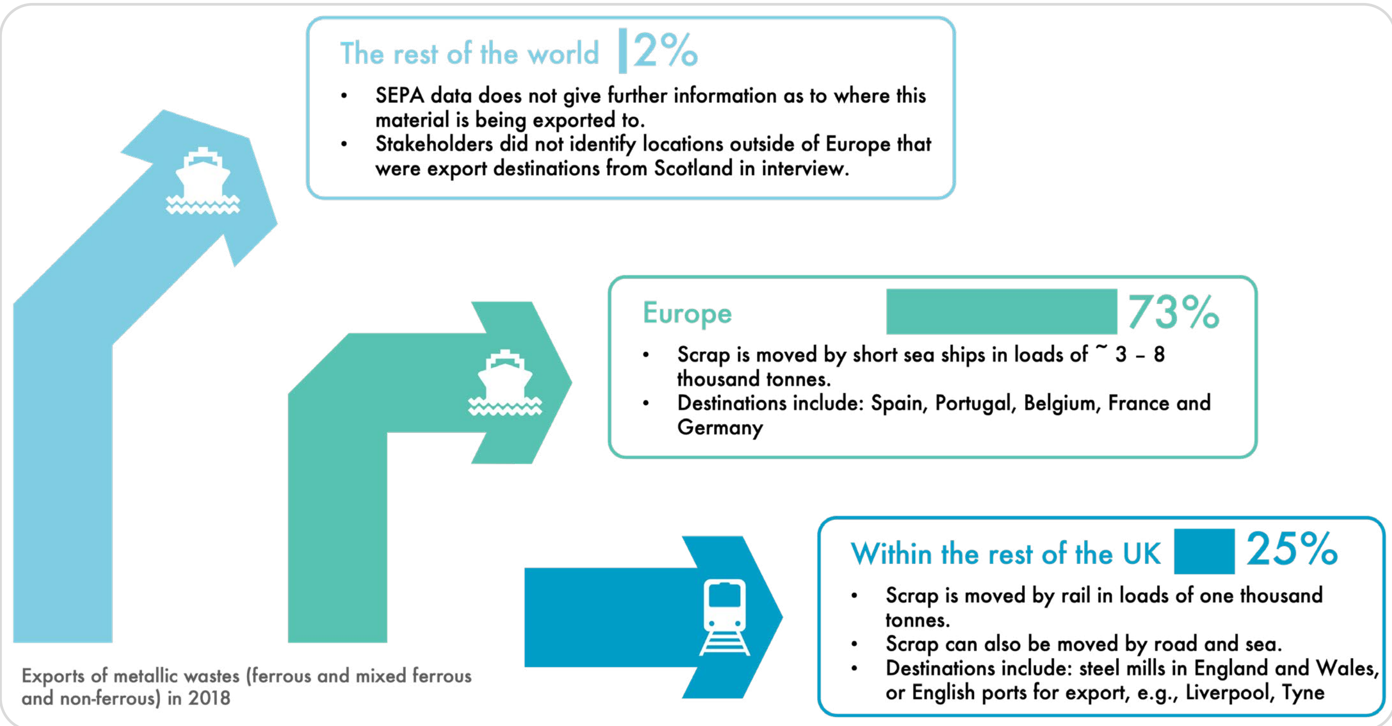
- Wind turbine decommissioning is considered by stakeholders to be an attractive new market for decommissioners and scrap processors.
- Compared to oil and gas decommissioning, stakeholder indicated they anticipated wind turbine decommissioning could have:
- **More consistent assets** – There will be less variation between turbines in structure, design, and materials.
- **A more predictable timeline** – Where decommissioning activities are a precursor to repowering on the same site, operators would want to remove the decommissioned turbines as quickly as possible.
- **Less contamination** – From hydrocarbons, asbestos, and other hazardous materials found in oil and gas assets.

2.7 Where does scrap steel go to be recycled?

SEPA data on waste generation provides some high-level information on the destination of metallic wastes (ferrous and mixed ferrous and non-ferrous). On the assumption that very little, if any, steel scrap would be recycled (i.e., remelting in a furnace) within Scotland[a], we can assume that all steel scrap arisings would be exported for further processing or recycling.

Quarterly waste return data aggregated into annual data by SEPA distinguishes between three categories of export destination: Rest of UK, Europe, and the rest of the world. The figure below shows the breakdown of export destination of metallic wastes in 2018 - note this data may have changed at the time of reading this report. Most of this waste (73%) was exported to Europe, with much of the remaining waste exported to the rest of the UK (25%). Export to the rest of the UK, however, does not necessarily mean that this scrap will enter a furnace in the UK. It may instead be destined for an English port for export. It is not clear where the scrap that is exported to the rest of the world is destined to and via what type of vessel. With the current lack of deep-sea docks in Scotland, we assume this must be short sea, in 3-8

Figure 10: Export destinations for Scottish scrap steel[b], Source: SEPA[22]

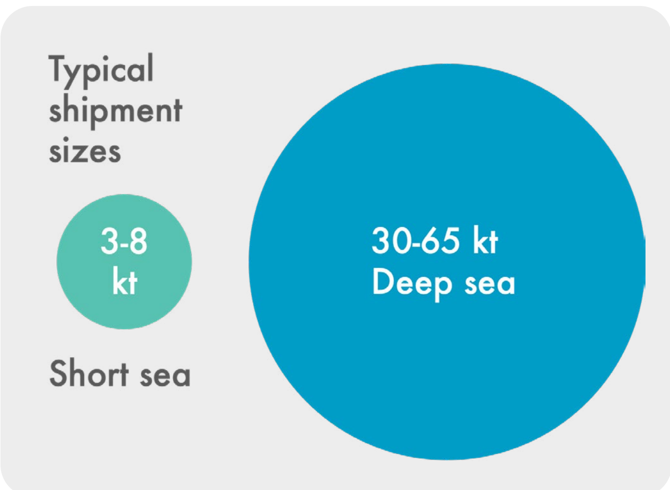


[a] This assumption was validated by stakeholders during interview.

[b] This breakdown is shown as a proportion rather than as tonnages to illustrate the relative size of export streams. Total reported tonnages for export in 2018 (590 kt) are not equal to total waste recycled (623 kt) as SEPA data reports a small volume of domestic recycling (33 kt), We were unable to verify the form of this recycling activity during this study as stakeholders had indicated there is no domestic recycling of steel in Scotland.

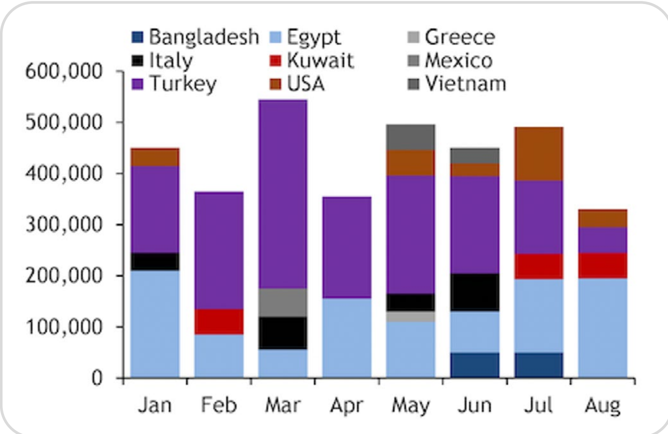
There may be further scrap steel embodied within other waste types (e.g., discarded equipment, discarded vehicles), which could, in part, explain why reported metallic wastes are ~300 kt lower than the population-based upper bound. Additionally, some stakeholders suggested that some waste streams, e.g., end-of-life vehicles, may leave Scotland before being captured in the waste statistics. Under both these scenarios, the difference would likely be exported to the rest of the UK as it is unlikely that large volumes of scrap could be exported overseas without being captured in official statistics.

While most of the scrap steel exported from Scotland is destined for Continental Europe, primarily for use in EAFs, this is largely driven by the focus of current export infrastructure on short sea freight. In contrast, a higher proportion of scrap from the rest of the UK is exported longer distances, a proportion of which is for use in basic oxygen furnaces, due to greater access to deep sea docks.



These docks include Liverpool, and Southampton, and more recently, Avonmouth, Immingham, Sheerness, Tilbury, and Hull[23]. Exports from deep sea docks can be sent to the Far East, the Mediterranean, US, and South Asia, as shown in the figure below.

Figure 11: UK deep-sea ferrous scrap exports 2021 (tonnes). Source: Argus Media[23]



The current assessed differences in export destinations are the only appreciable difference between how scrap steel is processed in Scotland and the rest of the UK as reported during stakeholder interviews.

Stakeholders were able to provide information on a broad range of factors that may influence the decision as to where Scottish scrap is exported to, as shown in the following diagram.

Figure 12: Factors impacting on choice of export destination. Source: Stakeholders interviews

Pricing

- The price offered by a steel mill is the most significant factor in choice of export destination.
- Currency prices may have an influence on the value of an offer for export.

Scrap availability

- The volume and grades of scrap available from the exporter will influence which steel mills will be interested in procuring these materials.
- The demand for scrap from steel mills will be influenced by their production schedules, including what products they want to produce, volumes, downtime, etc.

Logistics

- Export destinations are influenced by the access to freight routes, e.g., rail connections, short sea and deep sea docks.
- Freight availability can also influence export destination - vessel and container availability has been a recent challenge, inline with global shortages.
- Rail freight can be limited by availability of drivers, rolling stock, and route capacity.
- Current freight logistics are aligned with the existing market, which is export-focused.

Customer relationships

- Scrap exporters often have a diverse range of customers they supply to manage variation in their demand.
- These relationships have typically been built over many years, helping build credit surety – i.e., confidence in payment and insurable.

2.8 Summary

- We acknowledge that due to a delay in publication of this report certain data used in the original study may be out-of-date and figures used as part of the analysis will have provided outputs that are now not necessarily representative of the current status.
- The current scrap steel market in Scotland is estimated to be between 620-930 kt, however, the Covid-19 pandemic did depress the market in 2020 and 2021, primarily driven by the decline in manufacturing activity (manufacturing scrap) and new vehicle sales (end-of-life vehicles).

- Between arising and entering a steel mill for recycling, scrap is sorted and consolidated by a network of scrap processors.
- Currently, nearly all scrap is estimated to be exported out of Scotland for recycling with 73% going to Europe. 25% is exported to the rest of the UK, which may then be recycled within UK steel mills, or exported to a range of destinations.
- However, the scrap industry is facing a period of potentially rapid change driven by increasing market competition. These changes could lead to a shift in where Scottish scrap steel is exported to. This competition is driven by factors including: el producers are looking to acquire scrap processors to ensure supply of scrap.

    - Market consolidation – steel producers are looking to acquire scrap processors to ensure supply of scrap.
    - Investment in infrastructure – EMR's deep sea dock development may allow them to offer more competitive prices for scrap, which could lead to a shift to more Scottish steel being exported to destinations currently only accessible via deep sea docks.
    - Market competition – the planned development of large-scale green hydrogen steel projects across Europe will increase the foreign demand for high quality steel scrap.
    - Domestic steel production – interest in developing domestic steel production capabilities (e.g., Ardersier) could create more domestic demand for steel scrap.
- Oil and gas decommissioning will release large volumes of steel scrap into the market over the coming decades; however, it is unclear what proportion of this would reach Scottish ports.

3 Exploring the economic and environmental impacts from steel recycling in Scotland

This section explores the potential economic impacts associated with the operation of an Electric Arc Furnace (EAF) steel recycling facility in Scotland.

Although this study predominantly focuses on the economic case, deciding whether an EAF would be a viable option for Scotland may also be viewed from a strategic point of view. This would be based on the concept that steel that is used in Scotland could be recycled here, rather than exported. In an increasingly uncertain international market this could offer strategic benefits to Scotland in helping reduce its reliance on (often carbon-intensive) imports, e.g., steel from China produced via blast furnace-basic oxygen furnaces. Insights from stakeholder interviews on the current scrap market indicated that other countries, such as Norway, are more likely to take a domestic approach, decommissioning their offshore assets in their own country, which has supported the development of mature decommissioning industries. This demonstrates that a more circular approach to managing Scotland's scrap steel is possible.

3.1 Overview of methodology

This study analyses and assesses three scenarios, with focus given to the different economic impacts and opportunities that could be realised through EAF steel recycling in Scotland. Scenarios 1 and 2 focus on a 300 kt EAF in Scotland, one producing a construction grade product[a] (Scenario 1) and the other producing a high value product[b] (Scenario 2), while Scenario 3 assesses a 1 Mt EAF also producing a construction grade product.

[a] An example of a construction grade product would be carbon steel, which possesses a relatively low price in comparison to other steels and enjoys flexibility of use within a multitude of different construction environments.
[b] An example of a high value product would be stainless steel. Its relatively high price is based on its high corrosion resistance, enhanced ability to function at high and low temperatures as well as its strength and durability.

Proposed scenarios

- Scenario 1 – 300 kt EAF producing a construction grade product (low value)
- Scenario 2 – 300 kt EAF producing a high value product
- Scenario 3 – 1 Mt EAF producing a construction grade product (low value)

Within the study, modelling compares the economic impacts – including employment, GVA and profitability - associated with each of the scenarios outlined. As part of the study an Excel-based economic model was developed, which contains details on the methodology used to calculate all the quantitative results contained within this report. Information is also provided in the model on what sources have been used to derive the input variables as well as explanatory notes on why certain assumptions have been made.

It was deemed unlikely that a domestic steel plant producing 1 million tonnes of a 'high value' product each year would have a large enough market domestically in which to sell its product into - due in part simply to the size of the domestic market and the fierce international competition a high value product would face. Modelling this scenario presents additional challenges as it would need to assume that some of the excess product is exported, which adds other considerations e.g., ease of access to international markets, local regulations/taxes, import duties etc. It was therefore decided not to model this scenario and to focus only on assessing the three scenarios already outlined.

The first step of the economic modelling involved desk-based research, which helped identify the various cost categories that would need to be incorporated into the assessment. Further research was then carried out into how best to monetise these costs – with costings largely based on publicly available information and from making assumptions based on expert input on similar EAF projects in Europe and North America. The analysis draws upon Scottish economic data as much as possible to ensure the model itself is as representative and applicable to the Scottish economy as possible. The modelling focuses solely on the EAF operation and does not include a full cost analysis of the supply chains involved. Economic impacts within the supply chains are however recognised via the use of Scottish government multipliers (discussed in the sections entitled 'Employment impacts' and 'Gross Value Added to the Scottish economy').

Locational factors were outside the scope of the cost modelling as it was not possible to identify an exact site for a potential plant. Locational considerations are also inherently difficult to monetise, due in part to a lack of region-specific data and the lack of an implicit financial cost associated with many of the factors. Other factors such as how the plant would be powered e.g., via hydrogen power, hydro-electric power etc., was also out of scope, with the report focusing predominantly on the economic impacts of an EAF rather than any potential carbon benefits.

We recognise the growing momentum of hydrogen direct reduced iron (DRI) as a potential route of also producing low-carbon ('green') steel alongside an EAF. This technology is however out of scope for this research as hydrogen DRI is a method for producing primary, or 'virgin', steel, whereas an EAF focuses solely on secondary, 'scrap', steel. Zero Waste Scotland however recognises the significant potential environmental benefit associated with hydrogen DRI, and this more nascent technology may well feature in future research in this area.

3.2 Location of a new EAF

Although not quantified, it was important to recognise and acknowledge the locational factors that would likely influence an investor's decision when identifying a suitable location for a new EAF plant. Through desk-based research a multitude of locational factors were identified (as bulleted below). Each of them is pertinent to understand given they are likely to be crucial factors in deciding whether an EAF is a viable proposition or not.

