ZERO WASTE SCOTLAND

HOW SHOULD SCOTLAND MANAGE ITS SCRAP STEEL?

THE ENVIRONMENTAL ASSESSMENT

This is the first in a series of papers looking at ways in which production of Scottish steel could bring more environmental, economic and social benefits. This paper focuses on the environmental evidence for returning steel production to Scotland in a sustainable way and ensuring valuable scrap steel is utilised most effectively. Future publications will explore the economic and social cases. Zero Waste Scotland is funded by the Scottish Government to lead Scotland's transition to a circular economy.

The following analysis has been conducted using UK-wide data, the best available evidence at the time of writing this report, which was scaled by population to Scotland. This was to allow for different scenarios to be modelled and compared.

As part of our ongoing work in this area we will engage with Scottish industry to gain a more detailed understanding of Scottish scrap steel arisings and their export destinations.

KEY MESSAGES

- Today, producing 1 tonne of steel from Scottish scrap sent to Turkey emits 1.6 tonnes of greenhouse gases.
- Producing 1 tonne of scrap steel in an Electric Arc Furnace (EAF) plant in Scotland could reduce this to 0.64 tonnes of greenhouse gases. This would result in significant saving of 60% of emissions.
- Scotland's low carbon electricity grid presents a significant advantage to steel producers.
- Additional carbon savings are possible through encouraging local reuse of steel.

The way we produce steel today has a carbon cost

Nearly 820,000 tonnes of Scottish scrap steel was exported for remelting in 2018 from sectors such as construction, automotive, aerospace, and oil and gas decommissioning[1]. UK-wide data shows that the steel is exported by sea to locations such as Turkey, Pakistan, and Spain where it is remelted in a mix of Blast Furnace-Basic Oxygen Furnace (BF-BOF) and EAF plants.

Traditional BF-BOF plants combine small amounts of scrap steel (typically about 18%[2]) with virgin iron ore and require large amounts of coal to operate. In contrast, more modern EAF plants can take 100% scrap[3] and use electricity to melt it, rather than coal. This modelling has assumed that about 45% of Scottish steel is sent to BF-BOF plants and 55% to EAF plants[3]. Based on 2018 scrap steel generation in Scotland, the total carbon impact of producing steel from Scottish scrap is estimated to be up to 1.3 $MtCO_2e$ per year. Switching to Scottish based EAF plant production would save up to 790,000 tCO_2e per year. This represents a significant proportion of Scotland's annual carbon footprint of 70.7 $MtCO_2e$ and is a substantial saving (over 1%) which could be realised from better management of a single waste material.

