SUSTAINABLE STEEL MANUFACTURING

Professor Claire Davis
Warwick Manufacturing Group, University of Warwick
claire.davis@warwick.ac.uk

Dr Sumit Hazra
Sumit.Hazra@warwick.ac.uk

The steel industry is one of the major contributors to global CO_2 emissions, being responsible for around 5% of CO_2 emissions in the EU and 7% globally [1]. In the UK the steel industry contributes 2.8% of our CO_2 emissions, accounting for 14% of industrial green house gas emissions [2]. However, the steel sector is now undergoing a major transition away from high CO_2 emitting manufacturing processes with an accelerating pace of change being driven, in part, by increasing customer demands for 'green steel' to support reduction of Scope 3 emissions.*

The current steel making approaches are predominantly based on blast furnace-basic oxygen steelmaking (BF-BOS), which emits 2.32 tonnes of CO_2 per tonne of steel produced (tCO_2e/t) and electric arc furnace (EAF) production at 0.67 tCO_2e/t. Approximately 70% of world production was BF-BOS in 2021 and the global production (and consumption) of steel is almost 2 billion tonnes per year and continuing to grow, figure 1. Global steel consumption is predicted to continue to increase following population growth, with continued increased demand also predicted in the UK. An alternative to BF-BOS production is replacement with EAF, where the reduction in CO_2e is primarily associated with the substitution of iron ore and coke as the raw material feedstock by recycled scrap steel. EAF production accounts for around 30% of global steel production so is an established technology, however this is predominantly for lower quality steel grades such as re-enforcement bar for construction [4]. This is due to the pick up of residual elements (e.g. Cu, Sn, Cr) from the scrap steel, which affect the steel processing and properties. Where EAF is used to produce high performance steels careful sorting and selection of scrap steel is required and often additions of clean iron (direct reduced iron, DRI) are used to dilute the residual element content in the composition. Unfortunately, the production of DRI has associated CO_2 emissions, being 1.4 tCO_2e/t for natural gas fired DRI [5], however the trend is to move to hydrogen produced DRI. Significant investments are being made in hydrogen steelmaking, including sector leading projects such as Hybrit in Sweden / Finland [6], where fossil free production of iron pellets has been achieved at pilot plant levels and plans are in place to bring fossil free steel to the market by 2026. Investments are proposed by major steel producers in the EU to generate hydrogen DRI (for example at Tata Steel Netherlands [7]). This is alongside major investments to replace BF-BOS with EAFs and DRI (for example Eur 1 Bn for Salzgitter [8]). With the planned increase in EAF production there is growing demand for steel scrap, which is graded by quality. Increasing competition for steel scrap as a feedstock into EAF steelmaking will disrupt current supply chains; for example ArcelorMittal have acquired the Scottish recycling business John Lawrie Metals Ltd., as part of the company's strategy of increasing

* Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly affects in its value chain.

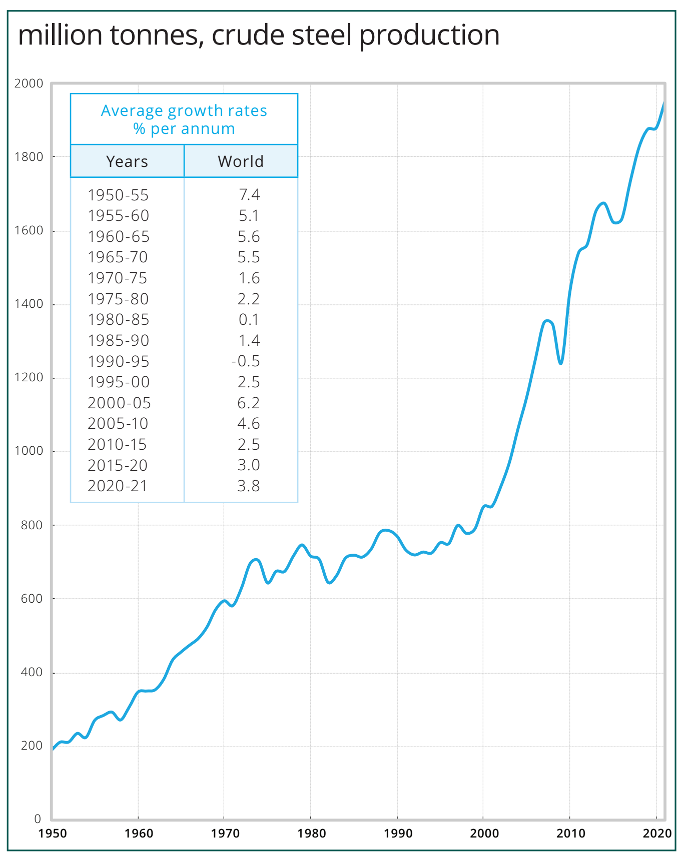

Figure 1: Growth in world steel production [3]

the use of scrap steel to lower CO_2 emissions from steelmaking[9].

The UK produces approximately 7 Mtpa of steel and contributes approximately £2.4 billion, 0.1% of the UK economy and 1.2% of manufacturing output and supported 39,000 jobs in Great Britain in 2021[10]. Current production is based on 78% BF-BOS and 22% EAF, with the EAF production being split between construction products (Celsa) and high performance steels (Liberty Steel and Forgemasters). The UK is in a favourable position for the transition to low CO_2 steelmaking via EAF as it produces 11.3 Mtpa of scrap steel, of which 8.7 Mtpa is exported. Therefore, there is potential for the UK to develop a sustainable supply chain for recycled scrap steel as feedstock into EAF steelmaking to meet the required UK demand for steel production. However, not all steel grades can be produced by the current quality of recycled scrap steel requiring investment in improved sorting technologies and parallel production (or importing) of (low CO_2) DRI. In addition, clean energy is required, at reasonable cost, to allow steel production to be 'green' and competitive as steel is a globally traded commodity.