- Proximity to scrap steel sources and transport links
    - Access to major trunk roads will ensure transportation costs are minimised as far as possible. It is likely that transporting scrap steel by road is only economically viable up to 100 miles, therefore it would be advantageous if major scrap producers fell within this radius. Previous modelling has shown transport factors to have the greatest impact on the cost of steel, out of the parameters investigated[24].
    - Currently, under Scenario 3 i.e., a 1 Mt plant, Scotland does not possess enough scrap steel domestically to feed the site. Therefore, proximity to a port with good road and rail links may be necessary to import additional steel that may be required. Currently approximately 620-930kt p.a. of scrap steel is available in Scotland, as per 2018/2019 data. Therefore, even under the assumption that 100% is retained domestically there would still be a shortfall. This would be further exacerbated if some of that steel is re-used rather than supplied to domestic facilities for recycling. However, changes to steel scrap arising from decommissioning activities could change this position, as explored in section 4 of this report.
- Proximity to labour markets/ skilled workforce
    - The employment impacts associated with a 300 kt and 1 Mt plant are discussed in detail in the Section entitled 'Employment impacts'. Job creation because of an EAF plant is expected to be significant (650+) therefore proximity to population centres is important to provide adequate skilled staffing for the plant.
- Proximity to a suitable electricity grid
    - Due to the sheer scale of electricity that would be required to operate an EAF, proximity to a stable and reliable source of power is vital to minimise costs and ensure the plant is adequately serviced. Ideally, access to a 275 kV or 400 kV grid network would be advantageous to ensure lower connection costs and stable supply. This will ensure minimal impacts on the grid when operating at peak load (particularly relevant when considering the 1 Mt plant).
    - There is scope for an EAF operator to consider negotiation with electricity generators to build a 'direct line' of electricity supply to the plant. The greatest carbon benefit would come from renewable sources, but issues of intermittent supply would need to be mitigated against through methods such as storage and diversification of generation methods[25].

3.3 Employment impacts

Economy-wide employment impacts in this report have been estimated using employment multipliers. These consider how changes in output or employment within a particular industry translate into additional employment in the wider economy. For example, a steel industry multiplier of 2 would suggest that for every direct steel job created in Scotland one further job is created within the wider economy. There are two types of multipliers used in the analysis, described below:

- **Type I multiplier** – which calculates direct and indirect employment impacts (at 1.5)
- **Type II multiplier** – which calculates direct, indirect[a], and induced[b] employment impacts (at 1.9)

The job impacts within this study draw upon the employment multipliers set out in the Scottish Governments Supply, Use and Input-Output Tables[26]. Further multipliers, calculated by Oxford Economics for use in the EU, and by the ONS for the UK government were evaluated; however, both were deemed unrepresentative for Scotland due to the greater share of steel in the European and rest of the UK economy (in comparison to Scotland) as well as general differences in the composition of other national economies.

These multipliers have been used to calculate the number of additional jobs that would be created – either within upstream or downstream industries, as well as within the wider economy – because of an EAF investment in Scotland. The modelling assumes that the production of construction grade steel (low value) and high value steel are similarly labour intensive, and as a result the employment impacts remain the same regardless

[a] Indirect jobs are estimated to be created though the wider supply chain associated with steel production, such as raw materials, transport, electricity generation, and repair and maintenance of equipment.
[b] Induced jobs are jobs estimated to be created through the spending of employees in shops, services, and other businesses within the economy.

of the grade being produced. Direct employment is estimated by benchmarking employment information at other EAFs (in Europe and North America[a]), which is then scaled based on the two plant capacities - the 300 kt (Scenario 1 & 2) and 1 Mt (Scenario 3).

To calculate employment levels for a hypothetical 300 kt and 1 Mt plant, CELSA's plant in Cardiff and Big River's plant in Arkansas[27] were used as a baseline for analysis, both of which have production capacities of over 1 Mt per annum. In modelling the 300 kt plant it was not appropriate to directly scale down employee numbers in parallel with output, as that would not consider the fact that smaller plants need marginally more workers than larger plants i.e., due to economies of scale. Therefore, a diseconomies of scale factor was used to ensure employee numbers decrease at a relatively slower rate than production, i.e., a 300 kt plant has a higher employee/steel-production ratio compared to a 1 Mt plant.

From the modelling, it was calculated that a 300 kt plant would require around 350 employees, with a 1 Mt plant requiring 493 people[b]. Table 4 below presents these employment impacts. It is expected that a 300 kt and 1 Mt plant would stimulate the creation in total of approximately 665 and 937 total jobs respectively - either directly at the plant or within the wider Scottish economy.

Table 4: **Employment impacts resulting from a 300 Kt and 1 Mt EAF plant**

Plant size (Scenario)	Direct Scottish EAF employment	Indirect jobs created - Type I	Induced jobs created	Total jobs (Direct, indirect, and induced) - Type II
300 kt (Scenario 1 & 2)	350	175	140	665
1 Mt (Scenario 3)	493	247	197	937

[a] Only EAF plants located in Europe and North America were considered due to the more capital-intensive nature of plants here relative to places such as Asia, where employment levels tend to be higher due to the lower cost of labour. Employment levels in capital-intensive economies are likely to better reflect the potential employment impacts of a plant located in Scotland.

[b] Calculated using the same employee/steel production ratio as CELSA and Big River.

It is worth noting that employment impacts can vary significantly depending on the multipliers used. If Oxford Economics' EU employment multipliers were used, total economy-wide job creation for a 300 kt plant is estimated to be anywhere between 2,030 and 2,750, and between 2,650 and 3,620 for a 1 Mt plant. These figures are likely optimistic, but it is worth considering that job creation could be greater than those implied by the Scottish government multipliers if steel production were to become a more integral and sizeable part of the Scottish economy – which are generally lower in comparison to most other steel multipliers used in Europe and North America.

Table 5 below presents the annual income tax and national insurance receipts that could be received by the government based on the employment numbers presented in Table 4.

Table 5: Employee tax receipts garnered (Income tax & National Insurance) Table note: Estimates are based on an average Scottish steel worker salary of £35,196 and median Scottish salary of £26,260[28].

Plant size (Scenario)	Direct employees	Indirect and induced employees	Total
300 kt (Scenario 1 & 2)	£2.6 M	£1.5 M	£4.1 M
1 Mt (Scenario 3)	£3.7 M	£2.1 M	£5.8 M

3.4 Social impacts

Apart from the direct economic impacts, an EAF steel recycling plant might also have effects on people and the community. Such social impacts can take multiple forms including displacement effects, distributional impacts as well as factors such as the development of human capital within the local population.

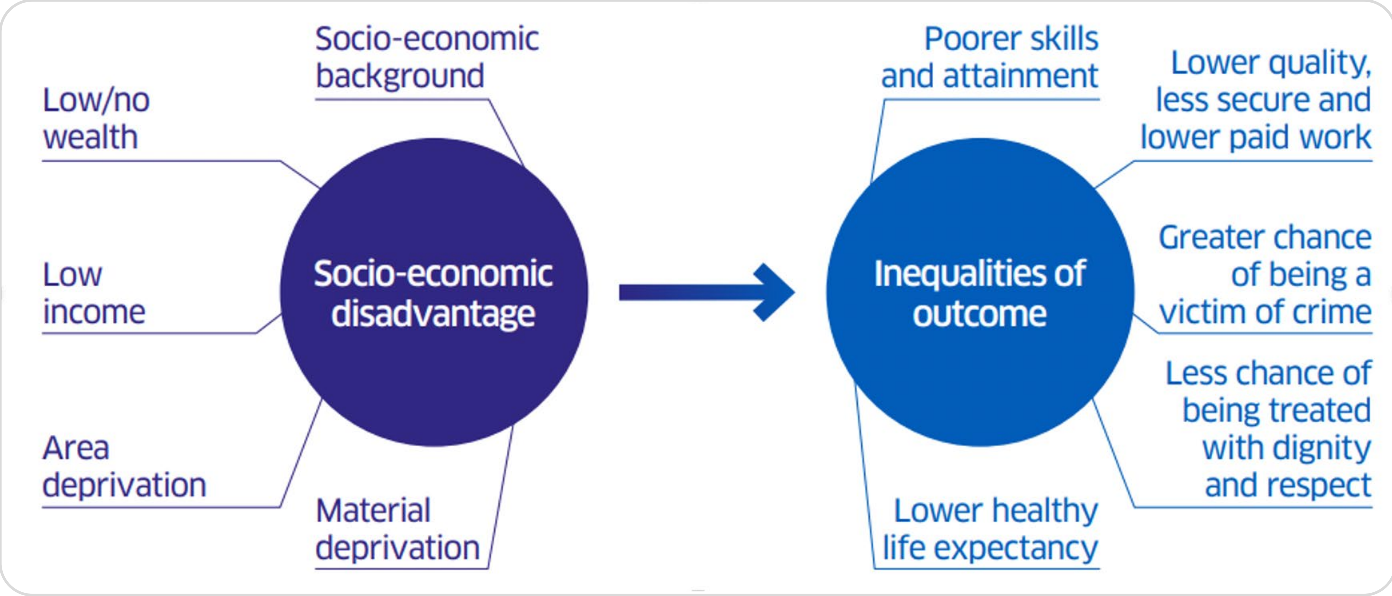
Consideration into displacement effects should be taken when reviewing the employment impacts presented in scenarios evaluated in the economic analysis paper.
By constructing a new EAF, it is not necessarily the case that all the jobs associated with the plant are new (and did not previously exist). The EAF could simply be displacing jobs from one location to another. It is important to consider other industries this investment could affect to ensure the analysis is only discussing the creation of new jobs and not double counting jobs that already existed pre-investment. However, EAF steel recycling facilities do not currently exist in Scotland and therefore displacement is less likely to occur.

There may be some displacement effects within the steel exporting business, with jobs lost because of steel being retained for domestic recycling instead of being exported. However, these are expected to be minimal as companies could shift their export of scrap steel towards supplying domestic recyclers instead. There could potentially be positive displacement effects if carbon-intensive industries, such as oil and gas, lay off workers during their decommissioning process and these workers then move sector to take up jobs in steel production. However, this assumption does not take into consideration that individuals' skill sets are not necessarily easily transferable across industries and rarely is it as simple as simply shifting employment from one sector to another. With the current lack of steel production in Scotland, it is unlikely that the skills required to run an EAF would be found within the workforce, necessitating investment in upskilling and training.

Structural changes to the labour market could be supported under the Scottish governments Climate Emergency Skills Action Plan (CESAP) via the 'Just Transition' mechanism whereby support will be made available for industries detrimentally impacted by the transition to net zero. Most likely though, job losses are to be witnessed in scrap metal recipient countries, and perhaps a very limited number in Scottish ports. However, they are deemed to be minimal (or outside the geographic scope of this project) and therefore did not justify an impact assessment within the economic analysis.

Distributional impacts may also feature in any financing decision when looking into whether to support investment into Scottish EAF facilities. Distributional effects focus on how decisions impact different groups of people within the economy. Often decisions that positively impact more marginalised groups, or areas of higher deprivation, will be given a higher weighting when monetising the economic impacts associated with the project. This is the backbone of the UK Government's 'levelling-up agenda', whereby areas of socio-economic disadvantage will be prioritised for public investment. In Scotland, criteria that would be considered in carrying out an assessment into such a project falls under the Fairer Scotland Duty and the Equalities Impact Assessment (EQIA). The Fairer Scotland Duty places a legal responsibility on public bodies in Scotland to actively consider how they can reduce inequalities of outcome caused by socio-economic disadvantage, when making strategic decisions. Some of the bodies covered by this duty include the Scottish National Investment Bank as well as development agencies such as Scottish Enterprise, Highlands, and Islands Enterprise (HIE) and South of Scotland Enterprise. The criteria in which this decision making is based is shown in Figure 13.

Figure 13: **Criteria of Socio-economic disadvantage and inequalities of outcome decision making**
Source: Scottish Government[29]



Despite this, positive distributional impacts are only likely to be considered when investing in an EAF if public bodies are financing the project. Private sector companies are less likely in the current economic conditions to consider this in their analysis and are more likely to prioritise the most profitable area in which to invest. However, this may change in the future if there is a shift to a stronger focus on the wellbeing economy.

An EAF plant could provide opportunities to those from disadvantaged backgrounds to upskill and develop their human capital, which then has knock on effects within the local economy as earned income is spent in other local businesses i.e., the multiplier effect. This analysis has not sought to assess the quality of jobs created; this would require consideration in the future.

3.5 Gross Value Added to the Scottish economy

Gross value added is a measure of economic productivity defined in the context of the steel industry as the value added/generated by a unit engaged in the production of goods and services (steel). It can be calculated as the revenues from selling the recycled steel minus the cost of raw materials, energy, and other inputs.

In this analysis, GVA is calculated based on the 'Micro Firm Level' approach, as set out in 'A Guide to Gross Value Added (GVA) in Scotland'[30]. This calculation draws its estimates from the hypothetical EAF cost model that is presented in the accompanying Excel spreadsheet. The formula used for Gross Value Added is
presented below.

GVA = Turnover (or sales) less the cost of bought in goods & services (excl. employee costs)

Table 7 below provides estimates for low and high value steel production at a 300 kt plant, and a lower value product at a production capacity of 1 Mt. In producing a higher grade of steel, the modelling assumes - based on discussions and best estimates - that CAPEX costs are 25% higher (due to the additional equipment required), energy/ electricity costs are 50% greater (due to the more energy-intensive nature of the process) and that maintenance costs are 25% higher.

All other costs are likely to remain the same as when producing construction grade steel. GVA for each scenario has been calculated for a 10-year and 20-year period and then discounted to illustrate the value in present day terms to reflect the time preference of money.

GVA using this approach is inherently uncertain due to the fluctuating value of many of the input variables and assumptions (which are tested in the Sensitivity Analysis section). Nevertheless, based on the best available data and using average figures as much as possible, GVA results are presented in Table 6 and Table 7 below.

Table 6: GVA to the Scottish economy by scenario

Plant Capacity	Direct GVA (£m)	Indirect GVA – Type I (£m)	Induced GVA - Type II (£m)	Total GVA (Direct, Indirect, and Induced) (£m)
300 kt – Construction grade (Scenario 1)	4.6	2.7	1.8	9.1
300 kt – High value (Scenario 2)	194.7	116.8	77.9	389.4
1 Mt – Construction grade (Scenario 3)	91.9	55.2	36.7	183.9

Table notes: 1. Assumes a market price of £750 per tonne for construction steel and £1,500 per tonne for 'high value' steel.

Table 7: GVA to the Scottish economy by Scenario

Plant Capacity	GVA (2022) (£m)	GVA (10-year period: 2022 – 2032) - Discounted (£m)	GVA (20-year period: 2022 – 2042) - Discounted (£m)
300 kt – Construction grade (Scenario 1)	4.6	38.4	60.8
300 kt – High value (Scenario 2)	194.7	1,640	2,600
1 Mt – Construction grade (Scenario 3)	91.9	774.5	1,227

Table notes: 1. Assumes a market price of £750 per tonne for construction steel and £1,500 per tonne for 'high value' steel. 2. GVA discounted at 3.5% as per UK Government Greenbook guidance.

The GVA associated with Scenario 2 is considerably higher than those under Scenario 1 and 3, largely because many of the operational costs under Scenario 2 do not increase at the same proportionate rate in which revenue does i.e., the profit margin is considerably better under Scenario 2 than Scenario 1 and 3. We note that there would almost certainly be strong domestic demand for construction grade steel (low value) within Scotland and exporting outside the UK would not be necessary. There is likely to be lower domestic demand for a high value product, like stainless steel, which means exporting the product could be required. This could add additional complications and costs to any potential business model (although for the sake of simplicity the model assumes domestic consumption can meet the 300 kt production). Monetising the carbon impacts associated with an EAF in Scotland was out of scope for this analysis as this is a microeconomic business case assessment rather than a macroeconomic assessment of effects felt by all actors in the economy. Therefore, when assessing the impacts solely under economic criteria, Scenario 2 GVA is considerably higher than GVA under Scenario 1 or 3.

We note an alternative approach to calculating Gross Value Added is on a GVA per full time employee (FTE) basis. As GVA data specific to Scotland are not available, this approach would rely on using an average GVA per UK steel worker and estimates of direct employment figures to calculate total GVA rather than taking into account differences in the balance of costs and revenue between each scenario. Given this, modelling GVA based on the micro firm level approach rather than employment was the most appropriate approach.

3.6 The components of an EAF in Scotland

Table 8 below provides an overview of the costings involved in the construction and running of an EAF plant in Scotland. These categories have had costings applied to them to model the three different scenarios, as well as to test the impact changes to input values have on overall profitability and GVA within the economy as part of the sensitivity analysis (section 3.6.1).

It is worth noting that overall capital investment costs have not been included as a share of total costs as we assume that these will be repaid annually in the form of a business loan with interest added.

