



The Copper Ceiling: Why Scrap-Based Steelmaking Has a Shelf Life

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How Copper Accumulation Limits Steel Recycling

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Executive Summary

Scrap-based EAF steelmaking is central to steel decarbonisation, but it carries a built-in limit. Copper enters steel from scrap and cannot be refined out. With every recycling cycle, the copper locked into the scrap pool rises. Starting from today's level of around **0.12% contained copper**, three illustrative scenarios to 2100 show how quickly that level could climb.

Under the base case, contained copper crosses the 0.50% tolerance of rebar and merchant bar in the **early 2060s**, and by the late 2050s in the pessimistic case. Keeping steel within specification would then need large tonnages of copper-free virgin iron. By 2070, the base case implies around **900 million tonnes a year**, or roughly half the average EAF charge.

Where that iron comes from depends mainly on the cost of green hydrogen. Cheap hydrogen makes hydrogen-based DRI the natural diluent, aligning copper management with climate goals. Expensive hydrogen favours gas-based DRI and a permanent residue of blast furnace capacity, in direct tension with carbon policy. Scrap-side measures can slow the build-up of copper but cannot stop it. Policymakers, hydrogen investors and steel producers should plan for the constraint now, while lead times still allow.

Introduction

Every tonne of scrap melted into steel brings a small amount of copper with it, and no commercial refining process can take it out. Unlike carbon, phosphorus or sulphur, copper cannot be oxidised away. It stays in the product and returns to the scrap pool when that product is scrapped. Today the



effect is modest: average obsolete scrap carries around 0.12% contained copper. But the copper-rich products of the electrification era have not yet reached the scrap yard. When they arrive, from around 2040, even rebar and merchant bar could need dilution with virgin iron by the 2060s.

This matters because the world is betting heavily on [scrap-based EAF steelmaking](#) to cut emissions. Full circularity has a shelf life, and few in the trade or policy community are discussing it. The copper-free iron needed to extend that shelf life can come from hydrogen-based [DRI](#), gas-based [DRI](#) or residual blast furnaces. Which of these supplies it depends mainly on the future cost of green hydrogen.

Why Copper Is Different

Steel scrap already carries a range of residual elements picked up from earlier alloying or from components attached to end-of-life products: nickel, chromium, molybdenum, tin, and copper among them. Most of these can be diluted, blended, or in some cases partially removed. Copper is the exception. Once melted into liquid steel, no commercial refining process pulls it back out. Some research groups are exploring leaching, sulphidising and selective melting techniques to extract copper before or during melting, but these remain experimental and have not reached commercial scale.¹

The practical consequence is well understood at the plant level. Excess copper causes hot shortness, a form of surface cracking that appears during hot rolling, along with reduced ductility in flat-rolled products. This is why automotive exposed panels specify copper limits as low as 0.06%, while less demanding [long products](#) such as merchant bar and rebar tolerate levels up to 0.50%.²

Copper tolerance by application

Application	Maximum copper
Automotive exposed panels	0.06-0.08%
Deep-drawing tinplate and electrical steel	Below automotive exposed panel limits
General engineering and structural bar (SAE/ASTM standard residual limits)	0.35%
Merchant bar and rebar	0.50%

For reference on the feedstock side, premium prompt industrial scrap typically carries around 0.10% copper. Mixed obsolete No. 2 bundles can reach close to 1.0%, which is why blending strategy matters as much as the average figure.² This table, and the analysis that follows, applies to carbon and low-alloy



steel. Stainless steel falls largely outside its scope. Some grades, such as 17-4PH, add copper deliberately at 3-5% for precipitation hardening, inverting the contamination framing entirely. Stainless melting also generally runs on a separate scrap circuit from carbon and low-alloy steel.

Producers manage this today through blending. They route high-copper scrap toward tolerant products, pay a premium for clean prompt scrap, and dilute with copper-free DRI or HBI where flat-rolled specifications demand it.

Copper becomes a long-run problem, not just a routine input-quality issue, once dilution stops being cheap. It only works while copper-free iron units remain affordable and available relative to the tonnage that needs diluting. As the copper content of average scrap rises, and as EAF share of global steel production grows, both sides of that equation move the wrong way at once. Metallic inputs are already the largest single element of EAF production cost, as the [SteelOnTheNet EAF Cost Model](#) shows. Any rising premium for clean iron units therefore feeds straight into margins.

Today's Baseline: A Manageable 0.12%

A recent World Steel Dynamics assessment of the US scrap stream offers the clearest published baseline available.² Built on International Iron Metallurgy Association data, it is the source for the current-level figures below. The global scenarios, dilution modelling and hydrogen analysis that follow are SteelOnTheNet's own.

