CGR Spotlight Chapter | Mining in Brazil 2025

CGR

Spotlight Chapter

Unlocking circular value in the mining industry

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Vale S.A., founded in 1942 as Companhia Vale do Rio Doce, has grown into one of the world's largest mining companies, operating in more than 20 countries. Guided by its purpose to improve life and transform the future, Vale S.A. combines mining with logistics, energy, and steelmaking, while placing sustainability and prosperity for society at the core of its mission.

Vale Base Metals provides mineral security to a world in transition. With a vast endowment of copper, cobalt and nickel, established infrastructure, and rich operating history, we responsibly develop critical minerals that power the future.

We are based in London, United Kingdom with our global operations centre in Toronto, Canada. Our global mining operations are in Canada, Brazil, the U.K., Indonesia and Japan. Vale Base Metals is 90 per cent owned by Vale S.A. and 10 per cent by Manara Minerals Investment Company.

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Executive summary

Brazil's mining sector has long been a foundation of national growth and a major global supplier of iron ore, bauxite, niobium, and copper. Today, however, the industry is approaching a turning point. The traditional linear model of 'take–make–waste' extraction is increasingly facing challenges amid declining ore grades, rising waste volumes, and growing environmental and social pressures. At the same time, global markets are transforming. Demand for critical minerals essential to the energy transition is surging, while investors, manufacturers, and policymakers expect transparent, low-carbon, and resource-efficient supply chains.

To remain competitive, Brazil must shift from an extractive to a circular model: one that maximises resource productivity, reduces waste, and keeps materials in use across multiple lifecycles. Strategies such as reprocessing tailings, recovering by-products, designing for reuse, and establishing closed-loop partnerships can unlock significant economic and environmental value. These models redefine mining as a regenerative system that delivers growth through efficiency, innovation, and stewardship rather than volume alone.

Brazil has a unique advantage in this transition. The country has repeatedly demonstrated its capacity for large-scale industrial innovation, from the ethanol revolution to the rise of Embraer. It also benefits from a strong ecosystem of research institutions, advanced mining companies, and a growing policy focus on sustainability. Pioneering initiatives are already proving circular economy viability: Vale's Circular Mining Programme is reprocessing tailings to recover additional iron ore, produce sustainable sand and clinker substitutes. Vale Base Metals is developing projects to recover magnetite, copper and gold from copper tailings in Brazil. Vale Base Metals is also working with partners to recover nickel from refining slag and feeding the remainder material into the construction and fertiliser value chain; and to use nickel furnace slags for carbon sequestration. These projects illustrate the potential for circularity in mining to generate economic, social, and environmental gains simultaneously at scale.

Beyond the mine site, circularity also extends to Brazil's cities and infrastructure, the so-called 'urban mine'. As the country expands its renewable energy systems, vast quantities of copper and steel are being embedded in wind turbines, solar panels, and power grids. Designing these assets for reuse and recycling today will secure future supplies of critical materials and reduce dependence on imports. Building national recovery infrastructure, implementing traceability systems, and transforming Extended Producer Responsibility frameworks into true circularity enablers will be essential.

Circularity in mining can be a powerful central pillar of Brazil's national industrial strategy, fully integrated into the *National Circular Economy Strategy (ENEC), the Pro-Mineral Plan, and the Critical Mineral Mission*. By embedding circularity across policy, industry, and finance, Brazil can capture more value from its mineral wealth, reduce environmental impact, and position itself as a global leader in sustainable resource management. Through decisive collaboration and innovation, Brazil can become the world's reference point for circular solutions in mining and metals, transforming extraction into regeneration and leveraging its natural wealth to achieve long-term, inclusive prosperity.

1 Vision and objectives

Reimagining mining for a circular economy

Beyond extraction: Why circularity is urgent for Brazil's mining sector

Brazil's mining sector has long been a cornerstone of national economic development. As one of the world's leading producers of iron ore, bauxite, niobium, copper, nickel and other critical minerals, mining accounts for a significant share of Brazil's export revenues and industrial activity.[1] However, this economic model has historically relied on a linear "take-make-waste" system—an extractive paradigm that needs to usually compensate for the environmental, social, and economic costs it generates.