Table 8: **Costings involved in an EAF**

Category	Sub-category	Scenario 1 % Share of total costs	Scenario 2 % Share of total costs	Scenario 3 % Share of total costs
Investment costs	Capital expenditure for EAF plus basic downstream processing	-	-	-
Loan repayments/ cost of capital	Yearly repayments on the capital expenditure loan	17.9%	20%	17%
Operational costs	Land rental costs EAF electricity costs Energy costs downstream processes Labour costs Maintenance / Support costs Scrap steel (raw material) Other raw materials (coal, consumables)	44%	47%	40%
Raw material costs	Carbon taxes	35%	30%	40%
Taxation	Other taxes	3%	3%	4%
Revenue	Market value of final steel product	-	-	-

3.6.1 Sensitivity analysis

A sensitivity analysis determines how fluctuations in input variables affect the overall results of a model. In other words, sensitivity analyses focus on how various sources of uncertainty into the model contribute to the model's overall uncertainty. In the case of the EAF modelling, three input variables were identified as the most uncertain and subject to the greatest change over the past 5 years. These are: electricity prices, scrap steel prices, and the market price for finished steel products.

Table 9 illustrates the potential profitability that could be realised under each of the three modelled scenarios. Under the baseline parameters i.e., electricity prices, scrap steel costs and market steel prices, it appears that a 300 kt plant producing a construction grade product would not be profitable in Scotland, whereas both Scenarios 2 and 3 would be profitable. It should be noted that the level of profitability is quite uncertain and is further tested in the sensitivity analysis (Table 10).

Table 9: **Profitability of each EAF site (under baseline assumptions),**
Table note: Profitability based on a low value steel price of £750 per tonne and a high value price of £1,500 per tonne.

Site	Profitability (£m)
300 kt – Construction grade (Scenario 1)	~(-15.7)
300 kt – High value (Scenario 2)	~174.4
1 Mt – Construction grade (Scenario 3)	~48

Table note: Profitability based on a low value steel price of £750 per tonne and a high value price of £1,500 per tonne.

Table 10 sets out the baseline position that has been used when deriving the GVA and profitability figures for each scenario, which is then tested under the table sub-headings 'Sensitivity Analysis Results'. Each variable has been tested based on either market changes that have occurred over the past few years e.g., changes in electricity prices, or based on discussions that were had during the stakeholder interview process carried out in the first part of this study, e.g., price arrangements with electricity suppliers. These variables have been tested independently, as well as simultaneously, to help illustrate as large a variety of possible market fluctuations as possible. Figure 14 plots the percentage change in profitability because of the independent variable changes within the sensitivity analysis.

Table 10: Sensitivity testing – All Scenarios

Electricity cost (£/MWh)	Scrap steel price (£/tonne)	Market price for final product	Profitability (£ millions)			GVA (£ millions)		
			300 kt (Scenario 1)	300 kt (Scenario 2)	1 Mt (Scenario 3)	300 kt (Scenario 1)	300 kt (Scenario 2)	1 Mt (Scenario 3)
Baseline								
89.6 (Based on average price between 2017-21)	147.9 (Weighted price average over period 2018-2021)	750 (Assumed price of lower value product - Scenario 1 & 3)						
		1,500 (Assumed price of higher value product – Scenario 2)	-15.7 (Change from baseline)	174.4 (Change from baseline)	48.0 (Change from baseline)	4.6	194.7	91.9
Sensitivity Analysis Results – independent variable changes								
300% 269 (Late 2021 electricity prices)	-	-	-82.0 -421% (Increased loss)	75.0 -57% (Decreased profitability)	-173.0 –460% (From profit to loss)	-61.7 -1455%	95.3 -51%	-129.0 -240%
-25% 67 (Electricity price arrangement with supplier)	-	-	-7.3 54% (Decreased loss)	187.0 7% (Increased profitability)	75.8 58% (Increased profitability)	12.9 183%	207.2 6%	119.8 30%
-	50% 222 (Approximate average of scrap steel prices in 2021)	-	-42.4 -170% (Increased loss)	147.8 -15% (Reduced profitability)	-40.9 -185% (From profit to loss)	-22.1 -585%	168.0 14%	3.0 18%
-	-50% 74 (Approximate average of scrap steel prices in 2018)	-	10.9 169% (From loss to profit)	201.0 15% (Increased profitability)	136.7 185% (Increased profitability)	31.2 585%	221.3 14%	108.4 18%
		–50% 375 (low value) 750 (high value) (Price in 2019 for a tonne of hot rolled coil)	96.8 715% (From loss to profit)	399.4 129% (Increased profitability)	423.0 781% (Increased profitability)	117.1 2470%	419.7 116%	466.9 408%

Table 10: Sensitivity testing – All Scenarios Continued

50% 1,125 (low value) 2,250 (high value) (Current trajectory of steel over next year)	96.8 715% (From loss to profit)	399.4 129% (Increased profitability)	423.0 781% (Increased profitability)	423.0 781% (Increased profitability)	117.1 2470%	419.7 116%	466.9 408%

Sensitivity Analysis results – simultaneous variable changes

-	50% (approximate average of scrap steel prices in 2021	50% (Current trajectory of steel over next year)	70.1 546% (From loss to profit)	372.8 114% (Increased profitability)	334.1 596% (Increased profitability)	90.4 1884%	393.0 102%	378.0 311%
-	-50% (Approximate average of scrap steel prices in 2018)	-50% (Price in 2019 for a tonne of hot rolled coil)	-99.1 -530% (Increased loss)	-21.4 -112% (From profit to loss)	-230.0 -579% (From profit to loss)	-78.8 -1829%	-1.2 -101%	-186.0 -302%
300% (Late 2021 electricity prices)	50% (approximate average of scrap steel prices in 2021	50% (Current trajectory of steel over next year)	3.8 124% (From loss to profit)	273.3 57% (Increased profitability)	113.1 136% (Increased profitability)	24.1 429%	293.6 51%	157.0 71%
-25% (Electricity price arrangement with supplier)	-50% (Approximate average of scrap steel prices in 2018)	-50% (Price in 2019 for a tonne of hot rolled coil)	-93.3 -493% (Increased loss)	-11.4 -107% (From profit to loss)	-210.5 -538% (From profit to loss)	-73.0 -1702%	-8.9 -105%	-166.5 -281%

The overarching takeaway from the above sensitivity analysis is that both profitability and gross value added to the Scottish economy are highly sensitive to changing market conditions (input variables). The significant electricity price fluctuations that have been witnessed– and the importance of electricity to the overall EAF process – mean that any changes to this cost results in very significant changes to the modelled economic impacts. Furthermore, the analysis suggests that based on the most recent price of electricity (late 2021 prices) the economic viability of any potential EAF (under all 3 scenarios) would be under pressure[a]. Scrap steel price variations appear to impact total impacts the least, although they have exhibited significant price fluctuations over recent years. Scenario 3 appears the most susceptible to changes in input variables, witnessing the highest changes to profitability. Scenario 2 on the other hand appears to be the most resilient to market changes, remaining profitable under several of the sensitivity changes in which Scenario 1 and 3 do not.

Many of the factors determining these cost fluctuations are outside the control of a private sector company i.e., exogenous variables, which suggests that there may be a need for regulatory and policies changes to stabilise the EAF investment environment. This could come via factors such as subsidised electricity costs, or public/private financial agreements to help provide investors with certainty and improve their ability to hedge against market fluctuations (this is further discussed in section 3.11).

[a] Since this analysis was conducted, electricity prices have experienced even greater changes. This is further explored in section 3.8. 45

3.7 Green steel market

The global market for green steel products has been growing at a rapid rate, especially in Europe, as the competition to transition energy-intensive industries such as steelmaking to net zero intensifies. The current and future growth of the market is being driven forward by three main forces: Government policy, industrial investment, and consumer demand. Traditional market forces, based solely on global export markets operating at lowest cost, are quickly becoming replaced by those which more reflect the environmental costs of production.

Looking to the EU, comprising 47% of all international exports from Scotland[31], the EU Commission has enacted, or is soon to enact, a range of ambitious policies aimed at reducing the carbon content of steel production and imports. These include:

- A ban on scrap exports from within the EU to non-OECD countries which do not meet EU processing standards[32].
- A carbon border adjustment, making imports of carbon-intensive steel to the EU, more expensive[33].
- An extension of the Ecodesign Directive may include recycled content requirements for products, including intermediate products, such as steel[34].
- Product Environment Footprint (PEF) standards on carbon disclosure methodologies for a range of products[34].

These indicative policies make the likely future direction of travel clear – carbon-intensive steel products are set to become more expensive relative to their low-carbon counterparts. Inter-governmental deals are also becoming a key driver of financing steel decarbonisation. At COP26, several countries committed to support new markets for low carbon steel through pledging to achieve net-zero in major public construction projects using steel by 2050.

Government policy such as this, whilst primarily motivated by necessary climate change commitments, are also partly a response to growing consumer demand for products and services which do not contribute towards climate change, among other environmental issues.

The root cause of this growing demand for green steel is difficult to isolate and is likely multifaceted with government policy playing its own role. It can, however, be seen to be manifested in the growing share of green steel being used for consumer and industrial products such as automotives, construction, and ‘white goods’ industries.

There are many excellent examples of major European steelmakers transitioning towards green steelmaking in the coming decades:

- Europe's largest steel producer ArcelorMittal started to offer its first green steel solutions to customers in 2020 and will continue to scale up its offering in 2022 as it aims to deliver a 30% CO_2 emissions reduction by 2030 and achieve net-zero by 2050[35].

- Swedish steelmakers SSAB and LKAB and utility Vattenfall created Hybrit (Hydrogen Breakthrough Ironmaking Technology) in 2016 with the goal of developing a technology for fossil-free iron and steelmaking. The project produced its first steel in late 2021 and aims to be supplying the market with zero-carbon steel at a commercial scale by 2026, after the conversion of SSAB's Oxelösund BFs into an EAF[18].

- The H2 Green steel, or H2GS, project will see the construction of a greenfield steel plant in northern Sweden, including a green hydrogen plant as an integrated part of the steel production facility. Production is planned to start in 2024 and rise to 5 million Mt/year of high-quality steel by 2030. Companies which have signed supply arrangements for steel with H2 Green Steel include Adient, BE Group, BILSTEIN GROUP, BMW Group, Electrolux, Kingspan, Klöckner & Co, Lindab, Marcegaglia, Mercedes-Benz, Miele, Mubea, Purmo Group, Roba Metals, Scania, Schaeffler, Zekelman Industries and ZF Group[17].

- In October 2021, German steel stockholder Klöckner signed a distribution deal with H2GS to distribute up to 250,000 Mt/year of green steel from 2025 to meet the expectations of customers pressing for a lower emissions supply chain[36].

For many of these steel producers embracing green steel, the actual demand for the products has exceeded initial expectations and is coming from a broad range of industries[37]. This demonstrates that green steel technologies are economically viable, with customers willing to pay a premium price for products which have a reduced carbon footprint. Indeed, many customers which are themselves businesses have signed up for science-based environmental targets which cover Scope 3 emissions – those involving the sourcing of raw materials.

3.8 Electricity prices

Some cost drivers are shared between conventional and EAF steel production, such as labour and iron ore, but, crucially, the energy inputs are completely different – fossil fuels and electricity. As the cost of renewable energy continues to plummet whilst the cost of using fossil fuels rise, the relative competitive landscape for steelmaking could be significantly impacted in favour of EAF steelmaking.

An EAF operating in Scotland could utilise the UK National Grid, and therefore the prices set by the UK electricity market. Global energy prices, and indeed those in the UK, have seen significant fluctuations in recent years, influenced mainly the demand-side factor of the COVID-19 pandemic and the supply-side factor of the ongoing war in Ukraine, both pulling energy prices in opposite directions. The prevailing trend however has been upward. This is shown below in Figure 15 and Figure 16, with average electricity prices over the past ten years and six months, respectively.

As can be seen, for much of the past ten years electricity prices remained remarkably stable but have significantly increased and fluctuated in the past two years alone (Figure 15). Significant variation can also be seen in the last six months, reaching an all-time high of about £600/MWh in August 2022 (Figure 16).

Figure 15: Monthly UK electricity prices, Source: Trading Economics[38]

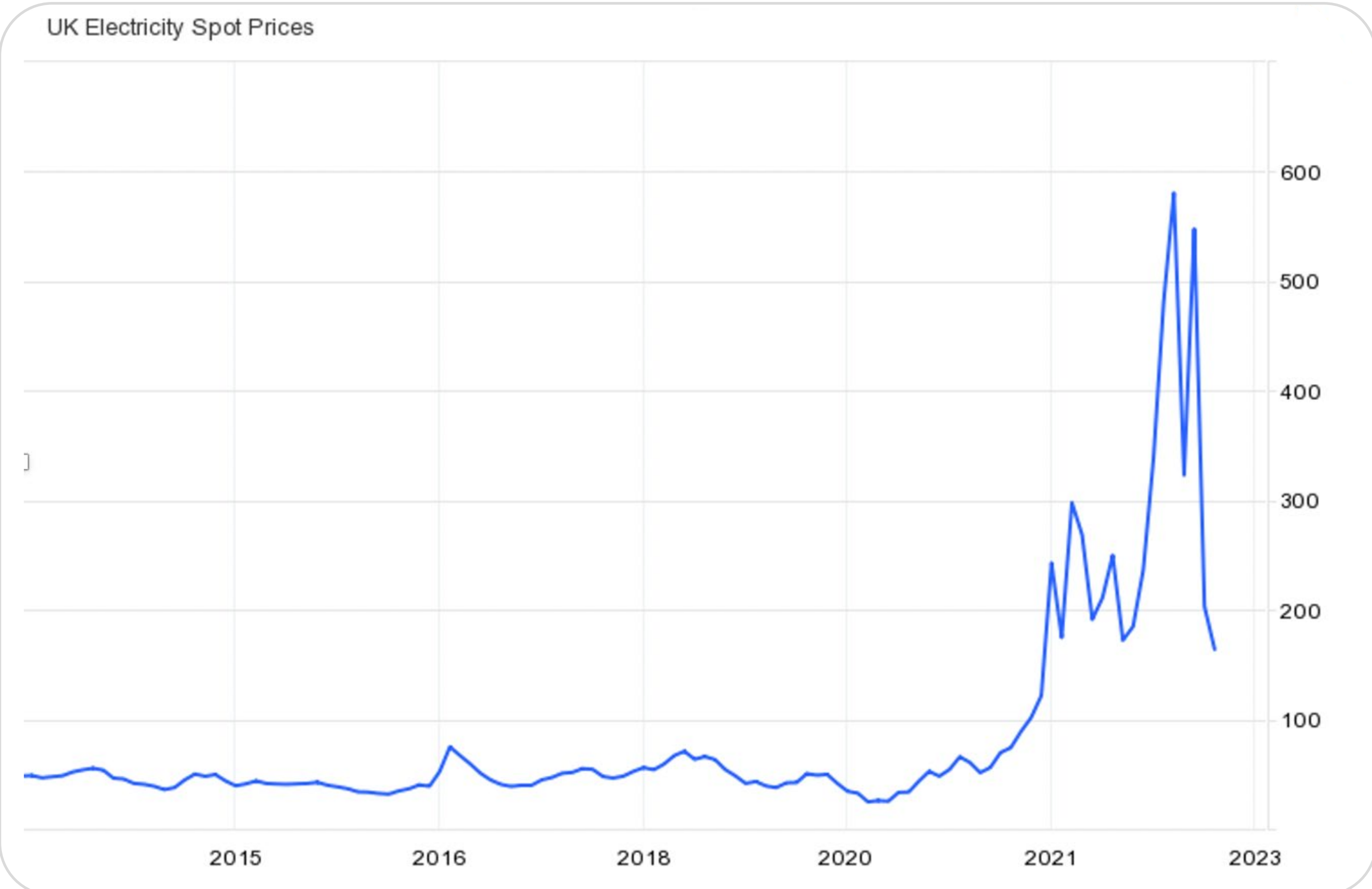
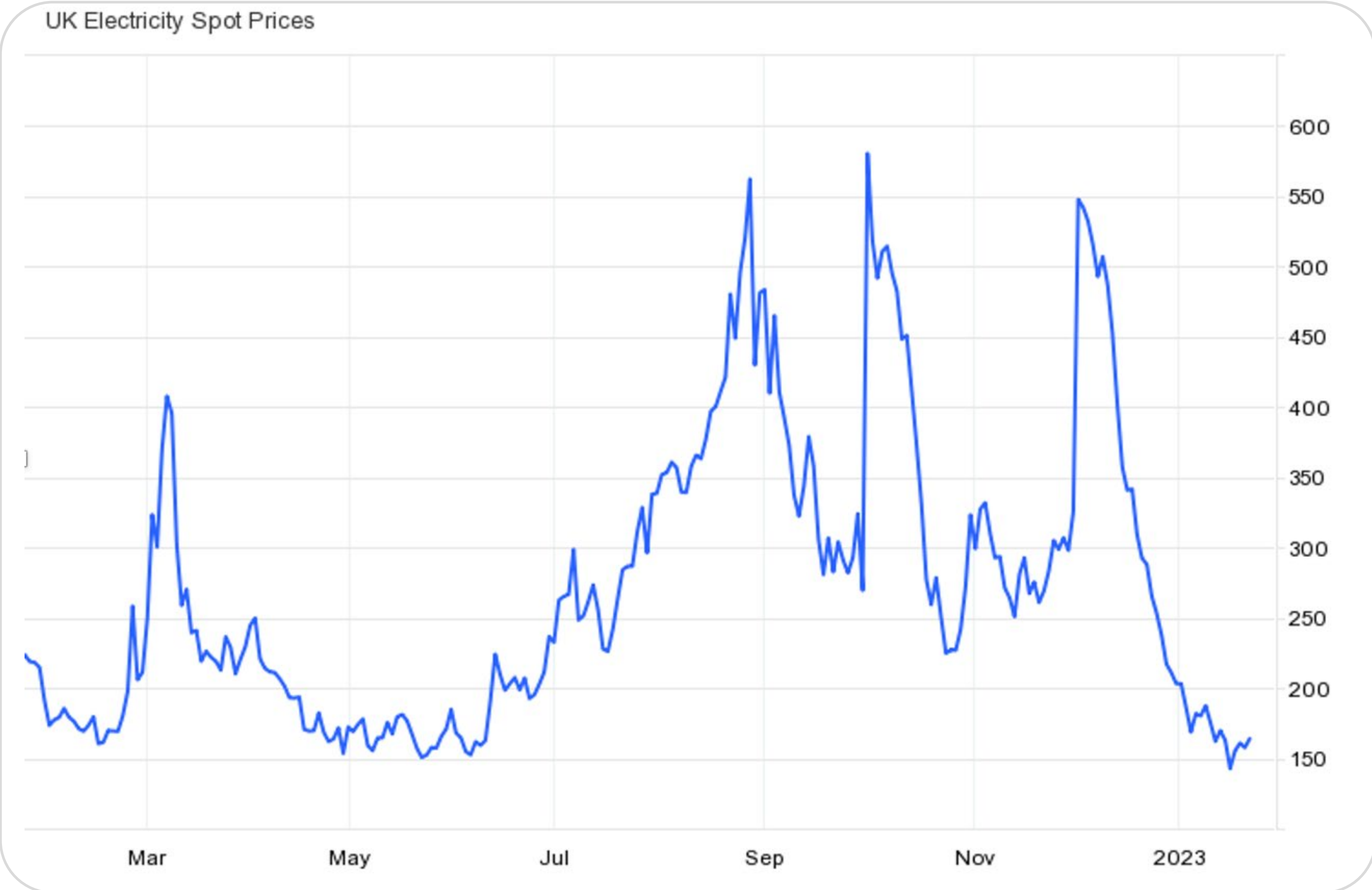