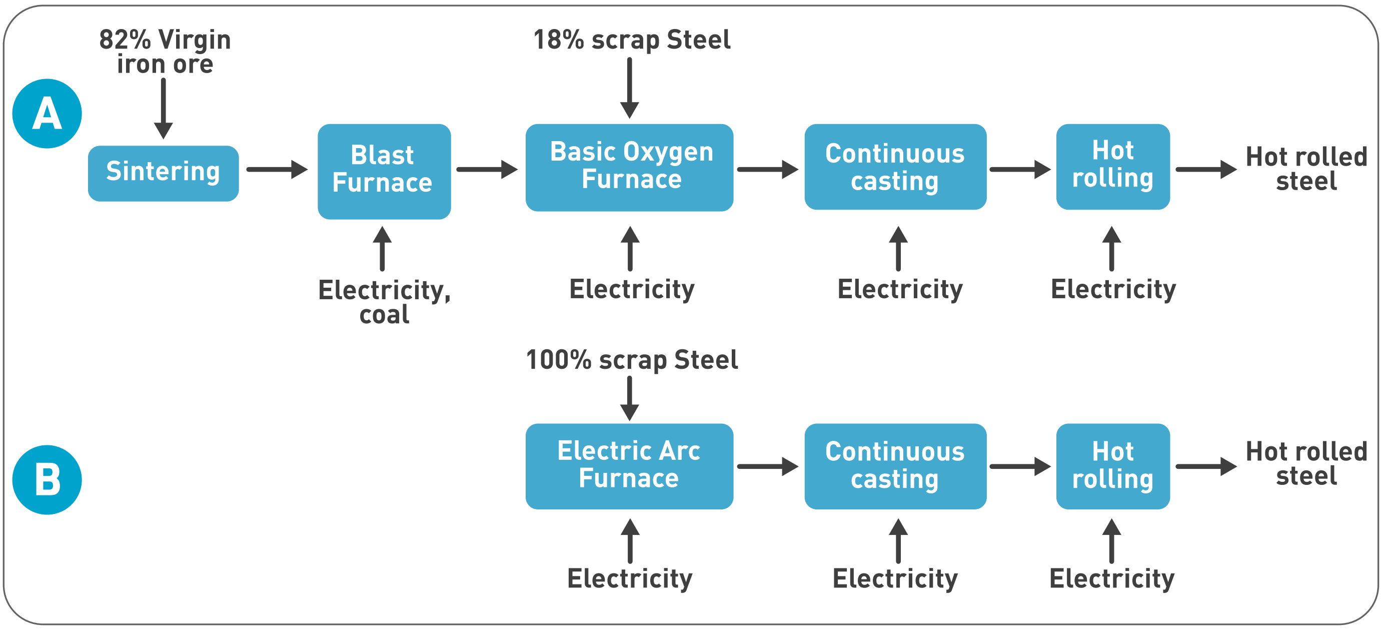

Figure 1 Simplified life cycles of steel reprocessing via (A) BF-BOF and (B) EAF

[1] Hall, R. (2020) Scottish Steel Sector Analysis, report commissioned by the Scottish Government.
[2] Liu et al. (2020) Numerical Investigation of Blast Furnace Operation with Scrap Charging, Metals, 10, 1666.
[3] Based on World Steel Association (2020) World Steel in Figures 2020.


MODERN EAF PLANTS CAN TAKE 100% SCRAP STEEL AND USE ELECTRICITY, RATHER THAN COAL, TO MELT IT.

THE OPPORTUNITY FOR SCOTLAND

There are several carbon advantages associated with moving scrap steel production back to Scotland. Firstly, EAF technology could be used, rather than BF-BOF route, which uses more virgin material and is more carbon-intensive.

Secondly, it would reduce the impact from transporting large amounts of heavy material over long distances. Finally, it would take advantage of the fact that Scotland has one of the lowest carbon electricity grids in the world (Table 1). On the basis that EAF plants use electricity to remelt scrap steel, Scotland could produce some of the greenest steel in the world.

Country	Carbon intensity of national electricity grid in 2018 (kg CO2e/kWh)
China[5]	0.556
Turkey[5]	0.441
UK[6]	0.253
Scotland[7]	0.044

Table 1 Carbon intensity of selected national electricity grid systems, 2018[4]

This carbon advantage is temporary, as other countries are actively 'greening' their grids. This means there is a time-limited opportunity to position Scotland as a leading location for low-carbon steel production.

By re-introducing steel production, using EAF processes, to Scotland we can save material, transport and energy emissions. An EAF plant would create highly skilled green jobs and give Scotland more control over a strategic resource which is vital to key sectors such as renewable energy. It would make an important contribution to achieving our net zero aspirations while reducing our reliance on overseas imports.

[4] The carbon intensity values in Table 1 were used in this study. A sensitivity analysis using alternative published sources (e.g. EIB for 2020) and found no significant impact on the results.
[5] Carbon Footprint (2020) Country specific electricity grid greenhouse gas emission factors
[6] BEIS (2020) Greenhouse reporting: conversion factors 2020
[7] Scottish Government (2021) Average greenhouse gas emissions per kWh of electricity

A SCOTTISH EAF PLANT COULD SAVE 60% OF GREENHOUSE GAS EMISSIONS ASSOCIATED WITH REPROCESSING STEEL.