As high-grade ores are depleted through decades of extraction, more material must be mined and processed to maintain output. This leads to greater land disturbance, higher water and energy use, and increased volumes of waste, including tailings and overburden. Although the mining industry is already innovating to address these issues it remains a challenge affecting mining companies, communities and governments.

At the same time, global markets are evolving. Policymakers, investors, and manufacturers—especially in sectors like electric vehicles, electronics, and renewable energy—are placing greater emphasis on supply chain transparency, resource efficiency, and lower environmental impact. While Brazil remains a major supplier of key minerals, continued reliance on a linear model of extraction may hinder opportunities to develop downstream industries, innovation in clean technologies, and competitive advantage in the energy transition. In other words, it may hinder the development of a new national circular resource industry.

The global energy transition is also reshaping demand. Bulk materials remain important, and there is growing interest in additional critical minerals for batteries, clean technologies, artificial intelligence and digital infrastructure. Meeting this demand will require not just more extraction, done sustainably, but more productive and efficient use of resources. As supply constraints, environmental limits, and political pressures make extraction alone increasingly insufficient, growing volumes of valuable materials in products, infrastructure, and mining tailings, slags and waste rock represent a largely untapped resource base. Applying a circularity lens in the mining and metals industry in Brazil may reveal new sources of materials that previously have been wrongly framed as waste or scrap.

Circular approaches—such as designing for circularity, reprocessing waste, recovering by-products, and extending material value—offer a practical path forward, particularly in Brazil. They are not only critically important given the environmental wealth in Brazil's biomes but increasingly important to maintaining Brazil's competitiveness, economic resilience, and long-term role in a changing global economy. These strategies also help retain value locally, reducing the risk of high-value resources and benefits becoming concentrated in wealthier countries as they are acquired from producing countries like Brazil and then reused outside of Brazil permanently.

From increasing volume to increasing circular value: what circularity in a mining industry looks like

The circular economy applied to mining breaks away from the current linear thinking. Rather than treating materials as disposable inputs and outputs, circularity emphasises the high value and durability of these materials, long-term resource use, waste minimisation, and value creation across the entire material lifecycle.

This shift introduces new ways to generate value beyond simply increasing volume. Circular business models illustrate how mining can support economic, environmental, and social gains simultaneously:

- **Mineral waste valorisation and multi-mineral mining** improve overall resource productivity by extracting multiple valuable minerals and resources such as silica and sulphur from mining residues and optimising land use—maximising output per hectare and turning waste liabilities into revenue-generating assets.
- **Design for circularity** allows products and infrastructure to be designed to maximise many circular strategies such as sharing, reuse, refurbish, repurpose before recycling the materials as a last resort strategy.
- **Urban mining and resource recovery** focuses on reclaiming valuable metals from urban sources like industrial equipment, vehicles and buildings—transforming end-of-life materials into high-quality secondary inputs and reducing pressure on primary extraction.
- **Closed-loop partnerships** involve collaboration between miners and manufacturers to source recycled materials directly from product lifecycles—creating secure, traceable supply chains, lowering material costs, and reducing reliance on virgin ore.
- **Resource-as-a-service** models shift ownership dynamics by allowing companies to offer materials to clients and reclaim them for reuse—promoting ongoing material efficiency, enabling predictable supply flows, and strengthening customer relationships.

These models exemplify how circularity reshapes the definition of value—rewarding durability, reuse, and closed loop collaboration rather than mere extraction volume. This is a systemic transformation requiring new business approaches offering clear commercial value, collaboration across organisational boundaries, and supportive policy frameworks to drive large scale change and make circularity the norm rather than the exception. It also presents an opportunity for Brazil to develop and export knowledge, expertise, and innovative circular solutions in the mining industry, creating additional value beyond the materials themselves and positioning the country as a global leader in circular mining solutions. These solutions have to include better mining techniques and resource optimisation offerings but most importantly new circular solutions including better finance, data and other services.