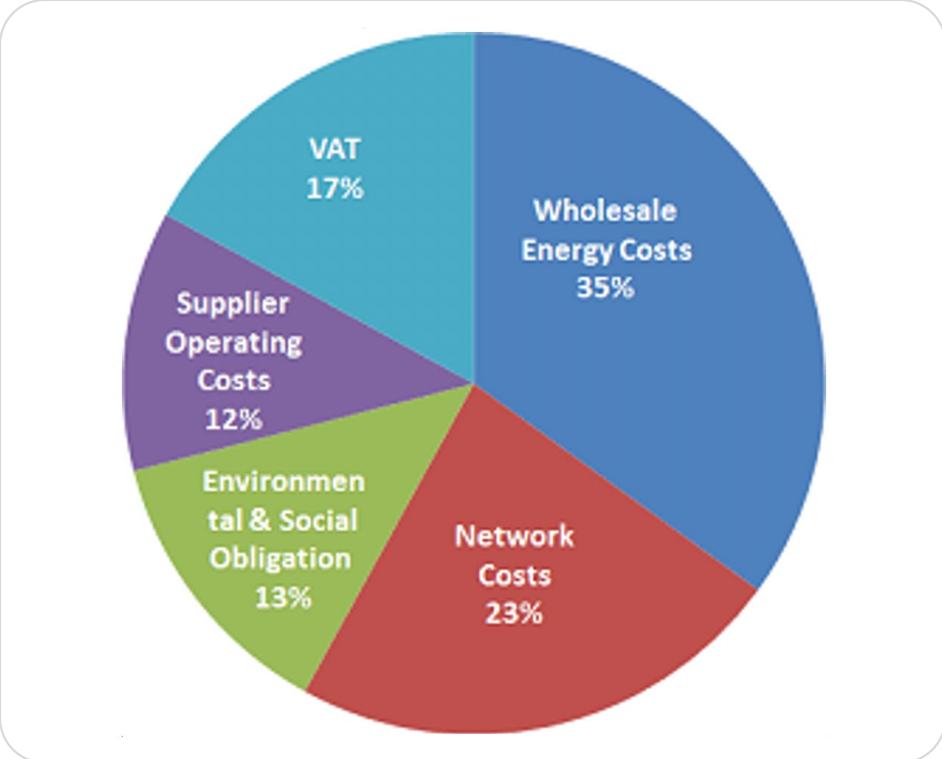
Figure 16: **Daily UK electricity prices - Last 6 months Source: Trading Economics[38]**



Given these ever-changing market conditions, it is difficult to determine with any sort of certainty what electricity price an EAF would be likely to pay over its lifetime. It is very clear however that the UK electricity market is very exposed to many factors out with the control of domestic production and policy.

This is because the price that is paid for electricity in the UK is, in part, fixed at the marginal price of gas, which itself is fixed at the price of the international markets it is traded on. The reason for this is that the price paid for electricity is set by the marginal generation unit; whichever type of power source meets the peak demand. Most of the time this is going to be gas power as it can be easily used to flex supply to meet demand. So, while the cost of domestic production of renewable energy has been plummeting for years, this often has no effect on the price of electricity bought and sold on the market. A detailed breakdown of the constituent parts of a typical UK business energy bill are shown below in Figure 17[39].

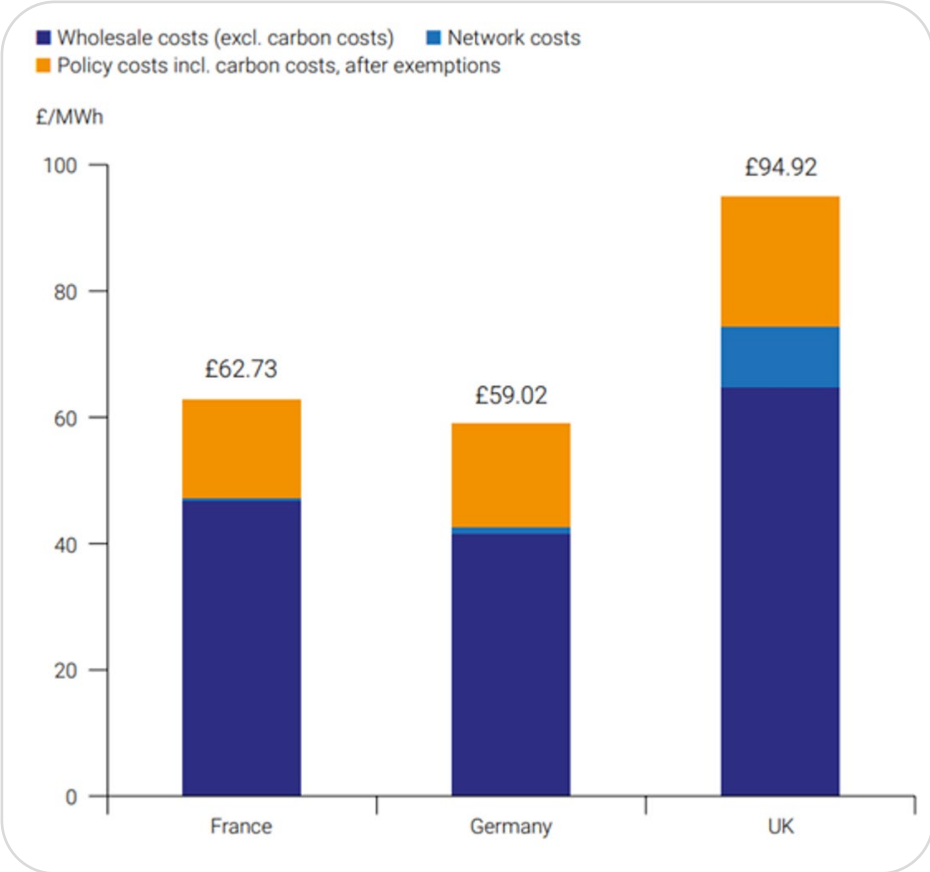
Figure 17: **Makeup of typical UK energy bill. Source: Business Juice[39]**



The price of electricity is also influenced by government policy decisions. In response to the cost-of-living crisis, the UK Government has provided unprecedented support for households and businesses. An EAF would fall under the category of non-domestic (business) users of electricity, and from October 2022 to March 2023 could have their energy prices capped at £211/MWh. This is compared to expected wholesale costs of around £600/MWh[40]. The situation around energy prices remains extremely fluid and unpredictable, but future government policy decisions may serve to significantly reduce the electricity price an EAF in Scotland may pay.

As shown in Figure 18, the wholesale piece of electricity was roughly comparable in 2020/21 for steel producers across the three countries, but network and policy costs are substantially higher for the UK than France or Germany. This demonstrates that, although the wholesale price of electricity is very susceptible to exogenous changes in international supply and demand, there is a substantial proportion of electricity costs which could be reduced via domestic government policy and economic reform. Such reductions would serve to make a Scottish EAF more economically competitive, especially relative to other European countries. Electricity prices are a strong determining factor for the location of EAF investment, with low-cost electricity generation grids being heavily favoured over high-cost alternatives, particularly for renewable technologies such as solar and wind[24].

Figure 18: Energy prices for steel producers in France, Germany, and the UK (2020/2021), Source: UK Steel[41]



What is not shown by this graph is the fact that electricity prices have experienced dramatic spikes with spot prices of over £2,000/MW[42]. While this reinforces the importance of electricity prices in the profitability of operating an EAF, the fact remains that the UK still faces considerably higher relative network and policy costs for each MWh of electricity purchased than countries of comparable size and economic composition. Recent steel industry news has cited energy costs as a key factor in challenging market realities[43].

The notion of electricity costs as determining factor for EAF investment is supported in literature looking into the interaction of locational factors and investment opportunities for EAF steel recycling plants[46]. The research found that access to low-cost electricity generation was a strong deciding factor in the allocation of electrified steel, and it cited Ireland and the Baltic states as working examples of this.

3.9 Cost of inaction

Although the profitability and GVA associated with each of the three scenarios evaluated in the economic analysis paper are highly uncertain and changeable, what the modelling does not capture is the cost of 'doing nothing' or the business-as-usual (BAU) position. Much of the decision making about whether an EAF is desirable for Scotland may come down to how much value is placed on becoming more circular, and the 'social cost of carbon' associated with current steel recycling practises i.e., exporting steel overseas to be recycled. In recycling steel within Scotland, benefits could be realised in mitigating much of the embodied carbon associated with the import of steel, whereby the environmental footprint has been demonstrated to be significant[25], as well as a strategic decision to recycle our own steel and retain ownership of and access to this material.

The Scottish Government may decide to take a strategic approach, whereby it is seen as important that steel used in Scotland should be recycled here, rather than exported – a model utilised by Norway. Furthermore, in an increasingly uncertain world this approach could offer domestic benefits to Scotland, with less reliance required on foreign exporters of steel e.g., China. Again, this benefit is difficult to monetise, and increasingly becomes a political/strategic decision rather than a purely economic one.

3.10 Steel reuse

Increasing steel reuse is an additional and valuable strategy to increase the circularity of steel use within Scotland. Little data exists on the scale of domestic reuse of steel scrap, but examples exist of businesses involved in the reuse of steel (for example, John Lawrie Tubulars reuse steel pipes as piling[44]). Analysis by Zero Waste Scotland on environmental impacts of steel recycling included a scenario on reusing 16% of domestic scrap arisings. Based on the analysis in Table 2, this equates to between ~100 and 150 kt of scrap at 2018 levels. Increasing reuse of steel could divert scrap away from use as an input into the recycling process. Under Scenarios 1 and 2 in the economic analysis, whereby a 300 kt EAF is evaluated, sufficient domestic scrap would be available to accommodate 100-150kt of reuse. However, under Scenario 3, where

a 1 Mt EAF is evaluated, reuse of domestic scrap would further reduce the reliance of the plant on imported scrap.

3.11 Market incentives and interventions

When discussing market incentives and interventions to aid the business case for an EAF in Scotland, these must lie within the limits of what market incentives and interventions are within the Scottish Government's range of devolved powers[45]. The consequence of this is that some potentially impactful interventions are out of scope as they lie within the UK Government's reserved range of powers. These include, but are not limited to currency, energy (most aspects), product standards, employment law, trade, and foreign affairs. For example, recent discussion around potential UK Government grants of around £300m each for British Steel and Tata Steel UK, are reported to be connected to supporting investment away from fossil-fuel and towards "green steel"[46]. At the time of writing (February 2023), this funding had not been confirmed. Regarding in-scope market incentives and interventions then, there are two main categories: public sector and private/third sector. The public sector consists of the Scottish Government and Local Authorities, and the private sector would be any organisation which is not-for-profit but not in the public sector.

In the private sector, as mentioned previously, energy prices have been a historic and persistent barrier to investment for an EAF in Scotland. To remedy this, Power Purchase Agreements (PPAs)[47] could be a powerful tool. A PPA is a contractual agreement between energy buyers and sellers, who agree to buy and sell an amount of energy which will be generated by a renewable asset. PPAs are typically signed to a long-term period between 10 to 20 years. The advantages of such an agreement would be two-fold: potentially cheaper fixed long-term energy costs for the EAF, mitigating some risk; and a guaranteed, large-scale, and long-term buyer for renewable energy in Scotland, providing further incentive for its deployment and their own financial security. Such agreement would

be especially advantageous in today's energy markets which are notoriously volatile and high cost.

Private businesses also have their own version of Green Public Procurement (GPP) which can have a substantial impact on the demand for green steel products, especially when these are tied in with infrastructure projects. In recent years, this can be seen with car manufacturers operating in Europe such as BMW and Mercedes-Benz. For such companies, manufacturing products with a low carbon content is a marketable advantage, due to the growing consumer demand for products and services which are low carbon. Having low embodied carbon during the construction phase of projects is also crucial for industries such as renewable energy developers, whose entire business model depends on energy generation with the lowest carbon emissions possible. Examples such as these show how in today's economic environment, the embodied carbon content of products and services can be a major factor in their success on the market.

3.11.1 Electricity price negotiations

Negotiating a better rate for electricity supply was a topic discussed within the stakeholder interview process as part of the research on the current steel scrap market in Scotland. It was suggested that a potential EAF could negotiate a discounted electricity price with suppliers on the condition that it would consume large quantities of electricity – essentially a bulk buy discount. A private wire or power purchase agreement (PPA) to pre-agree a fixed price for electricity would provide certainty to an EAF operator and ensure that market price volatility did not have greatly detrimental impacts on EAF viability.

In the sensitivity analysis a modelled assumption of a 25% discount on electricity was assessed. It was found that by reducing electricity prices by 25% this improved GVA by between 3% and 30% (depending on the scenario), with profitability also enhanced. However, for a 300 kt plant producing a 'low value' product no matter what the electricity cost reduction (even 100%) the plant would remain unprofitable. For Scenario 1 to be economically viable (profitable) other input factors would also need to be reduced alongside electricity prices. For significant economic impacts to be realised - under Scenario 2 and 3 - an electricity price reduction of somewhere in the range of 50% would be required.

3.11.2 Public financing options

In the modelling for the economic analysis paper, the assumption was that an EAF would be financed fully via the private sector i.e., a 100% loan taken out to pay for the capital expenditure associated with such a project. Alternative financing options i.e., public/private partnerships, could improve the economic viability of a plant.

Although no longer a member of the EU, there are various EU funding mechanisms that are available for projects that assist the energy transition, all of which could potentially be utilised in the construction of an EAF (bulleted below).

