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RP3.005
STEEL SCRAP AS A STRATEGIC COMMODITY FOR GREEN STEEL CIRCULARITY AND ANALYSIS OF TRAMP ELEMENTS ACCUMULATION

Policy brief

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PROJECT

RP3.005 Market, cost and locational factors for green iron and steel in Australia

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OTHER MATTERS:

STEEL SCRAP AS A STRATEGIC COMMODITY FOR GREEN STEEL CIRCULARITY AND ANALYSIS OF TRAMP ELEMENTS ACCUMULATION

Recycled steel and iron scrap is increasingly seen as a valuable commodity as countries move to decarbonise steel supply chains. Ferrous scrap can replace primary pig iron in steelmaking, avoiding the emissions associated with producing iron with coking coal in blast furnaces, and significantly reducing the overall carbon footprint of steel. However, not all scrap is equally suitable for recycling and impurities in low-quality scrap can accumulate and affect steel quality. Scrap from finished goods can include a mix of other materials which introduce impurities into the steelmaking process. While these impurities can be removed in a traditional basic oxygen furnace (BOF) as slag, they cannot be easily removed in electric arc furnaces (EAFs). With increasing circularity in domestic steelmaking and a move towards lower emission EAFs, it is critical to understand the impurities that would accumulate from successive recycling steps. Understanding how much steel scrap is generated in Australia, where it comes from, and how much is traded with other countries is critical to assess the amount of suitable scrap available for decarbonisation of domestic steelmaking.

This brief summarises the findings from an analysis of the quantity and quality of scrap generated in Australia and a sophisticated study of the accumulation of impurities during recycling of steel, carried out as part of HILT project RP3.005. Our findings show that about 40% of the roughly 4Mt of steel scrap generated annual in Australia is of high quality, and that just over half of the scrap is exported. Increasing circularity by using domestic scrap locally could provide enough scrap feedstock to more than double the production of steel from scrap and would avoid roughly 4.8 MtCO_2 emissions. Strategic interventions such as incentives to retain scrap onshore, investment in electric arc furnace capacity, and support for impurity mitigation technologies could support both circularity and decarbonisation goals of the Australian steel industry.

Globally, 70% of steel is produced through the heavily emitting BF-BOF pathway: using coal to reduce iron ore to pig iron, which is further refined to steel in a basic oxygen furnace with more coal. The remaining 30% is produced by electric arc furnace (EAF), which uses electricity to refine a mix of recycled steel and pig iron from the blast furnace, replacing the basic oxygen furnace step. To reduce emissions further, fossil fuels can be replaced in the iron making step with hydrogen (in a blast furnace, shaft furnace or fluidised bed reactor) or by electrolysis, although this is less commercially ready, to get direct reduced iron (DRI) to feed into the EAF. Currently, only a very small amount of DRI is produced globally. Both BOF and EAF can use scrap steel as a feedstock: EAF can take up to 100% recycled steel, while BOF can accept up to 30% (WSA). While DRI ramps up and EAF capacity expands, replacing primary pig iron with recycled steel represents a significant opportunity to decarbonise and increase circularity, reducing overall intensity of steelmaking from 2.32 kgCO_2/kg crude steel (average for BF-BOF pathway in 2024, WSA) to 0.7 kgCO_2/kg crude steel (average for scrap-EAF, WSA). The key limitation is the availability of scrap steel for recycling, and the quality of that scrap.

We employ a systematic materials flow analysis approach combined with mass balance using data taken from Australia's National Waste Database, Australian Bureau of Statistics, Steel Statistical Yearbook, and UN Comtrade to identify and track scrap generation and trade in Australia. The quality of Australian scrap is estimated by classifying scrap by intermediate steel product type in each end-sector, each of which have different specifications for tramp element inclusion (i.e. the sum of the densities of Cu, Sn, Cr, Ni and Mo elements contained within the steel). We then estimate the accumulation of tramp elements in the steel products after multiple scrap utilisations through computational equilibrium thermodynamics modelling, assuming a 'closed system' where all steel is recycled domestically. We define scenarios to explore different ratios of BOF and EAF steel production capacity within the closed system. Together, these analyses allow us to assess the potential for circularity to drive decarbonisation in Australia.