Analysis: Comparing the carbon impacts of scrap steel production scenarios

Zero Waste Scotland has conducted an analysis to quantify the carbon benefits of producing scrap steel in Scotland. Life cycle assessment (LCA) was used to measure the greenhouse gas emissions associated with three scenarios:

Scenario 1: 100% of scrap steel is exported to Turkey and other major export locations; 45% is remelted via BF-BOF and 55% via EAF[8].
Scenario 2: 100% of scrap steel is processed in Scotland using an EAF[9].
Scenario 3: High-quality steel (16%) is reused in Scotland and the remaining scrap (84%) is sent to EAF in Scotland[10].

Each scenario considered the greenhouse gas impacts of producing one tonne of hot rolled steel in 2020. The scenarios were developed using data on Scottish steel material flows, including estimates of scrap steel arisings, export locations and production routes[10]. Most of the steel production material and energy inputs for BF-BOF and EAF plants were adapted from a study of steel production in China[11]. Nation-specific electricity grid factors were used. The analysis measures GHG emissions in 2020 and may not reflect future impacts.

The carbon impacts of the three scenarios are shown in Figure 2. Scenario 1 represents business as usual (BAU) and shows that each tonne of hot rolled steel produced from Scottish scrap emits around 1.6 tonnes of greenhouse gases. 60% of these emissions can be saved by moving to an EAF plant in Scotland (Scenario 2). Further savings are possible through reuse (Scenario 3), which depends on the share of high-quality scrap steel available.

[8] The scrap steel sent to the BOF-route is assumed to be combined with virgin steel production (82% virgin steel, 18% scrap) and these additional material requirements are included in the analysis, in accordance with standard LCA practice.
[9] The quality of output from an EAF is dependent upon the input material. However, an EAF-based steel reprocessing system could entirely replace primary steel production by seeding scrap steel with Direct Reduced Iron (DRI) produced using green hydrogen.
[10] Hall, R. (2020) Scottish Steel Sector Analysis, Table 5. Reuse is defined as repurposing steel without remelting.

Based on 2018 scrap steel generation in Scotland, the total carbon impact of producing steel from Scottish scrap is estimated to be up to 1.3 MtCO_2e per year. Switching to Scottish based EAF plant production would save 790,000 tCO_2e per year, or 60% saving compared to the 2018 baseline. This represents a significant proportion of Scotland's annual carbon footprint of 70.7 MtCO_2e and is a substantial saving (over 1%) which could be realised from better management of a single waste material[12 13].