- The Recovery and Resilience Facility
- Just Transition Mechanism
- InvestEU
- Innovation Fund

The Scottish/UK governments could establish similar funding mechanisms to support private sector investment into the steel recycling sector. The Scottish National Investment Bank could be a source of funding for a project such as an EAF, with its remit to "provide patient (long term) capital to businesses and projects throughout Scotland to support the development of a fairer, more sustainable economy"[48]. The bank has an ambition to invest its allocated public capital and encourage additional private capital to invest alongside it. Three recent examples of EU governments assisting in the financing of green EAF plants are shown below.

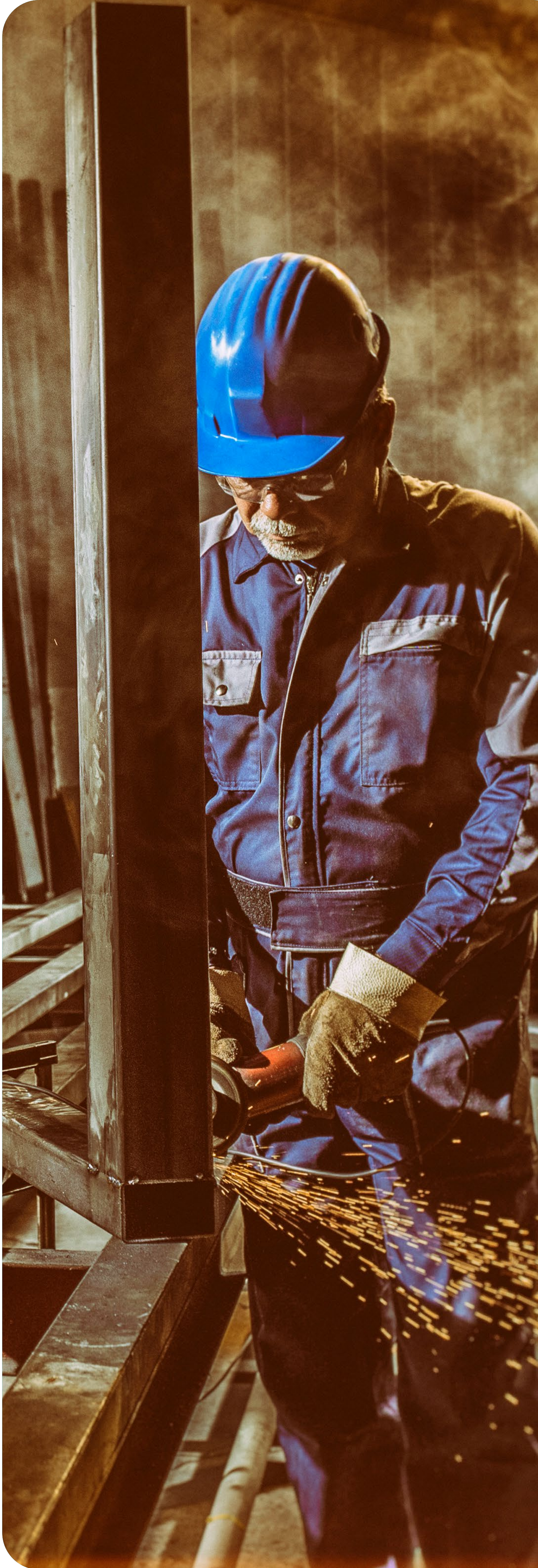
- ArcelorMittal's Fos-sur-Mer plant in southern France that ArcelorMittal was due to invest 63 million euros in cutting the plant's carbon emissions. This will include a €15 million subsidy provided by the French state[49].
- Swedish Environment Agency putting £2.3 million of financing towards H2 Green Steel[50].
- ArcelorMittal signing an MoU with the Spanish Government supporting €1 bn investment in decarbonisation technologies. The government will endeavour to "provide maximum financial support for the project, in line with Spanish legislation and European Union regulations"[21].

3.11.3 Reductions in carbon taxes and business rates

Although business rates have not been modelled under the analysis for the economic paper, they could be a lever for supporting future EAF investment. Furthermore, the adoption of carbon border taxes could increase the competitiveness of domestically recycled steel compared to imports of more carbon intensive steel made using fossil-fuel based furnaces (e.g., the blast furnace-basic oxygen furnace route, or EAFs with higher grid emissions).

3.12 Summary

- The Gross Value Added to the Scottish economy from each of the three EAF scenarios assessed is likely to be significant (at a minimum £9.1 million annually).
- Up to around 1,000 economy-wide jobs could be created under the 1 Mt plant scenario – this would help stimulate economic growth, contributing significant tax revenue for the government and driving economic activity in a variety of industries via multipliers.
- It remains uncertain whether the business case exists for such a facility to be built and operate in Scotland. As has been indicated in the sensitivity analysis, there is great uncertainty as to how resilient a privately financed operation could be to changing market conditions, and the direct influence these would have on company profitability.
- Many of the key factors behind whether the financial case exists rely on external market forces, whether that be changing electricity costs, or the market price for scrap and finished steel – all outside the control of a private economic actor.
- Some variety of market mechanism and/or policy action may be required to help de-risk the investment environment and provide more certainty for potential investors.



4 Exploring the potential opportunity for developing a circular steel supply chain in Scotland

Scotland's continued progress towards net-zero requires the construction of new power generation infrastructure to harness energy from different natural sources of energy e.g., tidal, solar and wind.

Scottish wind power, in particular offshore wind power in the North Sea, is currently one of the largest renewable energy markets in the world. The realisation of two major wind power leasing rounds, ScotWind Round 1 and INTOG, will provide more than 32 GW of power generation in the North Sea by 2033[?], requiring construction of over 1,600 20 MW, or equivalent, turbines. These projects are used in this report to provide a benchmark for the steel required for wind power generation. Although not included in this analysis, it is noted that the Scottish Government is also targeting expansion of onshore wind power, with 20GW of onshore wind capacity anticipated by 2030 using new and old sites[52].

This section assesses the types, masses and production routes for the steel required to produce new wind turbines and whether this steel can be obtained from the decommissioning of retired oil and gas (O&G) assets from the North Sea as they come to the end of life. The general assembly and major components for a wind turbine are shown in Figure 19[53].

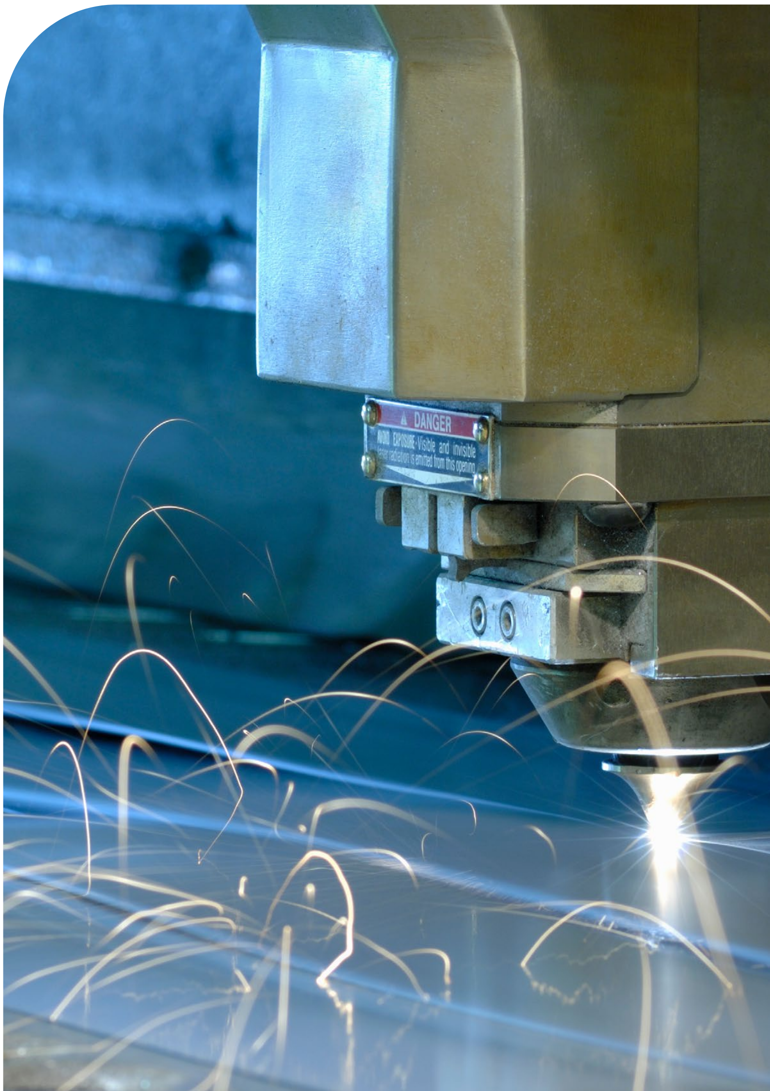
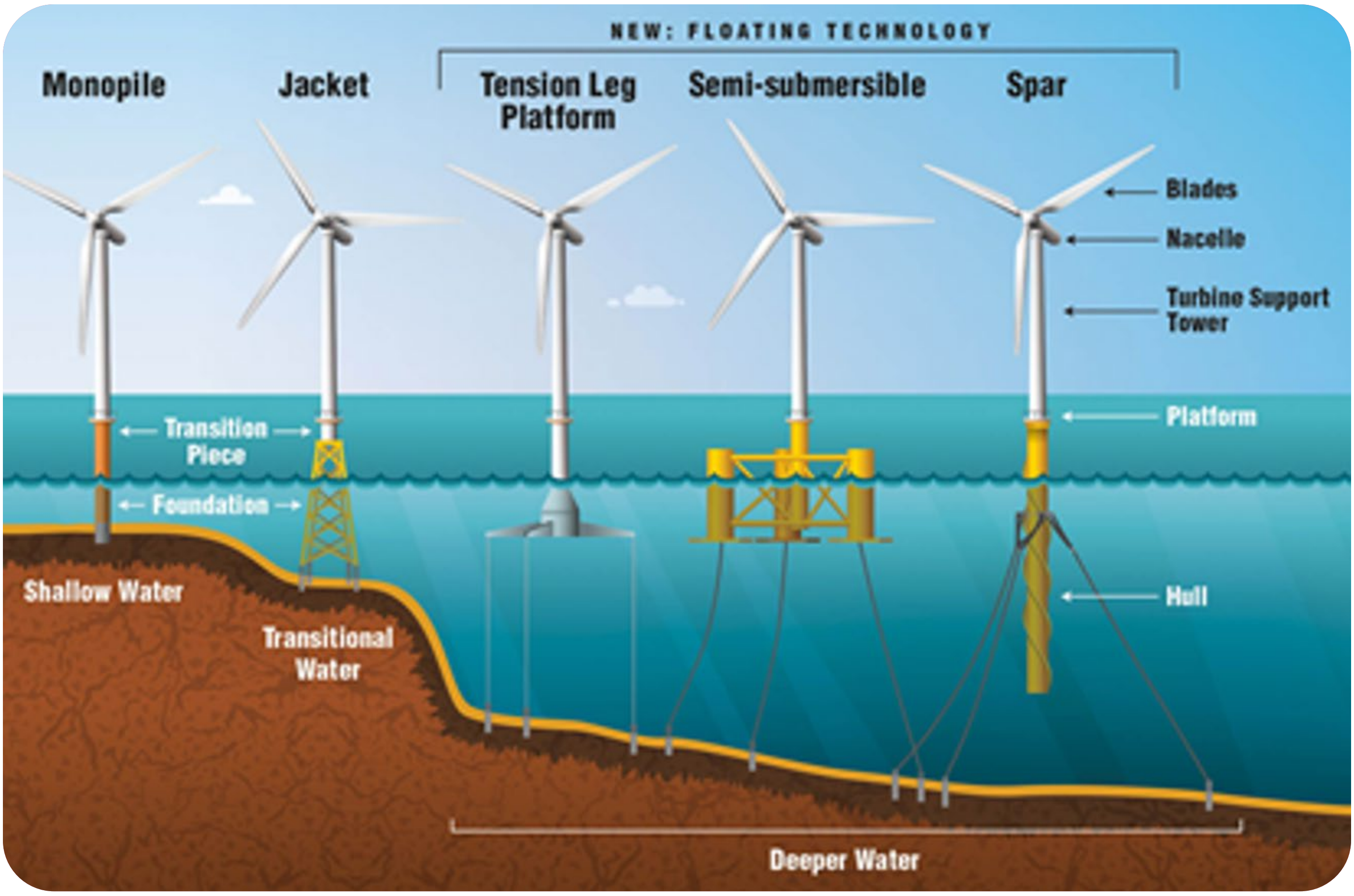


Figure 19: Wind turbine general assembly and major components[53]



4.1 Steel demand for the energy transition – offshore wind

The bulk of the steels used in the construction of wind turbines and oil and gas assets are similar in terms of their chemical composition specification. The similarity of steel grades, in terms of composition, is important for the steel recycling process, this is because different steels have different compositions, and some alloying elements cannot be removed from scrap during the EAF process. This means that it is easier to recycle construction steel grades into other construction grades; in contrast, it can be very difficult to produce low alloy grades through the steel recycling route and some steel grades cannot currently be produced from scrap via EAF production.

Typically, construction steel grades are used for structural components in wind turbines and O&G platforms (towers, legs, super structures) with more specialist steels used for drive systems and fluid transmission pipework. Structural components represent the bulk of the mass for wind turbines and O&G platforms, decommissioned O&G platforms should therefore be a high-quality source of scrap steel for recycling into new construction grade steels for wind turbine construction if scrap sorting is carried out.

Table 11 shows examples of the different steel grades that are used in wind turbine construction as well as O&G platform construction.

Further information on the types of steel required for wind turbine construction are shown in the Technical Appendix.

Table 11: Example steels grades used for components in wind turbine and O&G platforms[54],[55],[56],[57]. Construction steels (green row) represent the bulk of steel used in both structures; construction steel is used for more than 90% of a wind turbine. Other steels are listed for comparison but represent much smaller quantities.

Wind Turbines	Oil and Gas Platforms
Construction Grades • S275 • S355 • S420 • S460	Construction Grades • S275 • S355 • S420 • S460
Gear Box Steels	Stainless steels
Bearing Steels	Nickel Based Alloys
Bolting Steels	Bolting Steels

The mass of steel required to manufacture offshore wind turbines in Scotland in the next decade was estimated using the total amount of power that will be generated from the full realization of ScotWind Round 1 and INTOG leasing rounds. The following assumptions and statements were used:

- ScotWind Round 1 and INTOG projects are set offshore and are expected to feature a mix fixed and floating turbines. ORE Catapult[51] expect that when floating farms are manufactured, the dominant turbine size will be 20 MW. For fixed turbines, the expected size will be between 15 and 20 MW.
- The estimate does not consider the materials required to complete the build for the six projects already consented but not yet installed for the earlier leasing rounds[a]

ScotWind Round 1 and INTOG will provide an estimated total capacity of 32 GW (ScotWind Round 1 = 27,626 MW[58], INTOG = 4,500 MW[51]). The number of 20 MW turbines required to provide this much capacity is 1,606.

The ORE Catapult estimate the steel required for Scotwind Round 1 and INTOG to be 6,939 kt and ~1,550 kt respectively[51]. However, the ORE Catapult Scotwind estimates only

[a] This accounts for the difference between estimates presented here and elsewhere for the total steel required to realise Scotland's offshore wind projects.