We find that approximately 4 million tonnes of steel scrap were recovered annually in Australia over the last few years, and that on average, Victoria and New South Wales together contribute about 63% of the total. Most Australian scrap is collected 'post-consumer' which is designated as high residual scrap (~54%-67% from 2013–2022), as it includes relatively complex products at the end of life. This means that 60% of Australian steel scrap falls within the low-quality categories: Q3 (0.25-0.35% total tramp elements) and Q4 (>0.35% total tramp elements). The rest is recovered from manufacturing (28%) and fabrication (12%), which tends to result in higher quality scrap as it is mostly from flat intermediate steel products. This means that around 40% of Australian scrap can be assigned to Q1 (<0.18% total tramp elements) and Q2 (0.18- 0.25% total tramp elements) categories (Figure 1).

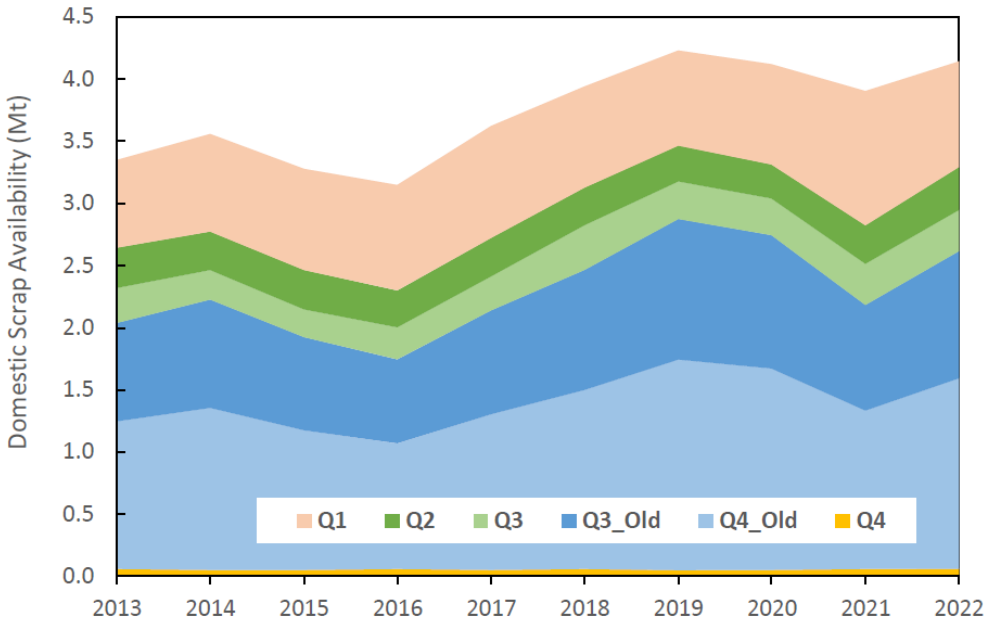

Figure 1. Quantity of scrap generated in Australia categorised by quality. Higher quality scrap tends to be from the manufacturing and fabrication of intermediate steel products, categorised as Q1 or Q2 depending on the fraction of tramp elements included in the steel: Q1 <0.18% and 0.18<Q2<0.25%. Post-consumer scrap from end-of-life products tends to result in low-quality scrap: Q3 0.25<Q3<0.35% and Q4 >0.35%.

Of this scrap, just over half was utilised locally, and the rest exported overseas, with Bangladesh, Vietnam, and Indonesia the top three export destinations. The high export volume reflects the low demand for scrap steel in Australia, as currently only a small proportion of steel is produced via EAF of scrap, ~12-17% between 2013-2022. However, annual Australian scrap consumption is consistently increasing, doubling from 1.1 Mt in 2013 to 2.3 Mt in 2022. This trend is driven by increasing domestic production of steel products, and particularly from increases in production via EAF, as well as a small increase in the proportion of scrap used in both BF-BOF and EAF routes domestically.