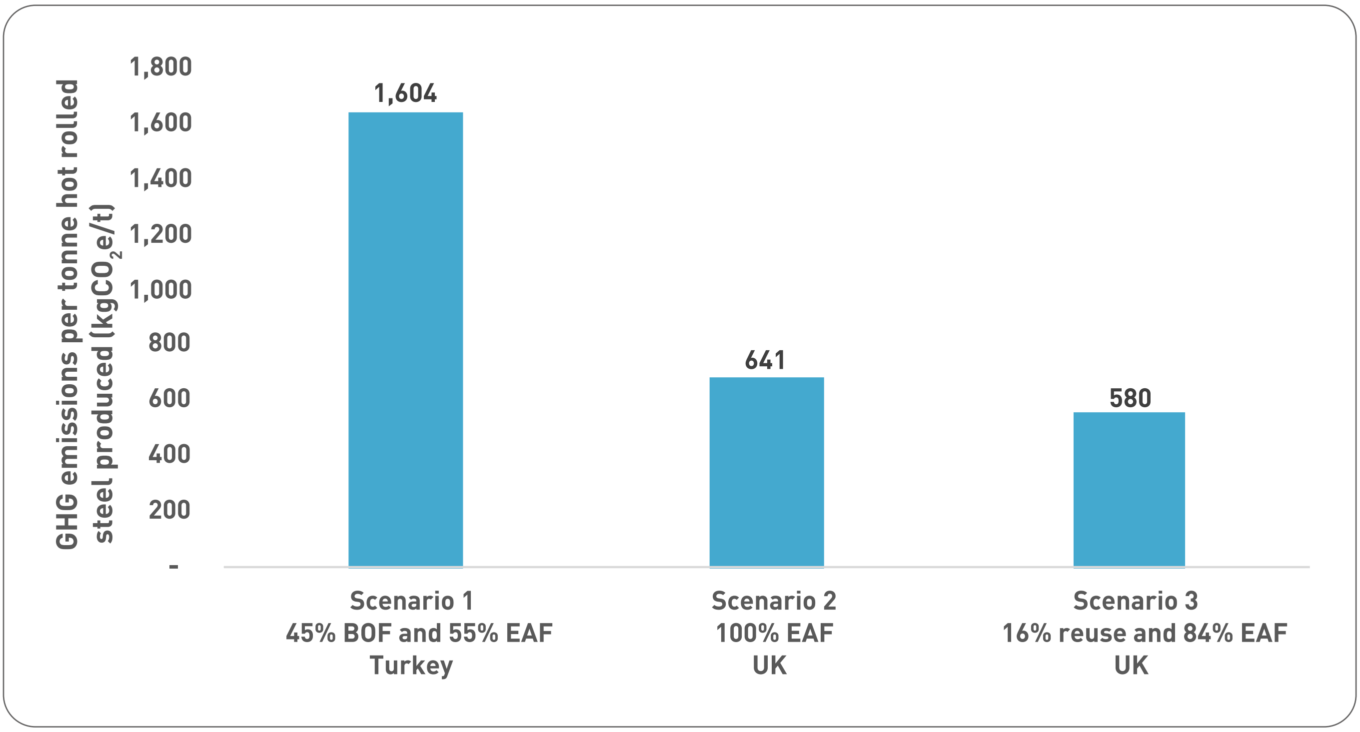

Figure 2 **Carbon impacts of Steel production from Scottish scrap scenarios**

[12] Scottish Government (2021) Scotland's Carbon Footprint

[13] These figures do not include the embodied impacts of building an EAF plant in Scotland (in line with LCA practice). The embodied carbon impacts are difficult to estimate without accurate site-specific data. However, a high-level estimate of the construction impacts of a medium sized (500,000 tonnes per annum) EAF plant and supporting infrastructure was estimated at 190,000 tCO_2e using Ecoinvent V3 data. The carbon cost of the plant construction would be paid back in less than a year, based on the savings suggested in this study. A more detailed analysis of this costs is required in the future.

ANALYSIS BY PRODUCTION STAGE

Figure 3 shows that the most carbon-intensive stage of the BAU case (Scenario 1) is the blast furnace, where coal is added. The most carbon-intensive stage of steel production in an EAF plant in Scotland (Scenario 2) would be the use of electricity in the EAF plant.

Transport has a marginal impact in both scenarios, despite the export of thousands of tonnes of steel overseas by ship[14]: the extraction, production and use of materials such as coal, iron and scrap steel, contributes a much greater share of the overall carbon footprint of steel production than transport.