The change in steel production away from BF-BOS to EAF (with DRI) requires huge investments due to the expensive infrastructure associated with the industry. Alignment with planned refurbishment or replacement of ageing plant is obviously preferred but also requires associated development in green energy, such as hydrogen production and networks. Implementation of new technologies to the steel industry are also being considered for reducing CO_2 emissions using the current infrastructure. Carbon capture utilisation and storage (CCUS) trials with the steel industry are being announced globally[11, 12], potentially allowing BF-BOS steelmaking at very low tCO_2e/t levels, which could be an important approach for production of high quality steels. Approaches to use low CO_2 energy vectors, such as biomass, within the BF-BOS route and increasing the input of recycled steel scrap (current levels can be up to 20% scrap use) can help soften the transition and provide shorter term benefits in reducing CO_2 emissions.

A sustainable UK steel industry provides significant benefits to the wider UK manufacturing sector. For example, approximately 900 kg of steel is used per vehicle[13] with Britain's biggest car factory, Nissan in Sunderland, making around 500,000 cars a year with around half the steel being supplied from the UK[14]. At around 2.32 tonnes of CO_2 per tonne of steel produced by the BF-BOS route significant savings will arise from transitioning to 'green steel', with domestic supply chains providing manufacturing resilience and low transportation CO_2 costs.

Sustainability in the steel sector not only requires changes to the steel production methods but consideration of material efficiency and material circularity. Material efficiencies include strategies such as using higher strength thinner sections, reducing product size (for example smaller cars) and designing for longer life (including repair). Material circularity includes reuse and remanufacturing of steel components. The construction sector already promotes the reuse of steel construction products, with expected increases in the amount of steel that can be reused as design for disassembly becomes more widespread, which is being facilitated by standardisation of components and connections[15]. The Steel Construction Industry (SCI) has published a protocol setting out recommendations for data collection, inspection and testing to ensure that reclaimed structural steelwork can be reused with confidence[16]. Research carried out by the Steel Construction Institute[17 ref. in 15] has estimated that there is around 100 million tonnes of steel in buildings and infrastructure in the UK. This 'stock' of steel is an important and valuable material reuse that will be reclaimed and either reused or recycled in the future. Increasing material reuse and reducing material usage is important as it may lead to lower cost of products, leading to improved standards of living as longer term (by 2050), it is expected that material prices will rise as the earth's natural resources get depleted[18].

Increased reuse and advances in design for disassembly and sortation of end-of-life products, to provide high quality 'scrap' steel as feedstock into low CO_2 steelmaking, will provide sustainability to the steel industry and wider sustainability for UK manufacturing.

Acknowledgements:
Professor Zushu Li and Dr Russ Hall from WMG, University of Warwick

Further reading recommendation:
UK Parliament POSTNOTE Number 672, May 2022

References:

1. IEA. (2020). Iron and Steel Technology Roadmap). https://www.iea.org/reports/iron-and-steel-technology-roadmap
2. ONS (2021). Atmospheric emissions: greenhouse gases by industry and gas. https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsatmosphericemissionsgreenhousegasemissionsbyeconomicsectorandgasunitedkingdom
3. World Steel in Figures 2021-22, https://worldsteel.org/wp-content/uploads/World-Steel-in-Figures-2022-1.pdf
4. Christensen CM, 'The Innovator's Dilemma', Harvard Business School Publishing, 2016, p.67
5. Comparative life cycle assessment of natural gas and coal-based directly reduced iron (DRI) production: A case study for India, Journal of Cleaner Production Volume 347, 1 May 2022, 131196, https://doi.org/10.1016/j.jclepro.2022.131196
6. https://www.hybritdevelopment.se/en/
7. https://www.tatasteeleurope.com/corporate/news/Tata-Steel-invests-65-million-euroin-next-phase-hydrogen-route
8. https://www.salzgitter-ag.com/en/newsroom/press-releases/details/salzgitter-ag-receives-official-notice-of-government-funding-for-the-salcosr-low-co2-steel-production-program-20702.html
9. https://corporate.arcelormittal.com/media/news-articles/arcelormittal-acquires-steel-recycling-business
10. Contribution of the steel industry to the UK economy https://commonslibrary.parliament.uk/research-briefings/cdp-2023-0016/
11. https://www.jfe-steel.co.jp/en/release/2022/220620-2.html
12. https://corporate.arcelormittal.com/media/news-articles/carbon-capture-in-the-steel-industry-arcelormittal-mitsubishi-heavy-industries-engineering-bhp-and-mitsubishi-development-sign-collaboration-agreement
13. https://worldsteel.org/steel-topics/steel-markets/automotive
14. https://www.autocar.co.uk/opinion/industry/how-car-industry-could-save-britain%E2%80%99s-steel-industry
15. https://www.steelconstruction.info/Recycling_and_reuse#Reusing_structural_steel
16. SCI P427 Structural Steel Reuse, Assessment, testing and design principles, 2019
17. Ley, J.: An environmental and material flow analysis of the UK steel construction sector, DEng thesis submitted to the University of Wales
18. https://www.unep.org/explore-topics/resource-efficiency/what-we-do/international-resource-panel ■