We then assess how maximising circularity by recycling domestic steel would affect the quality of the final steel product by modelling the accumulation of impurities assuming a closed system where all scrap is recycled and then used domestically. Understanding the extent of impurities accumulation is crucial to ensuring the quality of the newly produced steel. The outcomes depend on whether scrap is processed via the BOF route, mixed with pig iron at a maximum concentration of 20%, or in an EAF at 100%. When processed via the BOF route, the impurities are no longer present in significant amounts in the remaining steel output after the first cycle as the addition of primary pig iron reduces the percentage of tramp elements.

This phenomenon, known as the dilution effect, results in a gradual decline in tramp element concentrations. In contrast, in an EAF, the concentrations of copper, nickel, molybdenum, and tin continuously increase due to the absence of dilution from hot metal and slag removal.

Figure 2 shows the effect of the different mix of production routes on the ultimate retention of the tramp elements in steel, after an infinite number of recycling steps, as a function of the EAF portion in the steelmaking process and initial scrap quality. Increasing the EAF portion in the steel production mix increases tramp elements as more scrap is used and it can extend the number of cycles required for these elements to stabilise because the dilution effect is less pronounced. It is evident that using 100% EAF results in significantly higher accumulated tramp elements over extended time compared to scenarios that include a portion of the BOF route. The inset graphs present data for the 0–70% EAF cases to highlight trends on a smaller scale. The results clearly indicate that increasing the EAF portion, or utilising more scrap, leads to higher tramp element accumulation. However, this increase remains relatively minor even as the EAF share reaches 70%. Beyond this point, however, the accumulation of elements becomes more pronounced.

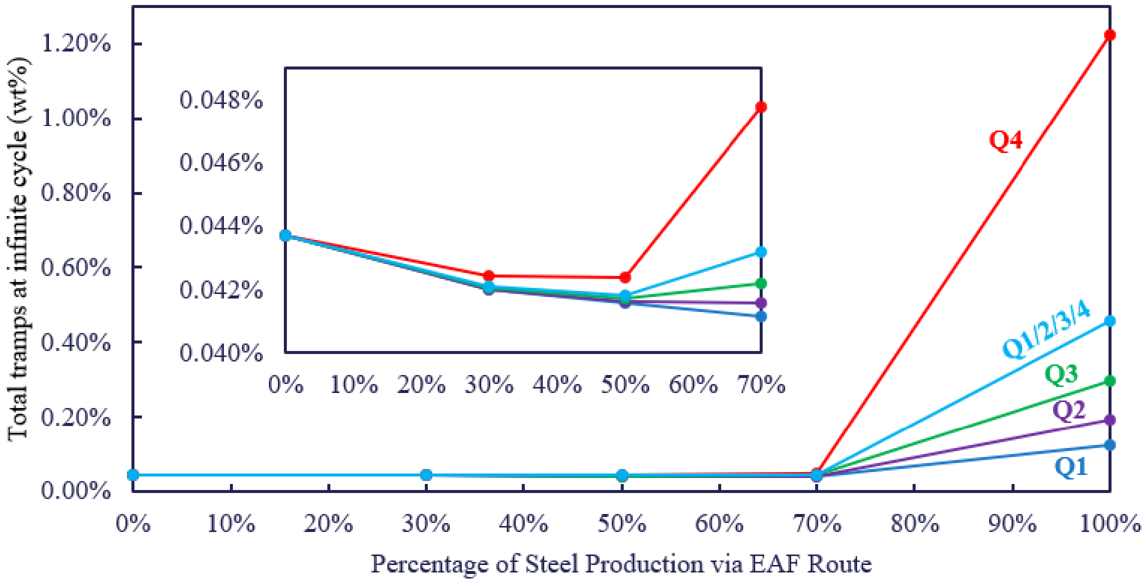

Figure 2. The change in the accumulated tramp elements in recycled steel, assuming a closed, circular system where all scrap is recycled domestically. The percentage of steel produced in the system from 100% recycled steel via EAF is varied. The remaining fraction is produced by standard BF-BOF routes using 20% scrap and 80% primary iron feedstock. Tramp elements include copper, nickel, tin, and molybdenum.