Brazil's growing role in the global mineral economy

Brazil currently extracts five billion tonnes of raw materials and exports around one-third of them,[2] capturing only a fraction of the embedded economic value from its mineral wealth. Circular business models offer a way to increasingly retain and grow this value by promoting reuse, recycling, and integrated resource management within national borders. To fully seize the expanding opportunities presented by recoverable resource stocks—both in mining residues and in urban stock —some Brazilian companies are already deploying these circular strategies in the mining industry and the broader resource value chain but it needs to become the norm at the country level to fully deliver it whole environmental, social and economic value to the Brazil as a whole.

With a vast mineral base, a maturing industrial ecosystem, strong research capacity and growing momentum for sustainable development, Brazil is well positioned to not only meet global demand for clean energy minerals but also lead in how those minerals are sourced and reused.

Unlike many resource-rich countries, Brazil has done similar transformations before – e.g. the development of the ethanol industry or aerospace manufacturing industry. Brazil can build on its experience and its industrial capacity, strong scientific community, and rising political will to move beyond raw exports toward higher-value, integrated value chains aligned with climate and development goals.

Embracing circularity in mining can become a key strategic advantage, helping Brazil reshape its mining sector and broader resource sectors as a driver of innovation, inclusive growth, and responsible stewardship. The vision is to build a regenerative, competitive circular resource economy that supports long-term economic resilience and environmental protection providing access to socio-economic opportunity to all.

Aims of the CGR Spotlight Chapter: Mining in Brazil 2025

1. **Develop a vision for circularity in the mining industry** that enhances economic resilience, improves resource efficiency, and positions Brazil as a global leader in resource productivity and sustainable practices.
2. **Quantify the potential for circular value creation** in Brazil's mining sector by identifying opportunities in material recovery, by-product reuse, and urban mining.
3. **Build momentum and stakeholder alignment** by raising awareness of circular strategies and showcasing their economic and environmental benefits.

2 Resource productivity

Quantifying the potential of circularity in mining

Mining tailings are the largest solid waste stream generated by humanity, with around 13 billion tonnes of tailings produced globally each year—equivalent to roughly 1.6 tonnes per person.[3] Brazil's mining sector generates significant volumes of tailings, slags, and other by-products that have traditionally been seen as waste. These materials can pose environmental challenges, including soil and water contamination, habitat disruption, and long-term land degradation.[4]

By shifting focus from extraction alone to maximising resource productivity, circular strategies can transform these mining residues into high-value resources—such as additional sources of critical minerals, materials for carbon capture, fertilisers, or construction inputs. This approach reduces environmental impacts while unlocking economic value previously lost in waste streams. Aligning with emerging global standards, Brazil has the opportunity to innovate in sustainable mining and resource recovery.

To assess the circular potential of Brazil's mining residues, this section explores how much tailings are available for recovery, their composition, and the feasibility of high-value applications. It also considers key challenges and opportunities for scaling reuse—especially in the context of iron and copper ore tailings, which often contain recoverable resources like silica and copper. Details on data sources, assumptions, and estimation methods are provided in appendix A: methodology.

Tailings—especially older ones—can contain more copper than some newly mined ores. Iron and copper tailings are considered prime targets for recovery. For every tonne of copper and iron ore mined, the metals recovered are a very small fraction of the material, highlighting that the vast majority is left as tailings and other residues, which represents a significant opportunity for resource recovery and circular innovation.

In Brazil 267 million tonnes

of iron ore tailings were available for recovery in 2023

Of which **only 5% was recovered**.

In Brazil 94 million tonnes

of copper ore tailings and other metals were available for recovery in 2023

With **limited knowledge** on how much is recovered.

The potential reuse of mining tailings depends heavily on their composition. In both iron and copper tailings, **silica is the dominant component—making up approximately 56% to 63%** on average, based on available data. This high silica content supports their potential in civil engineering applications, particularly as aggregates in various sizes, such as sand. One common example is their use in low-value products like **precast concrete blocks and pavers**—often viable near mine sites but limited by transport costs and low market prices. Overall, current reuse of tailings remains economically limited. However, **higher-value opportunities are emerging**. For both legacy and active mine sites, options like ore sand, clinker substitution, and CO_2 removal could unlock significantly greater economic and environmental benefits. While much of this analysis focuses on the circular potential of iron and copper tailings, additional examples are included to illustrate the wider applicability of circular approaches across Brazil's mining sector. The following examples illustrate how some of these pathways are already being explored in practice.