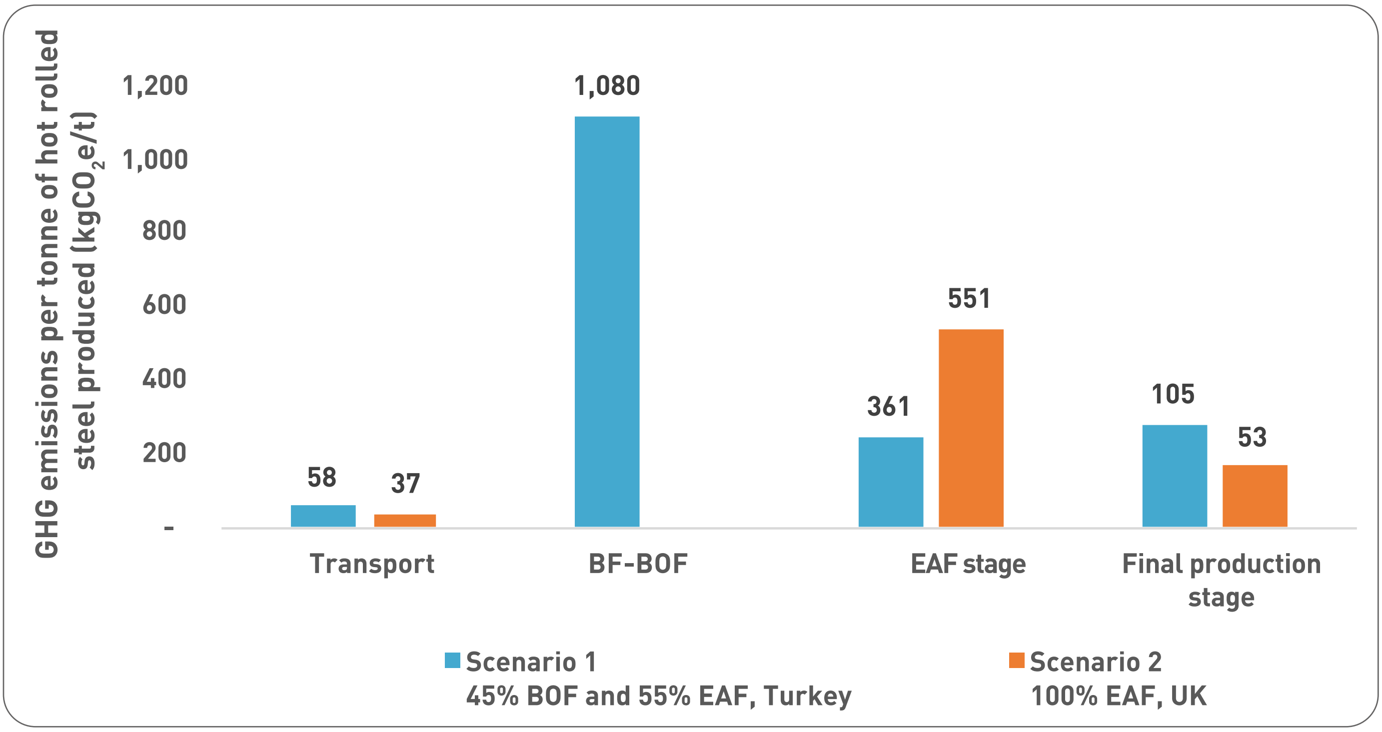

Figure 3 **Carbon impacts of scrap steel production scenarios, by production stage**

[14]Although modelling demonstrates that emissions from shipping are significantly lower than steel production emissions, any reduction in this activity still has a global emissions benefit.

The EAF route has a lower carbon footprint than the BF-BOF route, because it uses electricity rather than coal as a primary energy source. In addition, EAF plants can use 100% scrap steel to reduce their footprint even further. However, the extent of this added benefit depends on a steady supply of the most appropriate types of scrap to avoid the need for virgin material inputs.

When comparing EAF production locations, a low-carbon grid reduces carbon impacts substantially. A Scottish EAF plant would have 8% of the energy GHG emissions of a Turkish EAF plant (Figure 4). This is an important consideration, because it is harder to reduce the materials used in this process[15] and, therefore, their carbon impacts.

The energy demand of a medium sized (500,000 tonnes per annum) EAF plant, would consume about 218 GWh electricity[16]. This is comparable to 1.5% of Scotland's non-domestic electricity consumption in 2018[17]. At this scale of demand and supply, it is unlikely an EAF plant's electricity consumption would significantly affect grid requirements. However, a more detailed assessment of this issue is required, which should include consideration of the intermittent demand on the grid created by an EAF plant.