Maximising circularity within the steel industry requires that all scrap generated in Australia would be recycled and processed into steel domestically. The analyses in this report can be synthesised to assess the potential for circularity to drive decarbonisation in Australia. Figure 3 shows that Australian steel producers could access an additional 1.74 Mt of recycled steel by stopping exports of scrap. If all of this scrap were kept onshore, it could provide feedstock to more than double production via EAF, from current value of 1.43 Mtpa to ~3 Mt, and avoid roughly 4.8 $MtCO_2$ emissions, (assuming steel would have been produced using the BF-BOF route, with 2.3 $kgCO_2$/kg crude steel, and is now produced with 0.7 $kgCO_2$/kg crude steel (WSA)). Assuming total production in Australia stays the same (at 5.62 Mt) this would mean that 56% of Australian steel production could be processed via the EAF route utilising domestic steel scrap. At this portion of production, tramp accumulation should remain below 0.05% for all scrap quality categories.

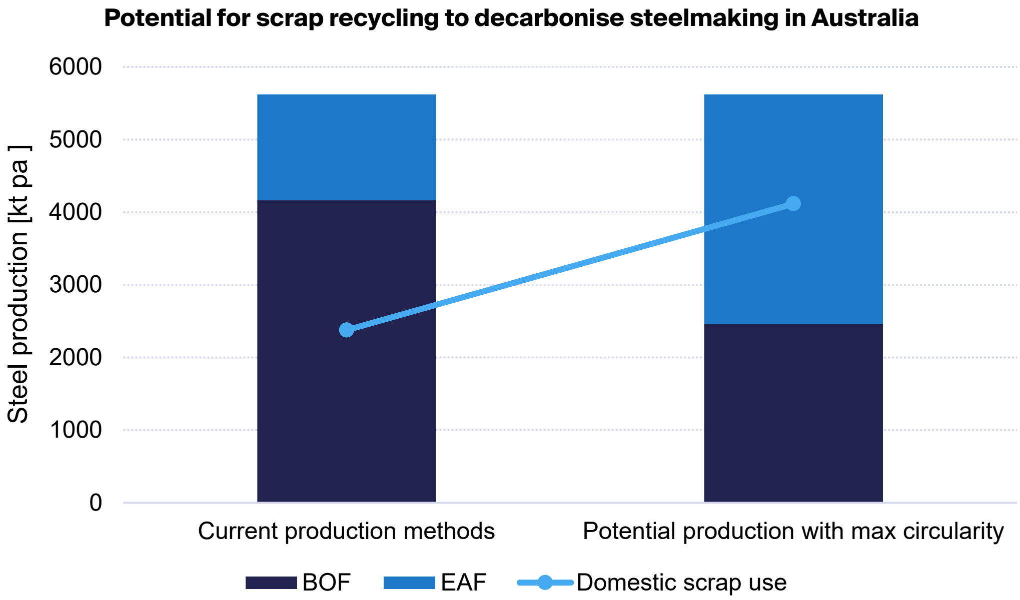

Figure 3. Potential for scrap recycling to decarbonise steelmaking in Australia. Graph compares the current mix of steelmaking in Australia with a scenario where all domestic scrap is recycled in Australia via a mix of EAF (at 100% mix) and BOF (at 20% mix), assuming no increase in the total steel manufacturing capacity.

From a policy perspective, these findings highlight that maximising domestic scrap recycling could substantially reduce emissions in Australia's steel industry, i.e. up to 4.8 $MtCO_2$ annually, by shifting production toward EAFs. However, policies must also account for tramp element accumulation, which can compromise steel quality if scrap recycling is expanded without BOF blending or improved impurity management technologies. Strategic interventions, such as incentives to retain scrap onshore, investment in EAF capacity, and support for impurity mitigation technologies, could enable Australia to advance both circularity and decarbonisation goals in steelmaking.

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