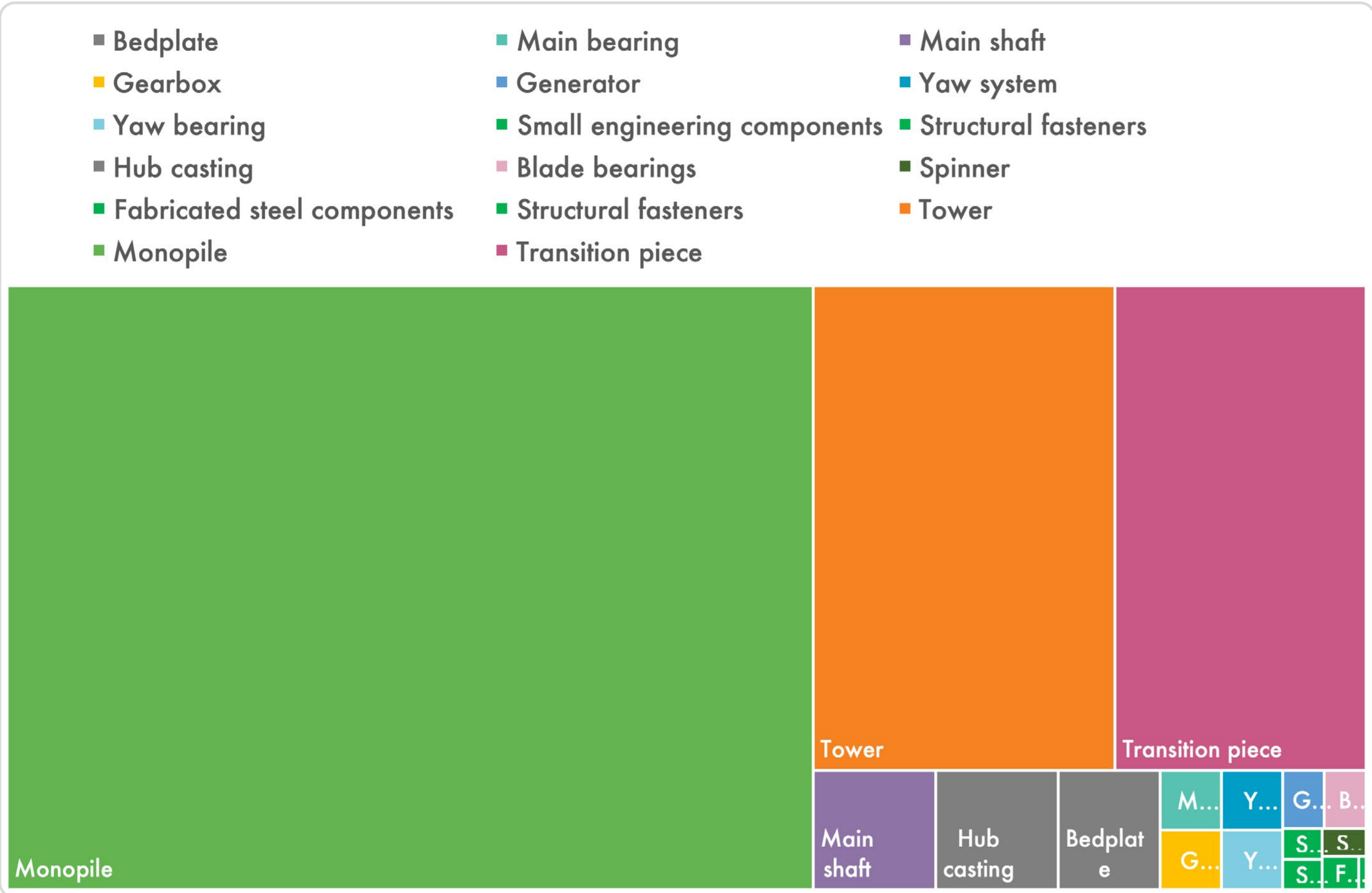
account for generation capacity of 26,935 MW. Depending on whether the remaining 691 MW of awarded leases announced subsequently are concrete or steel floating substructures, the ORE Catapult steel tonnages can be scaled to give a steel demand of between 7,012 kt and 7,129 kt for Scotwind Round 1.

The total amount of steel required to satisfy ScotWind Round 1 plus INTOG is therefore estimated to be between 8,562 kt and 8,679 kt (~270 kt of steel per GW). 958 kt of ductile iron casting is also required, based on the assumption that 32 tonnes of iron per MW is required in the turbine nacelle[51].

Breaking down the steel grades required on an individual turbine basis provides further insight into the demand for different types of steel and their production volumes.

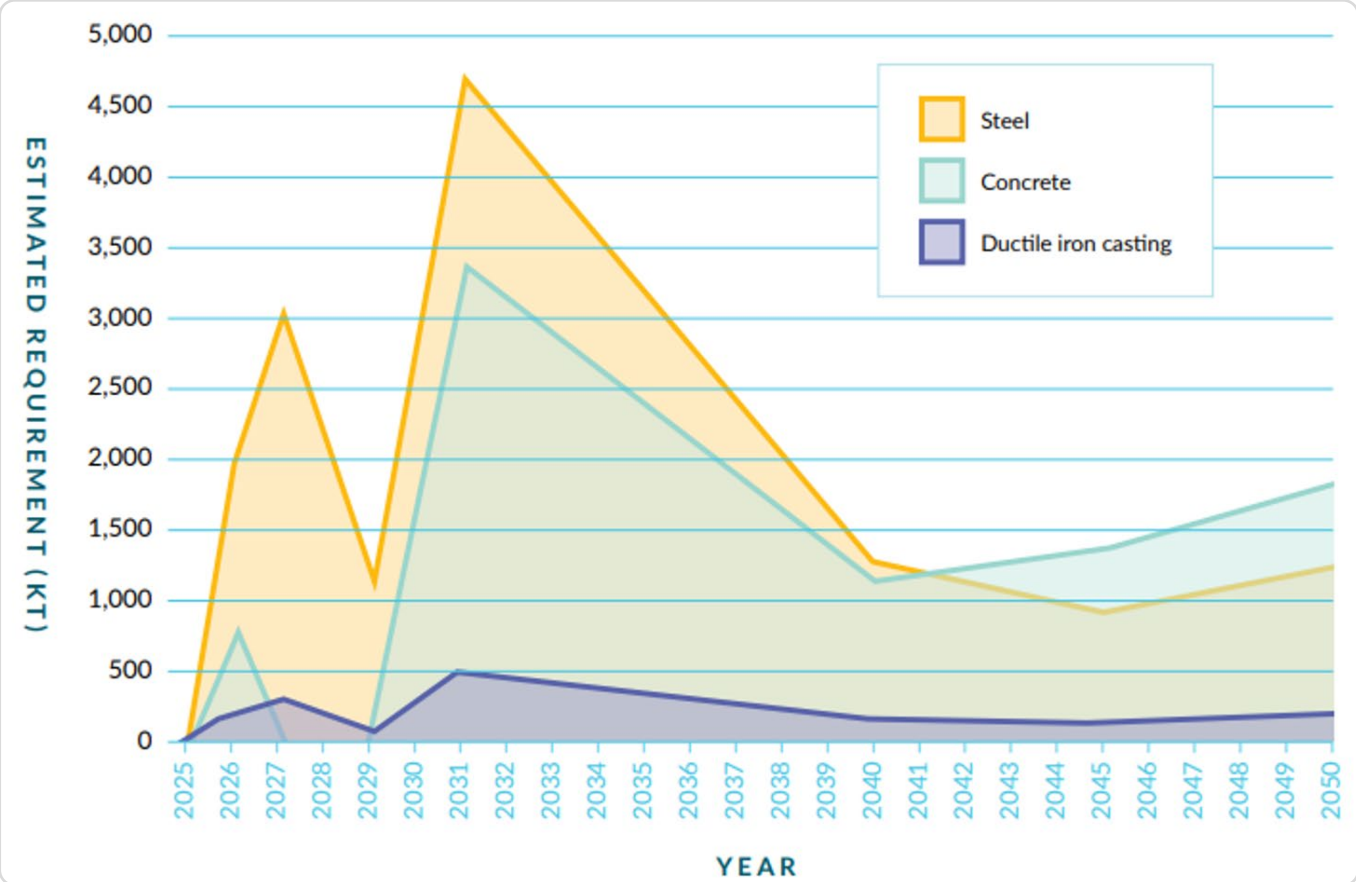
Figure 20 shows a representation of the different steel types used for major components in a 20 MW wind turbine, construction steels represent more than 90% of the overall structure used in the turbine. The remainder is made up of spherical grade cast-iron and specialist bolting, bearing and electrical steels. A more detailed table with exact grades is included in the technical appendix.

Figure 20: Representation of steel types for major in a 20 MW monopile design wind turbines. Green represents construction steels, dark blue represents bearing steels, light blue represents electrical steels, grey represents cast-iron, yellow represents components with a verity of steel grades and brown represents specific bolting steels. Source: BVG Associates[57]



Analysis by the ORE Catapult estimates annual material requirements between 2025 and 2050, which will include demand for Scotwind, INTOG, and future leasing rounds between 2035 and 2050, as shown in the figure below. Much of the steel demand prior to 2033 is connected to installation of Scotwind wind farms (Figure 21).

Figure 21: Material Requirement 2020-2050 (highest demand). Source: ORE Catapult[51]



4.2 Estimated masses of steel available from decommissioned oil and gas assets

O&G platforms coming to, or already at, the end of life could provide a rich source of steel for recycling into wind turbine applications. Information from the OEUK Interactive Decommissioning Toolkit[59] gives an estimate of the annual tonnage of material available for onshore recycling per year, as shown in the table below. This includes material from both topsides and substructures. We assume that the only material available for onshore recycling is steel.

Table 12: Annual onshore recycling tonnages (tonnes). Source: OEUK[59]
Notes: CNS – Central North Sea; NNS&WOS – Northern North Sea and West of Shetlands; SNS&IS – Southern North Sea and Irish Sea

Region	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
CNS	12,933	2,146	160	26,298	45,295	82,991	107,566	70,620	41,620	107,941
NNS& WOS	38,389	-	6,264	41,483	135,495	118,123	79,811	45,000	74,723	4,225
SNS& IS	26,499	7,388	27,228	5,013	4,587	44,519	-	23,367	22,816	13,475
TOTAL	77,821	9,534	33,652	72,794	185,377	245,633	187,377	138,987	139,159	125,641

The following assumptions and notes were used to compare steel arising from decommissioned O&G platforms and demand for construction steels for ScotWind Round 1 and INTOG (~8,620 kt).

- Production of 1t of new steel requires 1.2t of scrap steel through the EAF steel production process, this is assumed to be the worst-case scenario. Losses are caused by poorly sorted scrap steel where high levels of residual elements must be removed or diluted[60]
- Construction grades of steel are the bulk of both O&G platforms and wind turbines.

Using these assumptions, we estimate:

- In the UK Continental Shelf there could be as much as 1,216 kt of steel available for recycling from decommissioned O&G platforms in total between 2022 and 2031 (if UK decommissioners have access to all platforms in the North Sea[a]).
- This could be recycled to produce 1,013 kt of construction grade steel.
- This would be equivalent to approximately 12% of the steel demand for ScotWind Round 1 and INTOG.

Additional to the steel available from decommissioned O&G platforms, scrap steel will become available from decommissioned onshore wind turbines. This steel has not been included in the analysis as it represents smaller quantities. It is estimated that by 2050 onshore wind decommissioning could provide as much as 1,128 kt of scrap steel[61]. This scrap stream will start from a low annual baseline to reflect the small annual volumes and sizes of onshore turbines becoming available for decommissioning. However, these assets will still provide a valuable contribution to the domestic scrap steel market in Scotland.

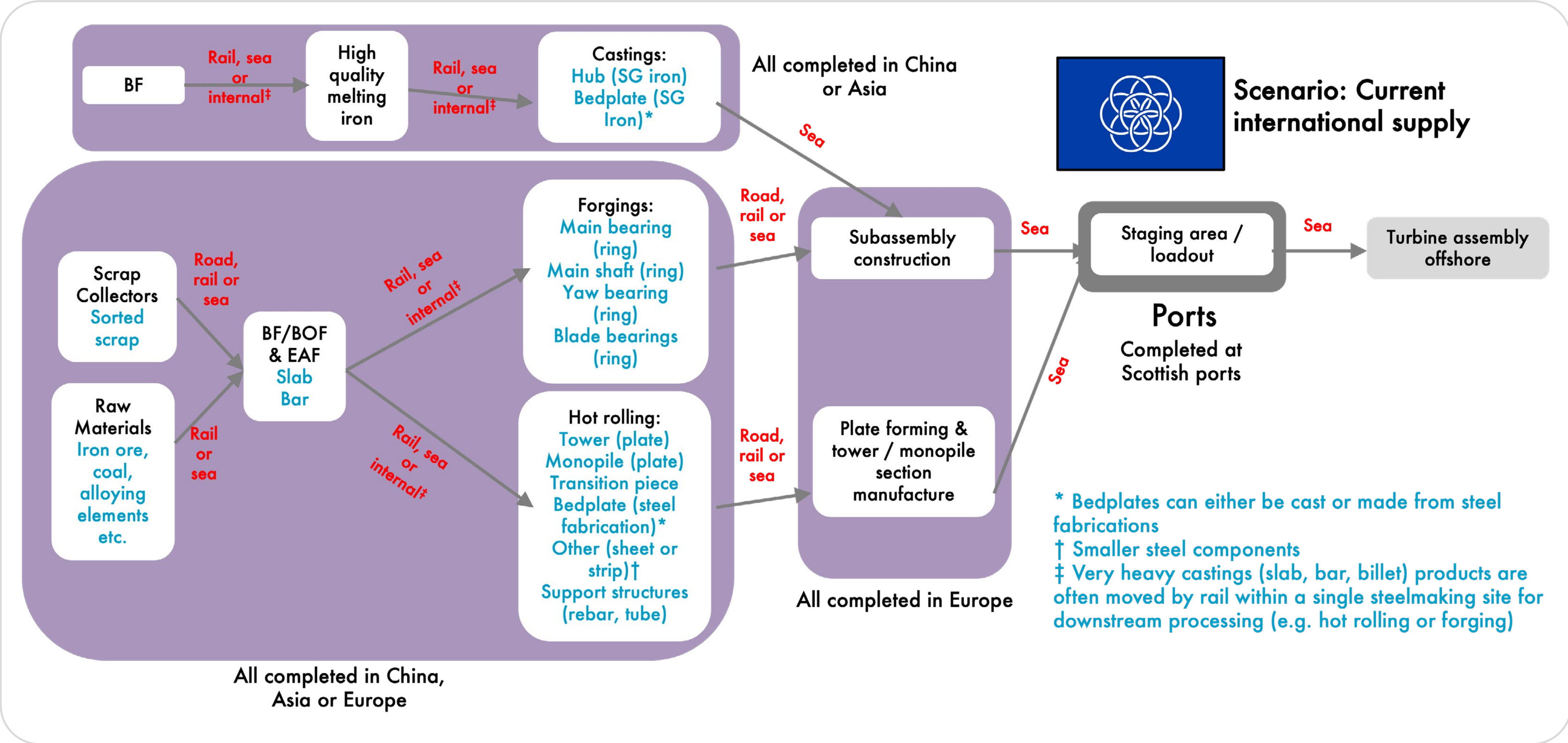
[a] This assumption is made to assess the theoretical potential of steel available from the UK Continental Shelf and may not reflect current practice (with potentially only about 10% of O&G platforms estimated to be currently decommissioned in the UK, although this could be higher).

4.3 Current wind turbine steel supply and manufacturing routes

The steel required for wind power generation in the UK is almost entirely sourced from other countries, with the bulk of components and materials being sourced from either China, South Korea, or Europe. The steel used for current wind turbine projects is produced through a combination of blast furnace / basic oxygen furnace (BF/BOF) and EAF manufacture.

The current international supply chain and transport methods for offshore wind turbines constructed in the UK is simply represented in Figure 22. Figure 22 shows that the only activity currently happening in the UK is the assembly of major steel components is completed at staging / loadout areas and during the offshore assembly[57,62].

Figure 22: **Current supply chain and transport methods for offshore wind turbines used in the UK** [57,62]



4.4 Potential Scottish steel supply for offshore wind power

As explored in the first section of this report, Scotland produces between 620 ktpa and 930 ktpa of domestic scrap steel, which is currently exported, and theoretically could have access to as much as 1,216 kt of additional steel over the next 10 years from decommissioned O&G platforms in the North Sea. It should be noted that, given current practice, it is unlikely that all the platforms will be accessible for decommissioning in Scotland and that O&G platform operators will likely already have long term decommissioning contracts in place with decommissioning companies in other countries. To retain scrap steel in Scotland and divert it away from its current destinations (which are driven by market economics), intervention(s) would likely be required.

Offshore wind leasing rounds ScotWind Round 1 and INTOG will require approximately 8,620 kt for construction steel alone. Assuming that this is an indicative mass of steel for future wind power projects, it is therefore reasonable to consider whether Scotland could produce its own steel to supply future wind power projects from new EAF steelmaking plant built in Scotland to recycle Scottish scrap steel.

This assessment shows that there are two main routes to provide scrap steel to wind turbine manufacture from scrap steel that arises in Scotland: supply from domestic scrap steel and from decommissioning activity. The estimated annual volumes of steel scrap arisings and the resulting recycled steel production (assuming a 17% yield loss during recycling) are shown in the table below.