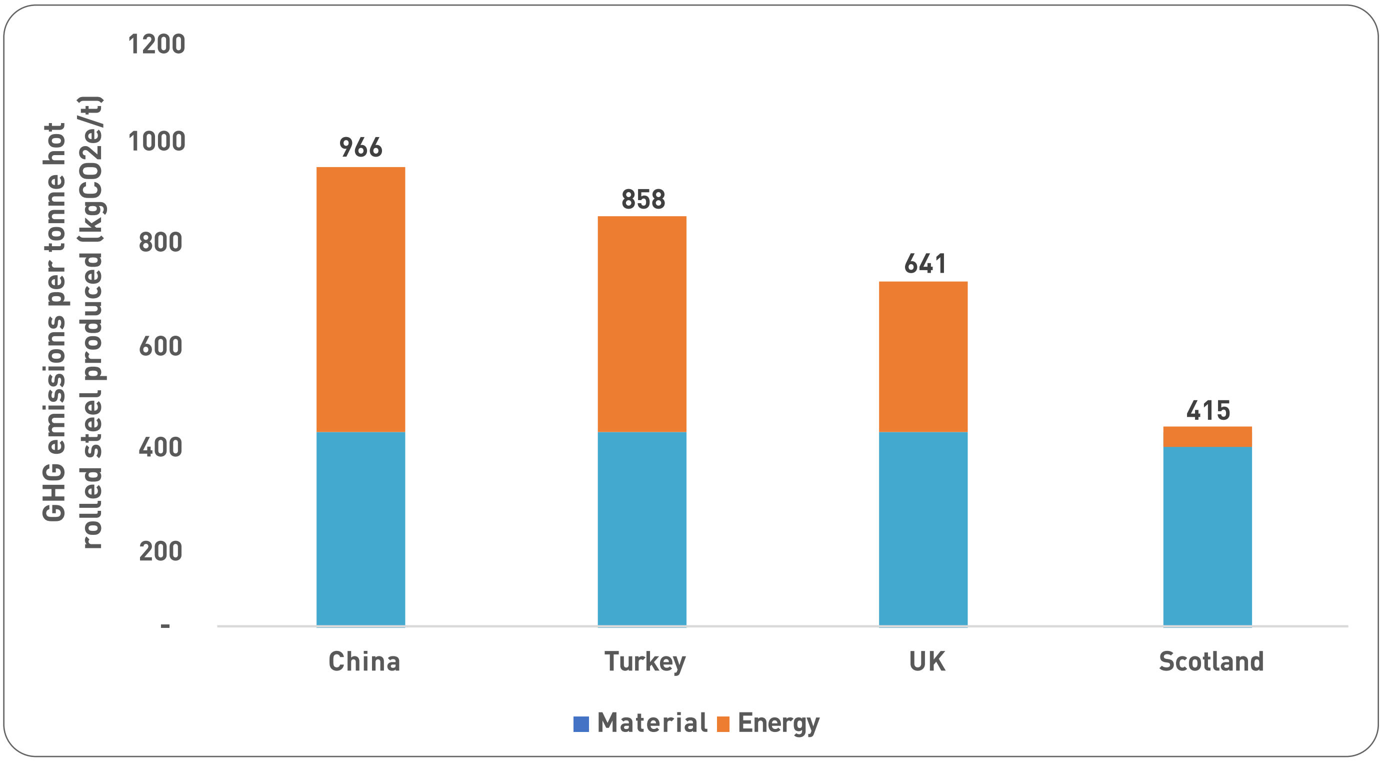

Figure 4 **Carbon impacts of EAF produced scrap steel (from 100% Scottish scrap) split by material and energy impacts**

[15] Material inputs to EAF include water and quicklime as well as scrap steel.
[16] Calculated based on EAF energy consumption from Liang et al. (2020).
[17] Scottish Government (2021) Scottish Energy Hub, Energy consumption by sector.

CONCLUSION

The carbon benefits of a transition to a more local, efficient scrap steel production route are clear and significant.

By developing an EAF plant for scrap steel in Scotland, emissions from material, transport and energy use could be reduced substantially, at a level that would make a tangible contribution to reducing Scotland's total carbon emissions. Change must happen fast to capitalise on Scotland's low carbon grid advantage. Further work is required to understand the long-term environmental case more fully. This should include site specific data of any potential EAF plants for Scotland, forecasting of national electricity grid intensity changes and the impact of EAF electricity demand.

There are other considerations which are also important in ensuring this opportunity is realised. In our next paper, Zero Waste Scotland will explore the economic and social factors central to this transition.


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