The World Steel Dynamics assessment distinguishes between two categories. "Contained" copper is already melted into the steel matrix from earlier cycles, while "free" copper is still physically attached to shredded fragments but not yet melted in. Average obsolete scrap today carries approximately 0.12% contained copper and 0.18% free copper, for a total of around 0.30%.²

The contained figure is the one that matters for a long-run model. Free copper is a flow variable: whether it becomes contained copper next cycle depends on shredder and scrap-yard removal efficiency, currently estimated at around 93% under typical operating practice.² Contained copper, by contrast, is a stock variable. It cannot be removed by any future improvement in sorting technology; it can only be diluted by blending in copper-free iron. This is the number that only moves in one direction absent deliberate intervention.

At 0.12% contained copper, today's system sits comfortably within tolerance for every product category except the most demanding automotive and electrical grades. Those already rely on premium prompt scrap and DRI blending. Earlier SteelOnTheNet analysis of [virgin steelmaking requirements in G7 economies](#) put these copper-sensitive applications at around 5% of steel use today. The question this article addresses is how long that comfort lasts.

The Compounding Mechanism: Cohorts, Not a Straight Line

It is tempting to model copper accumulation as a smooth annual growth rate, in line with the roughly 3-4% compound annual growth rate forecast for global copper demand.² That demand is driven by EV adoption, data centre electricity growth, and broader electrification. This would be a mistake. Copper does not enter the scrap stream when it enters a product; it enters the scrap stream when that product is scrapped, often decades later. Vehicles carry a lag of roughly fifteen years between purchase and scrapping. Machinery runs twenty to thirty years. Copper embedded in buildings can sit for forty years or more before demolition.²

This lag structure means scrap arising in any given year blends several historical cohorts. Each cohort carries the copper intensity of the era in which it was manufactured, not the copper intensity of products being built today. Today's scrap pool is still dominated by vehicles, appliances and machinery built mostly in the 2000s and 2010s, a pre-EV pre-mass-electrification era. That is a significant part of why today's contained copper level remains manageable.

The cohort now entering use carries substantially more copper. An EV contains up to four times the copper of a comparable internal combustion vehicle.² Smart buildings, expanded electrical infrastructure and denser wiring in modern construction point the same way. That higher-copper cohort is not yet in the scrap pool. It is queued up, and it will arrive in a wave beginning roughly fifteen years from now for vehicles, and considerably later for machinery and buildings.

Academic modelling supports this step-change framing over a smooth growth-rate framing. Researchers at the University of Cambridge built a full global steel supply chain copper mass balance and a dynamic stock-saturation demand model. They found that copper arising from conventional scrap preparation can be managed within the global steel system until around 2050, assuming coordinated global trade and extensive dilution. Beyond that point, the strategy becomes increasingly impractical.³ A separate European study found that the growing surplus of low-quality scrap will constrain the proportion of usable EU scrap to around 55% by 2050. This forces dilution with new steel and export of the remainder.⁴

A separate, independently constructed multi-cycle thermodynamic model, published in 2026 and applied to the Australian scrap system, reaches a consistent conclusion. As the share of EAF production rises, tramp element concentration, led by copper, rises with it across successive recycling cycles. The effect becomes pronounced under high-EAF-share production scenarios.⁵ Three independent studies, using different data and different geographies, point to the same underlying mechanism. The two with dated projections both place the pressure point around 2050.

Three Scenarios to 2100

To illustrate the shape of the problem rather than claim false precision, three tentative scenarios are set out below. They track contained copper concentration in average global scrap from today to 2100. The base case anchors on the World Steel Dynamics 2035 projection and the Cambridge 2050 threshold, then extends the trend using the cohort-lag logic described above. The pessimistic case assumes no improvement in shredder removal efficiency and faster-than-expected electrification. The optimistic case assumes removal efficiency improves toward the 97-98.5% range WSD identifies as technically achievable, combined with sustained growth in DRI dilution capacity.²

Year	Pessimistic	Base case	Optimistic
2026	0.12%	0.12%	0.12%
2035	0.22%	0.20%	0.16%
2050	0.38%	0.32%	0.20%
2060	0.55%	0.45%	0.24%
2070	0.75%	0.60%	0.28%
2080	0.95%	0.75%	0.32%
2090	1.15%	0.90%	0.35%
2100	1.35%	1.05%	0.38%

A note on precision. The scenarios and tables in this article are illustrative, not a validated forecast.⁶ They rest on stated simplifying assumptions: a constant global EAF production figure, a single blended target specification, and a smoothed extrapolation between two properly sourced anchor points. Those anchors are the World Steel Dynamics 2035 projection and the Cambridge 2050 threshold. The true rate of copper accumulation could plausibly run faster or slower than any of the three scenarios shown here, depending on future removal technology, product design, and trade patterns. The purpose of this analysis is not to fix a date or a tonnage. It is to establish the direction of the underlying mechanism, and the conclusion that follows from it: scrap-based steelmaking has a shelf life. The timing of the hydrogen cost curve, not the precise copper trajectory, is what determines how that constraint plays out.