Table 13: Annual Scottish steel scrap sources and recycled steel equivalent (kt). Source: Author analysis

Category (kt)	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Domestic scrap	620 – 930									
Decommissioning scrap	78	10	34	73	185	246	187	139	139	126
Recycling losses	116 – 168	105 – 157	109 – 161	115 – 167	134 – 186	144 – 196	135 – 186	126 – 178	127 – 178	124 – 176
Recycled steel	582 – 840	525 – 783	545 – 803	577 – 836	671 – 929	721 – 980	673 – 931	632 – 891	633 – 891	621 - 880

From this analysis, we can make the following observations:

- ScotWind Round 1 and INTOG will require 862 ktpa of construction steel over the next 10 years, although most of the steel will likely be required after 2025. This steel demand is assumed to be indicative of future wind energy project requirements.
- A combined supply of scrap steel from domestic and decommissioning sources could provide enough steel to satisfy the demand assuming that no steel scrap was exported from Scotland and domestic scrap arisings were towards the upper bound of the range.

Scrap steel from decommissioning is a high-risk material supply route for steelmakers to wind turbine manufacture for Scotland:

- Decommissioning of O&G platforms is not currently carried out in Scotland or the wider UK at a scale large enough to satisfy demand. Scrap steel from current decommissioning projects is exported for recycling in other countries.
- A new EAF steelmaking facility with casting and rolling capability could cost as much as £1 billion to build and would require a consistent volume of scrap steel supply as well as a suitable market to sell new steel into. O&G decommissioning and wind power projects by their nature have inconsistent material supply and demand requirements, smoothing out the supply and demand inconsistencies would be key to efficient EAF steelmaking operations. Using scrap steel from domestic projects could help to smooth out the supply.
- The inconsistent material demand of wind power projects would mean that new EAF steelmaker(s) in Scotland would need access to other markets (e.g., construction, other renewable technologies, and low-carbon technology infrastructure) for the steel produced as well as the offshore wind market to offset this risk and prevent stockpiling.
- Steel grades available from decommissioning, and the scrap quality control, may not be suitable for complete closed loop recycling into construction grades for wind turbines, therefore further study of the volumes and types of steel scrap that would be available would be required to mitigate associated risks[63,64].

The high capital and operating costs for EAF steelmaking requires a minimum amount of new steel production to ensure payback of operating costs and return on investment. The amount of steel that needs to be produced is linked to the sale price of the steel grades manufactured. The volumes that need to be produced are inversely proportional to the value of the steel grade manufactured, so higher value steel grades equal less production volume and vice-versa. Construction steels are low value steel products and therefore a steelmaker would need to make more construction steel than it would of a higher value product (e.g., stainless steel) to break even. Efficient EAF operation also requires continuous production due to operational constraints; intermittent production is less efficient due to factors such as warming and cooling of equipment.

Using the masses of steel and types required for ScotWind Round 1 and INTOG the most likely steel products that would be produced in Scotland in new EAF steelmaking plant are construction products (e.g., rebar, plate). This is because there is sufficient annual tonnage required to keep a new EAF steel plant operating efficiently (around 862 ktpa) – with the combination of domestic and decommissioning scrap, a new 800 ktpa to 1,000 ktpa EAF could be viable (though imports of steel scrap from outside of Scotland may also be required). Production of higher value steel products is unlikely to be economically viable as the volumes required each year (80 ktpa) is too small to justify the levels of investment[64].

New steelmaking plant is only part of the supply chain required to manufacture wind turbines in Scotland. Thought must also be given to the rest of the supply chain for manufacture and assembly of wind turbine components. Figure 23 shows what a domestic, Scottish, supply chain for steel and cast-iron components for wind turbines would require. Green boxes identify where current supply options exist, blue boxes identify where supply options exist either within Scotland or the UK, and red boxes indicate where there is no existing supply capability.

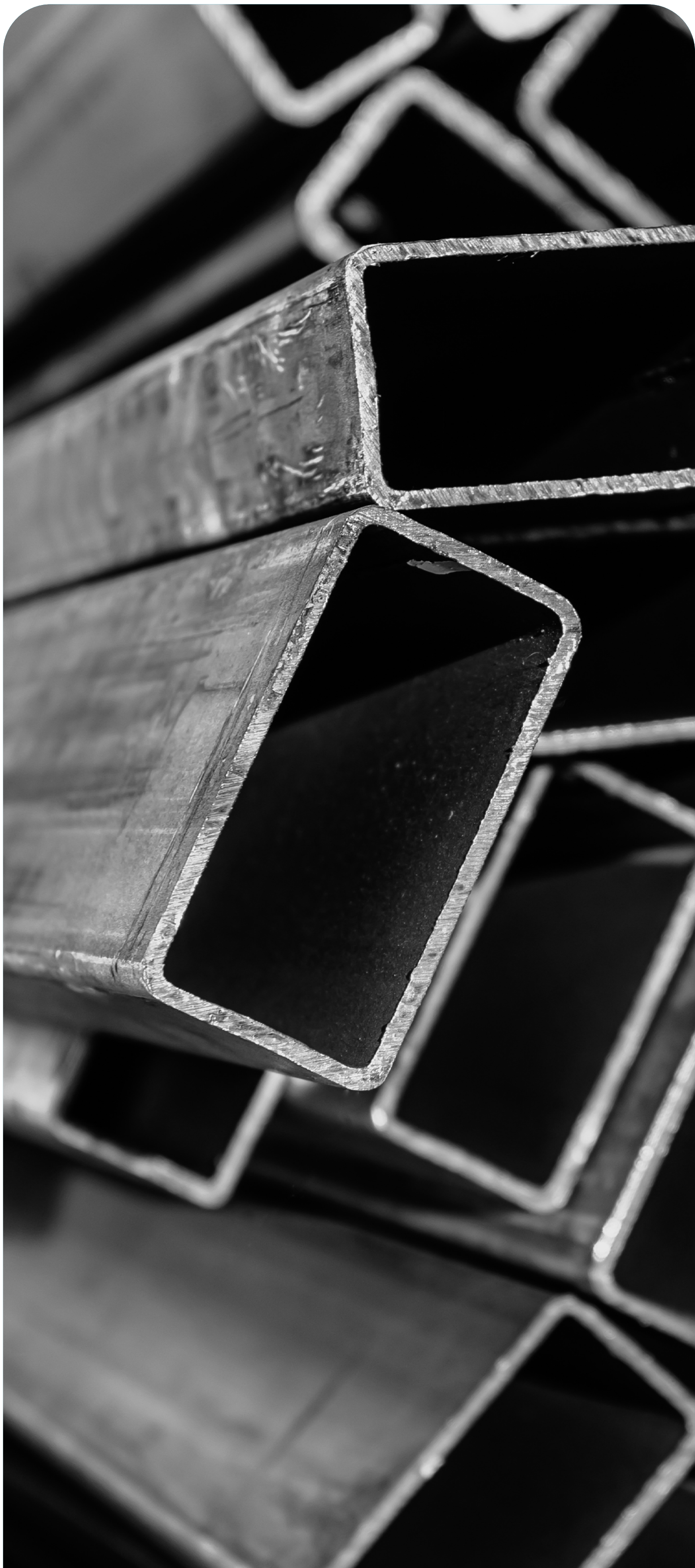


Figure 23: Supply chain and transport methods for Scottish manufacture of steel components for wind turbines. Green boxes identify where supply currently exists, blue boxes identify where some supply currently exists, and red boxes indicate where supply does not exist and would need to be developed[57,62].

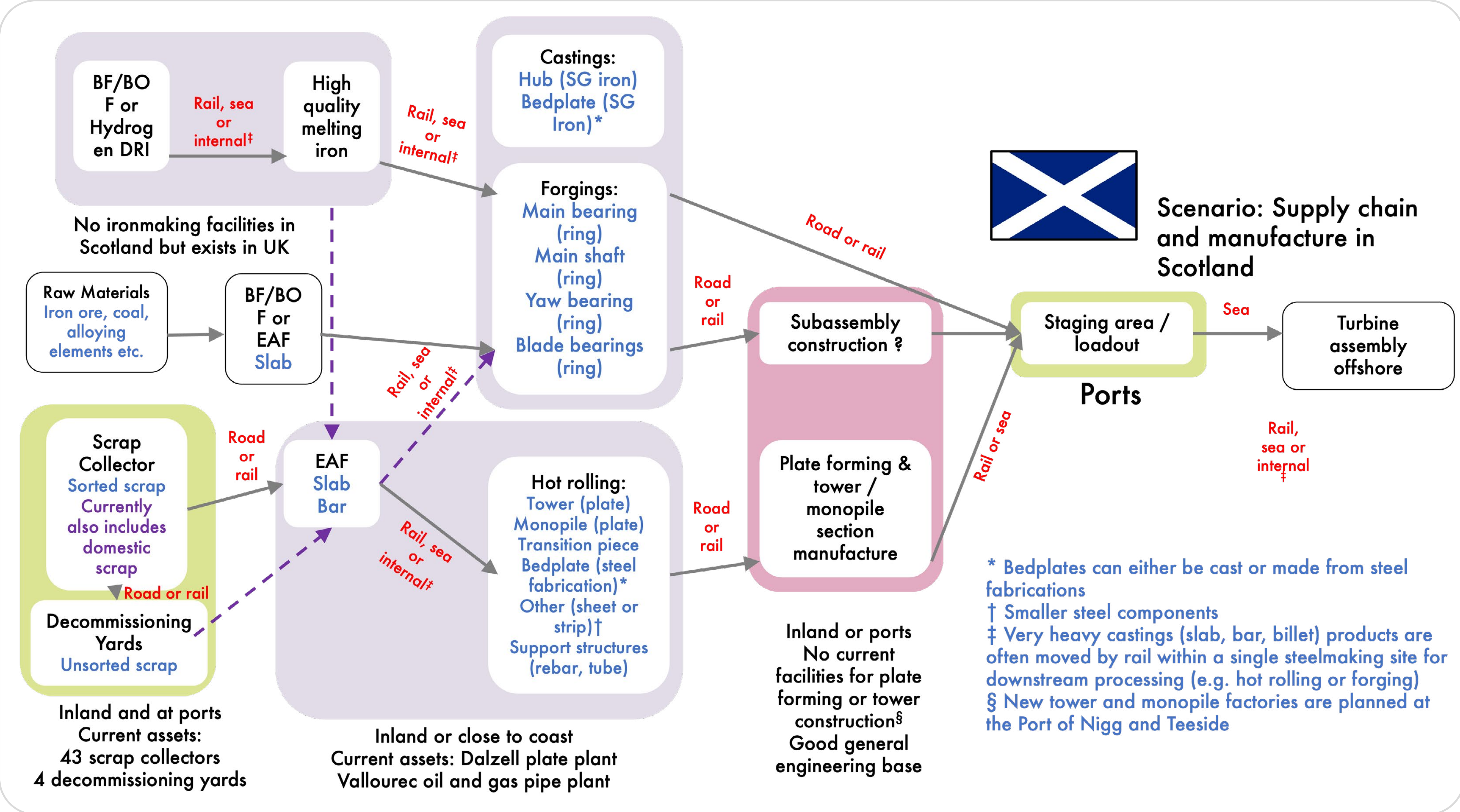


Figure 23 shows that significant development into high value assets to build a Scottish, or UK based, supply chain for wind turbine component and wind turbine manufacture would be required. Key points for consideration are:

- Steel mass estimates show that there could be enough scrap steel in Scotland to fulfil new EAF steel production for offshore wind using a combination of domestic scrap and decommissioned O&G scrap (assuming decommissioning of O&G in Scotland is scaled up sufficiently) and that the infrastructure for collecting / sorting the scrap steel already exists.

- Currently there are no manufacturers of large tower or monopile sections in the UK, the facilities required to complete these components would require large land areas as well as skilled labour. A new tower manufacturing plant has been proposed at the Port of Nigg on the Cromarty Firth, construction of the plant could start in late 2022 or early 2023. SeAH Wind plans to start construction of a monopile manufacturing facility at Teeside in July 2022, it is expected that the plant will be fully operational in 2026, [62,65,66].

- Tower and monopile sections are made from thick steel plates which are rolled into curved shapes and then welded together. There are two steel plate manufacturers in the UK, Liberty Steel's plate mill in Motherwell and Spartan UK (part of the MetInvest Group) based in Gateshead. Liberty Steel's plate mill can produce 250 ktpa of steel platel[67].

- The UK has capability for large castings and forgings, an example of this capability is Sheffield Forgemasters who already produce large castings and forgings for the energy market.

- Decommissioning yards do exist in Scotland although the amount of steel that they are currently handling is insufficient for supply to a new steel plant alone and would require significant scale up and investment to meet the needs of new steelmaking in Scotland and the right price signal for decommissioning yards to sell to the Scottish EAF facilities[62].

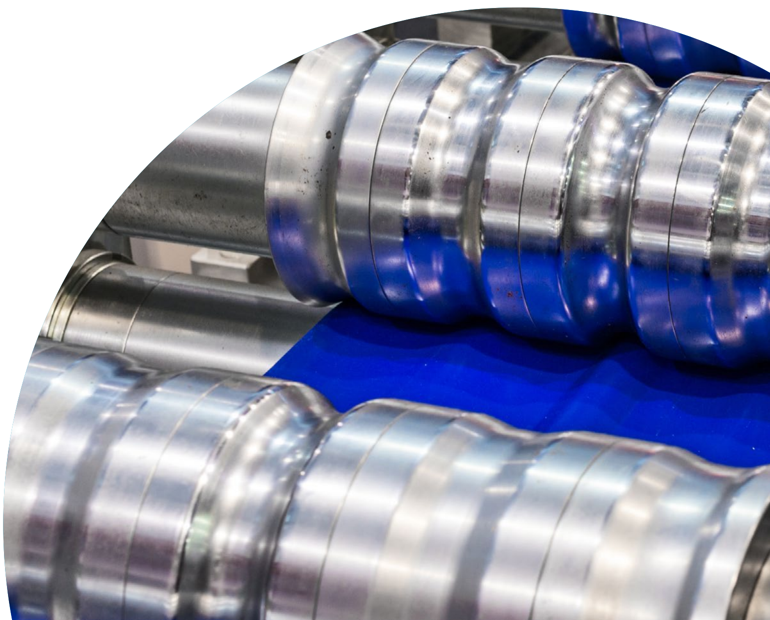
- Scotland, and the wider UK, has the expertise and skills to produce the steel and steel components required for wind turbine manufacture, bringing all of these together to develop the required supply chain would present significant challenges but may present a lower risk solution to building a supply chain than an entirely new supply chain in Scotland[67].

4.5 Social implications of developing Scottish supply chains for offshore wind

The social and economic implications of manufacturing steel components for offshore wind turbines in Scotland are larger and more complex than that of building new EAF steel plant alone. To enable manufacture of steel wind turbine components in Scotland consideration must be given to downstream processes and upstream processes such as scaling up O&G platform decommissioning, forging, plate forming, subassembly construction and fabrication.

Upscaling O&G platform decommissioning to achieve the masses of steel required for new EAF steelmaking would need to be completed strategically to ensure consistent supply of steel. Upscaling of decommissioning would create significant numbers of new jobs in coastal areas, potentially rekindling industry at ports or creating new industrial sites. This sort of upscaling would require considerable investment and a guaranteed market for the steel produced, decommissioning scrap not consumed in Scotland would almost certainly be exported for recycling.

Downstream processes (plate rolling, fabrication, forging, bearing manufacture) do not currently exist for wind turbine manufacture in Scotland. Manufacturing of this type does exist across the UK, skills and expertise could be brought into Scotland to enable creation of the necessary supply chains. It is difficult to say how many jobs would be created and what the potential economic implications for Scotland would be, that sort of forecasting is outside of the scope of this project. It is reasonable to say that the number of jobs created would be very significant and would represent the birth of a new industry for Scotland, and one that builds on the history of steelmaking in Scotland.



4.6 Environmental impacts of domestic steel recycling and wind turbine manufacture

Further work is required to better understand the CO_2e impact of domestic steel recycling and the manufacturing of components and products for the energy transition within Scotland. This would need to be compared with the current situation of exporting scrap and importing steel-containing products. However, carbon equivalent is only one of many environmental impact categories that would need to be considered when evaluating the impact of developing new large-scale industrial facilities within Scotland.