Two reference points give these figures context. Automotive exposed panel tolerance, at 0.06%, is already breached by average scrap today. This is precisely why premium prompt scrap and DRI blending are already standard practice for flat-rolled automotive production. The same quality logic helps explain [Japan's continued commitment to integrated steelmaking](#), given its large exports of premium automotive steel. The more consequential threshold is merchant bar tolerance, at 0.50%, since this represents the point at which even the most copper-tolerant commodity products require further dilution. Under the base case, contained copper alone crosses this threshold in the early 2060s. Under the pessimistic case, it crosses in the early 2070s. Under the optimistic case, it crosses in the early 2080s.



the pessimistic case, the crossing happens by the late 2050s. Only the optimistic case, combining improved removal technology with sustained DRI capacity growth, avoids the crossing within the century.

What Dilution Actually Requires

Concentration figures alone understate the scale of the challenge. What matters operationally is the tonnage of copper-free virgin iron units needed to bring an average tonne of scrap back within specification. The required virgin iron fraction follows a simple relationship: one minus the ratio of the target copper specification to the contained copper level in the scrap being diluted.

This can be applied to a blended target specification of 0.30%, representing an average product mix across tolerance bands. Global EAF production is held flat at an illustrative 1.8 billion tonnes a year, to isolate the copper effect from separate questions of demand growth. This produces the following indicative virgin iron dilution requirement.

Year	Pessimistic (<u>Mt/yr</u>)	Base case (<u>Mt/yr</u>)	Optimistic (<u>Mt/yr</u>)
2050	~380	~110	~0
2070	~1,080	~900	~0
2100	~1,400	~1,285	~380

Their value lies in the shape of the curve rather than the specific tonnage. Dilution requirements stay negligible for roughly two more decades, then rise steeply from the middle of the century onward under both the base case and the pessimistic case. By 2070, the base case implies that around half of the average EAF charge would need to be virgin iron. Even the optimistic case requires dilution by the 2080s.⁶ This is consistent with a broader finding in the literature. Scrap-based steelmaking, taken to its logical conclusion without intervention, is not indefinitely self-sustaining once copper is treated as a system-wide constraint rather than a per-plant blending problem.

The Hydrogen Fork

The tonnage above must come from somewhere, and this is where the copper problem intersects directly with steel's decarbonisation strategy. Copper-free virgin iron units can be supplied by three routes, each sitting on a different cost and carbon curve: [hydrogen-based DRI](#), natural gas-based DRI, or residual BF-BOF hot metal. Which of these becomes the default diluent over the coming decades depends substantially on the future cost of hydrogen. It does not depend on the copper mass balance itself, which is largely fixed by the scenarios above.

Two broad futures are worth setting out as genuine alternatives, since the honest answer is that either is plausible today.



Some industry roadmaps project green hydrogen costs falling toward \$1-1.50 per kilogramme by the 2040s and 2050s. At that price, hydrogen-based DRI becomes cost-competitive as the default copper diluent. In this future, the copper problem and the decarbonisation agenda converge. The hydrogen-DRI capacity the industry needs to build for climate reasons in any case also solves the dilution requirement. Copper management becomes an additional demand driver reinforcing existing hydrogen infrastructure investment, rather than a competing claim on capital.

Past experience counsels caution. As earlier SteelOnTheNet analysis of [green steel timelines](#) showed, each update of the hydrogen cost curve has pushed the competitive crossover further into the future. If hydrogen costs remain elevated, in the \$3-4 per kilogramme range associated with slower electrolyser cost reduction and constrained renewable power availability, the picture diverges sharply. Producers facing a growing dilution requirement then gain a real incentive to rely on gas-based DRI. Some may also preserve residual BF-BOF hot metal capacity specifically as a copper-free iron source. This is not because integrated steelmaking is competitive on tonnage cost, but because it remains the cheapest reliable route to guaranteed copper-free iron at scale. This need not mean a return to blast furnace steelmaking at current scale, since gas-based DRI could carry much of the load. It would instead be a permanent, carbon-intensive residual function, sized to the dilution requirement rather than to total steel demand. It would also sit in direct tension with decarbonisation and CBAM-style carbon policy, both of which are designed to eliminate exactly this kind of capacity. How carbon pricing is already [splitting the steel industry into two worlds](#) suggests that tension would be felt unevenly across regions.

Implications for Policy and Investment

Three implications follow, aimed respectively at policymakers, hydrogen infrastructure investors, and steel producers planning capacity beyond the current investment cycle.