In Scotland, public bodies and private companies operating in a public character, such as utility companies embarking on the types of developments considered in this report, namely the development of domestic steel recycling infrastructure, and/or domestic manufacturing sites for renewables infrastructure, may be requierd to assess, consult on, and monitor the likely impacts their the plans, programmes and strategies will have on the environment by way of an Strategic Environmental Assessment. Individual proposals would likely fall under the 2017 Environmental Impact Assessment (EIA)(Scotland) Regulations[68].

This report does not seek to undertake an Environmental Assessment for the development of a circular steel supply chain in Scotland but presents the topic areas and potential issues that might be of relevance for any future assessment. The following sections outline the required information as per the EIA Regulations.

4.6.1 Development description

This would include information on the location, physical characteristics of the site (including demolition and land-use requirements both during construction and operation), characteristics of operation (including energy and resource use), and estimated residues and emissions during both construction and operation.

Relevance for circular steel supply chain: The information here would be specific to the intended site of any future development. Information on energy and resource use, and estimated residues and emissions from, for example, an EAF and/or downstream manufacturing processes would be dependent on the intended scale of operation. Relevant information may be obtained through comparison with other sites, and/or life cycle inventory data.

4.6.2 Reasonable alternatives

This would include descriptions of reasonable alternatives, e.g., in terms of location, size/scale, and technology, comparison of the environmental impacts, and the rationale for selecting the preferred option.

Relevance for circular steel supply chain: The information here would include assessment and comparison of different options for a development. This could include assessment of different size EAFs.

4.6.3 Current state

This is a description of the environment, both now and in the future (based on likely evolution, as can best be assessed) were the development not to be implemented.

Relevance for circular steel supply chain: The information here would include information both general to Scotland and information specific to the intended site of any future development.

4.6.4 Assessment factor descriptions

This is a description of the factors specified in Regulation 4(3) that are likely to be significantly affected by the development. These include:

- Population
- Human health
- Biodiversity (e.g., flora and fauna)
- Land
- Soil
- Water
- Air
- Climate (including greenhouse gas emissions, and adaption impacts arising from climate change)
- Material assets
- Cultural heritage (e.g., architectural and archaeological aspects)
- Landscape

Relevance for circular steel supply chain: The information in this topic is more contextual and would likely be similar across many different EIAs and Strategic Environmental Assessments (SEAs). The information would provide background on the current Scottish context in each of the described areas.

4.6.5 Assessment factor effects

This is a description of the likely significant effects of the development on the factors specified in above. From Scottish Government guidance[69], the types of information to be described includes:

- The construction and existence of the development, including, where relevant, demolition works.

- The use of natural resources, in particular land, soil, water, and biodiversity, considering as far as possible the sustainable availability of these resources.

- The emission of pollutants, noise, vibration, light, heat and radiation, the creation of nuisances, and the disposal and recovery of waste.

- The risks to human health, cultural heritage, or the environment (for example due to accidents or disasters).

- The cumulation of effects with other existing and/or approved projects, considering any existing environmental problems relating to areas of particular environmental importance likely to be affected or the use of natural resources.

- The impact of the project on climate (for example the nature and magnitude of greenhouse gas emissions) and the vulnerability of the project to climate change.

- The technologies and the substances used.

For each of these areas, direct, indirect, secondary, cumulative, transboundary, short-, medium- and long-term, permanent, and temporary, positive, and negative effects should be considered.

Relevance for circular steel supplychain: Examples of the types of effects that could be included in this assessment are described below. Note, these are indicative examples, and are not the result of an assessment.

- Population: the development of large-scale industrial facilities in Scotland could potentially attract workers into the country. The developments could also influence the distribution of population and industry if there is a significant movement of workers into the development regions.
- Human health: the development of large-scale industrial facilities could impact upon air, land, and water quality due to emissions from industrial processes, which may then impact human health. These would be subject to stringent regulations to minimise negative impacts and meet legal obligations. The industrial processes involved in a circular steel supply chain could be dangerous (e.g., high voltage electric supplies, molten metal, movement of heavy items) and strict health and safely policies would need to be developed and adhered to, to reduce the likelihood and severity of accidents.

- Biodiversity (e.g., flora and fauna): the location of proposed sites for development of circular steel infrastructure would have specific potential impacts on the nature. The choice of location may be limited by the presence of protected species or require mitigating actions to minimise negative impacts and ensure ongoing protection of habitats.

- Land: the infrastructure associated with a circular steel supply chain would likely have a large, physical footprint, and this may limit the location of suitable sites in terms of factors such as proximity to residential areas and local topography. As per the National Planning Framework 4 (Policy9)[70], utilising existing acant and derelict land, or brownfield sites, sould be the first options considered.

- Soil: activities associated with the development of large-scale infrastructure for a circular steel supply chain, such as road and facilities building, lead to land-use change, which will have an impact on local soil. These impacts may include soil sealing, changes to soil biodiversity, and soil compaction[71].

- Water: the proposed location of infrastructure for a circular steel supply chain may impact upon local water courses. In addition, industrial processes may use water for a range of functions, such as cooling and cleaning, and these demands will need to be responsibly managed to ensure extraction does not create pressure on water resources and infrastructure. The treatment and discharge of water effluent from industrial sites will also need to be carefully managed to avoid detrimental impacts on local wildlife. Risk of flooding is also expected to increase because of climate change. Developments of new industrial facilities should be constructed with flood protection measures and consider their impacts on the capacity of nearby flood plains or defences.

- Air: emissions to air from industrial processes can both contribute to climate change and air pollution. Developments will need to assess their emissions and ensure regulatory compliances. Air emissions related to transport and energy generation will likely be of most relevance to the development of a circular steel supply chain. Electrification of transport and the transition to renewable energy sources would likely be the most significant mechanisms to reduce emissions impacts.

- Climate (including greenhouse gas emissions, and adaption impacts arising from climate change): as for air emissions, transport and energy use are key climate aspects related to developing a circular steel supply chain. Additionally, construction activities (including demolition) will have climatic impacts during both the construction process and the emissions embodied within the construction materials. A key question is how the climatic impacts of a localised circular steel supply chain in Scotland compares to the current global system, and this will be the subject of future research. This topic also includes consideration of mitigation against the impacts of climate change, and for example, developments located on the coast may need to consider changes to sea levels and weather patterns, for example.

- Material assets: this topic includes both natural and manufactured material assets. The development of aspects of a circular steel supply chain will contribute to developing Scotland's stock of infrastructure assets and will allow steel scrap to be retained within Scotland. The development and operation of industrial sites will use natural material assets for both fuel and construction, which should be managed to maximise resource and energy efficiency.

- Cultural heritage (e.g., architectural and archaeological aspects): while unlikely to be relevant for any proposed site(s) for developing a circular steel supply chain, developments could not be in the following designated areas: World Heritage Sites, Listed Buildings, Scheduled Monuments, Conservation Areas, Designated Gardens and Landscapes, Historic Marine Protected Areas, Scheduled Wrecks and Nationally Important Battlefields[72]. Additionally, as discussed in the section on Scotland's iron and steel history, Scotland does have a rich history and ongoing, albeit currently small-scale, steel manufacturing activities. The development of a circular steel supply chain could build on this heritage.

- Landscape: the proposed site(s) would require appropriate assessment during planning if they were proposed in the following designated areas: National Parks, National Scenic Areas, Local Landscape Areas, Regional Scenic Areas, and Local Landscape Areas[72].

4.6.6 Other information

Other information required by the EIA includes:

- Forecasting methodologies and/or evidence used to conduct the assessment, and a description of associated gaps, uncertainties, and challenges.
- Mitigation measures proposed to avoid, prevent, reduce, and/or offset significant negative environmental impacts during both construction and operation.
- Describing potential environmental impacts arising from risks of major accidents and/or disasters and related mitigation strategies.
- A non-technical summary of all information described in this section.
- Reference list.

Relevance for circular steel supply chain: A wide range of resources would feed into this information, including information from studies, such as this one.

4.7 Summary

- Scotland's energy transition is expected to create a large demand for construction materials, including steel, with over 8Mt of steel estimated to be required to supply the Scotwind Round 1 and INTOG offshore wind projects.

- Between 2022 and 2031, an estimated 126kt of material from decommissioning topsides and substructures from the North Sea will be available for recycling, although this may not all be recycled in Scotland or the wider UK. Significant intervention may be required to retain more decommissioning activities within Scotland in the future.

- Over the next decade, a combination of steel scrap from domestic and decommissioning arisings could, in theory, provide enough steel to satisfy the demand from Scotwind Round 1 and INTOG. would likely fluctuate by year, so may not be matched from a short-term perspective.

- There is, as yet a very limited wind turbine component and assembly manufacturing value chain within Scotland that could utilise domestic recycled steel. For a fully circular supply chain, these activities would need to be developed in parallel with decommissioning and recycling activities.

- Development of large-scale recycling and manufacturing infrastructure would likely have a significant impact on the environment. An environmental impact assessment would identify the full range of impacts that would need to be considered when evaluating proposed developments. Additionally, further work is required to better understand the CO_2e impact of domestic steel recycling and the manufacturing of components and products for the energy transition within Scotland.

5 Conclusions

Hundreds of thousands of tonnes of scrap steel are generated each year in Scotland and significantly more will arise from deconstructed energy assets in coming decades.

Scotland's energy transition will also require large quantities of construction materials, including steel. However, research finds Scotland exports nearly all the scrap steel it generates. Is there potential for this supply and demand of steel to be integrated and managed domestically, and what could this mean for Scotland?

The findings of this report demonstrate that while Scotland's scrap steel is currently recycled and recirculated at a global level, there are opportunities to increase the management of this material in Scotland, increasing circular practices that could both benefit the economy and the environment, while utilising and valuing this strategic material more effectively as we transition our energy sector to net zero. Shifts in the market are driving changes in export options and reuse routes, including sustainable investment interest, carbon costs and economic factors that could drive domestic steel recycling and processing (see section 3).

This study shows potential for significant gross value-added gains from the development of a Scottish electric arc furnace, with up to 1,000 associated jobs created (see section 3.3). Though this opportunity has been considered as primarily driven by the demand for steel to fulfil Scotland's renewable energy ambitions, such a domestic steel reprocessing asset could have the potential to supply other sectors while helping to alleviate concerns of steel supply constraints as globally countries look to decarbonise.

While uncertainty remains of the business case for reprocessing steel in a domestic electric arc furnace scenario, the sensitivity analysis carried out within this study considers multiple factors including potential carbon, electricity, and steel (final product and scrap) interventions. Inaction could mean higher prices for steel imported for domestic demand in the future, and ongoing environmental impacts from steel transportation and production (see section 3.9). The race to decarbonise steel across Europe is advancing (see section 2.5). Scotland is uniquely placed to take advantage of the growing market for green steel owing to extensive low carbon electricity generation and supply. As time progresses, this advantage will shrink as other countries decarbonise. However, the road to implementing a domestic steel value chain would likely be challenging and it would likely require strategic decisions at a governmental level to necessitate well considered intervention.

Steel demand in the energy transition outstrips supply, even factoring in decommissioned material from existing / future assets. Enabling domestic steel supply chains, whilst ensuring minimal associated environmental impacts has the potential to deliver a greener, more resilient energy system and sustainable steel at the heart of that story for Scotland.

6 Technical appendix

Input variable and assumption	Our approach	Future improvements/testing	Uncertainty (Red, Amber, Green)
Electricity prices	The electricity price used was based on the average electricity price over the past 4 years (i.e., 2021, 2020, 2019 & 2018). The premise behind this was to remove the extremes that have been witnessed in electricity prices over the past few years, ensuring a fairer illustration of past electricity prices rather than simply a 'snapshot' of electricity costs at time of modelling.	Due to the fluctuations in electricity prices of recent years this input factor will need to be continually updated. Although in this case an average figure has been used there might be future instances where using the current electricity price is more appropriate.	
Capital expenditure	Based on the projected cost of new EAF plants in Germany.	Greater research into CAPEX costs, and use of a larger 'basket' of EAF examples to create the baseline cost.	
Loan repayment	The modelling assumes that the loan taken out covers 100% of the capital expenditure required and is paid back over a 15-year period at an interest rate of 7%. The time and interest rate were based on research carried out into major banking groups (Barclays, Santander, HSBC) offering on business loans.	Different interest rates and repayment periods should be considered to better assess the impact in which the cost of capital has on overall economic impacts.	
Scrap steel market price	Based on the average price of scrap steel across previous 4 years (2021, 2020, 2019 & 2018), which is then weighted based on the types and volumes of scrap steel sold in Scotland. The model assumes that an EAF requires 1.2 tonnes of steel to produce 1 tonne of steel.	Depending on the final product being modelled a specific scrap steel type may be required. Therefore, future analysis could model the economic impacts depending on various types of scrap.	
Land rental costs	Land rental costs based on the cost of land in the North-East of England, and the size of the plant estimated at a quarter of the size of Port Talbot (which is approx. 650 hectares).	Prospective sites within Scotland could be looked at. Potentially brownfield sites may have a lower value than the average used within this analysis.	

Input variable and assumption	Our approach	Future improvements/testing	Uncertainty (Red, Amber, Green)
Labour costs	Modelling uses an average Scottish scrap steel salary of £35,196 and a median economy-wide salary of £26,260.	Labour costs should be updated as and when incomes grow, or data improves.	
Maintenance/ Support costs	Assumed that £100 of maintenance costs are required for every tonne of steel produced.	Further research should be carried out to calculate what a more accurate figure may be for maintenance costs.	
Employment multipliers	Modelling uses Scottish Government employment multipliers of 1.5 and 1.9.	It may be worthwhile modelling scenarios under UK or EU multipliers to look at what impacts could be under 'optimistic' or 'future' economic conditions.	
GVA multipliers	Modelling uses Scottish Government GVA multipliers of 1.6 and 2.		
Carbon and other taxes	Modelling uses most recent UK carbon price, carbon support tax from the world bank and the CO2 associated with the production of a tonne of steel.		
Revenue	Market price of final steel multiplied by production volume		

Calculated impacts

Calculation	How it was done	Future improvements/testing	Robustness
Employment impacts	Employment levels for EAFs of varying production capacity have been analysed, with a production value per FTE then calculated. This has then been scaled up based on a 300 kt and 1 Mt plant to deduce a direct employment figure with Scottish Government multipliers then applied to calculate indirect and induced impacts.	The use of different multipliers would be interesting to present different 'potential' employment opportunities, as impacts can vary significantly depending on the multiplier used.	

Calculated impacts			
Calculation	**How it was done**	**Future improvements/testing**	**Robustness**
GVA per FTE	The calculation uses total UK GVA added by the steel industry, which is then divided by the number of people in the UK working within the steel industry.	If specific Scottish figures became available, they could be used to provide a more accurate picture of the GVA created by employees.	
GVA based micro firm level approach	This provides a GVA by FTE figure, which can then be applied to the number of jobs created because of an EAF in Scotland.	Different approaches could be used when calculating GVA.	
Sensitivity testing	Formula used: 'Turnover (or sales) less the cost of bought in goods & services (excl. employee costs)' The testing changed input values, although only one input value at a time.	Look to test a variety of input values at the same time. For example, this analysis increased and decreased both scrap steel and final steel product price but did not carry out these changes simultaneously. This may occur in reality and would be interesting to test in future.	

10MW turbine metal components	Steel / Iron type	Mass (t)
Nacelle		
Bedplate	EN-GJS-400-18U-LT grade SG iron or a standard 355-grade steel.	50
Main bearing	Bearing steel, cast iron	15*
Main shaft	42CrMo4 or cast hollow from EN-GJS-400-18U-LT	60
Gearbox	Variety of bearing / gear steels, cast iron (EN-CJS-700-2U)	15*
Generator	Electrical steels, bearing steels, gear steels	10*
Yaw system	Bearing steels, gear steels	15*
Yaw bearing	42CrMo4 steel forgings, 100Cr6 bearings	15*
Small engineering components	Construction steels (S275, 355)	5*
Structural fasteners	Bolting steels (M30, M36, grade 10.9)	5*
Rotor		
Hub casting	EN-GJS-400-18U-LT	60
Blade bearings	42CrMo4 steel forgings, 100Cr6 bearings	10*
Spinner	Galvanised steel	5*
Fabricated steel components	Basic construction steel sections	5*
Structural fasteners	Bolting steels (M30, M36, grade 10.9)	1*
Tower		
Tower	Steel plate, S355J2G3 NL, thickness 10-70mm	600
Turbine foundation		
Monopile	Steel plate, S355J2G3 NL	2000
Jacket	Steel plate and tube, S355J2G3 NL	1450
Transition piece	Steel plate, strip and hollow section, S355J2G3 NL	500

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