For policymakers, the copper constraint argues for treating hydrogen cost reduction as [materials security](#) policy, not only as climate policy. Current European and national decarbonisation frameworks, including the schemes discussed in earlier SteelOnTheNet analysis of the [EU Steel and Metals Action Plan](#), are built around emissions targets. None currently account for a secondary, non-climate rationale for hydrogen-DRI capacity: keeping scrap-based steelmaking viable at all, for a widening range of products, as the century progresses.

For hydrogen infrastructure investors, the dilution requirement modelled above suggests total long-run hydrogen-DRI demand may be understated in models that consider decarbonisation drivers alone. That includes the [trillion-dollar hydrogen infrastructure estimates](#) already attached to steel decarbonisation. Copper dilution adds a second, independent demand curve. It strengthens the investment case for hydrogen if costs fall as planned. If they do not, it weakens the case for hydrogen specifically, while strengthening the case for virgin iron capacity generally.

For steel producers and their advisers, the practical takeaway is clear. Copper management deserves to be treated as a strategic sourcing and capital planning question with a multi-decade horizon, not solely an operational blending problem to be solved load by load. Scrap contracts, DRI offtake agreements, and long-term capacity planning should increasingly account for the direction, if not the precise timing, of the trends set out here.

Hydrogen decides how the constraint resolves, but scrap-side policy can slow the clock. Six levers stand out.

Policy levers worth considering

- **Scrap grading and classification.** Existing scrap grade specifications do not identify copper levels. A recognised, copper-denominated grading standard, alongside the traditional weight-based grades, would let the market price copper content directly rather than through informal load-by-load negotiation.
- **Mandatory testing and disclosure.** Routine copper testing at scrap yards and mill gates, with results attached to shipment documentation, would improve price signals. It would also give producers better visibility of the feedstock they are actually buying.
- **Design-for-disassembly requirements.** Extending producer responsibility rules for vehicles, appliances and electrical equipment to cover ease of copper component removal would reduce free copper entering the shredder in the first place. This addresses the problem at source, rather than relying solely on downstream sorting.
- **Trade policy alignment.** Scrap export restrictions, increasingly common as governments protect domestic EAF feedstock, currently focus on retaining tonnage rather than retaining quality. Differentiated treatment for low-copper versus high-copper scrap streams would better match trade policy to the underlying materials constraint. The European Commission's 2025 Steel and Metals Action Plan committed to reviewing options for restricting ferrous and non-ferrous scrap exports, alongside minimum recycled content targets in certain product sectors.⁷ Copper content deserves a place in that design work.
- **Removal technology funding.** Public research funding for copper removal or separation technology, alongside the well-funded hydrogen-DRI research agenda, would address the supply-side half of the problem that dilution alone cannot solve.
- **Strategic DRI capacity planning.** Government and industry capacity roadmaps for DRI are currently framed almost entirely around decarbonisation targets. They should explicitly model the additional, copper-driven demand this article sets out, since understating total requirement risks under-building capacity relative to actual need.

Conclusion: A Shelf Life on Circularity

Scrap-based steelmaking has a shelf life. Copper builds up in the scrap pool with every cycle, and no commercial process can remove it. Under the base case, contained copper breaches even rebar and merchant bar tolerance in the early 2060s. By 2070, around half the average EAF charge would need to be virgin iron. The exact dates are uncertain; the direction is not.

Scrap-side policy can slow the clock. Copper-based scrap grading, testing, design for disassembly and quality-aware export rules would all buy time, but they cannot stop it. How the constraint finally resolves depends on the cost of green hydrogen. Cheap hydrogen folds the copper problem into the decarbonisation agenda at little extra cost. Expensive hydrogen sets climate policy, which wants carbon-intensive iron capacity gone, against materials reality, which needs a permanent supply of copper-free iron.

The choices that decide this are being made now. Scrap export rules under review in Brussels and elsewhere focus on keeping tonnage at home, not quality. DRI roadmaps are sized to emissions targets alone. Both should count copper. Waiting until the 2050s means discovering the limit with the plants and electrolyzers needed to manage it still a decade from completion. The [steel decarbonisation timeline](#) is already too tight to absorb that delay.

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6. SteelOnTheNet analysis. Scenario modelling and dilution tonnage estimates are illustrative, built on the stated simplifying assumptions, and are not a validated capacity forecast. Dilution tonnage applies the required virgin iron fraction (one minus the ratio of target to contained copper) to a flat 1.8 billion tonnes a year of global EAF output. The blended target is 0.30%.

7. European Commission (2025). *European Steel and Metals Action Plan*, 19 March 2025. Sets out the Commission's intention to review options for restricting EU ferrous and non-ferrous scrap exports, and to set minimum recycled content targets in certain product sectors. See also SteelOnTheNet's analysis of the EU Steel Action Plan 2025.



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