- **Construction materials from iron ore tailings:** At Vale S.A.'s Carajás iron ore complex in Pará, Brazil, kaolinite-rich iron ore tailings are activated using renewable electricity to create a supplementary cementitious material (SCM) that reduces clinker demand and CO_2 emissions in cement production. This process currently reuses about 3,000 tons of tailings per day and produces a medium- to high-value product, priced between €30 and €100 per tonne thanks to improved concrete performance and carbon reduction benefits. Although this method works best with tailings that have a high kaolinite content, other tailings may need extra processing before they can be used, making this a promising but selective solution.[5] Similarly, Anglo American demonstrated success at its Minas-Rio operation with a pilot project that recycled tailings into 293,000 paving blocks in 2024, which were subsequently donated to local municipalities to pave access roads, providing a direct community benefit.[6]

  Vale Base Metals is also producing paving blocks from Tailings at Sossego Copper Mine in Carajas that are being used internally in their operations and donated to municipalities with the aim to have a commercial model in the near term. Waste rocks are also being considered by Vale Base Metals as a new resource stream, in particular for train rail beds. Furthermore, the company is researching more advanced, longer-term uses for these tailings, such as for the production of specialised construction materials for example as feedstock for 3D printing in construction. All these opportunities are less developed and need further research but are being supported by expert organisations such as the collaboration with the University of Sao Paulo (USP).

- **Agricultural remineraliser from copper tailings:** In Goiás, Brazil, copper mining tailings are being converted into agricultural remineralisers to supply essential nutrients like potassium and copper for soil amendment. A pilot project covering 900 hectares tested this approach with soy crops, showing promising results. With a potential to reuse up to 9.6 million tons of tailings annually, this medium- to high-value product (€50–€500+ per ton) could help reduce Brazil's dependence on imported fertilizers. However, wider adoption depends on regulatory approvals, market acceptance, and ensuring the tailings are safe—free of toxic elements and compliant with environmental standards.[7]
- **Revalorisation of copper tailings and waste rocks**: Vale Base Metals is exploring the recovery of valuable metals and minerals (such as magnetite and copper) from its copper tailings in Brazil with partners. This not only represents an opportunity to further increase the supply of critical materials from tailings but it reduces the environmental liability and also opens additional capacity for production of copper in the Salobo mine itself without the need to extend the tailings dam capacity.
- **Industrial slag valorisation**: The use of industrial by-products for valorisation in both the construction and agriculture sectors is another example of improving resource recovery. Vale Base Metals is working with partners to process nickel refinery slag from its Onça Puma facility to recover residual nickel and supply an input to the fertiliser value chain, or as a material suitable for construction and road building.
- **Enhanced rock weathering for carbon capture and soil health:** Enhanced rock weathering (ERW) is being adopted as a promising, high-value approach to carbon capture using mine waste. This process accelerates natural rock weathering, utilizing the reaction between minerals (like those containing magnesium and calcium) and atmospheric CO_2 to store the carbon in a stable bicarbonate form. For example, Anglo American is using smelter slag from its nickel operations in Goiás, Brazil, as a magnesium-rich mineral fertiliser. This not only removes CO_2 but also delivers agricultural benefits like PH correction to depleted soils, with the potential to sequester over 15 million tonnes of CO_2 from existing stockpiles.[8]

Similarly, Terradot, a climate tech company in Brazil, is currently crushing basalt waste rock and spreads it on farmland to capture CO_2 and improve soil health. Their pilot has applied 50,000 tonnes of rock over 2,000 hectares, with plans to remove 12,000 tonnes of CO_2 by 2029, with funding secured through carbon credits.[9,10]. Vale Base Metals is also assessing the use of nickel furnace slags as a material for ERW, although further research is needed it represents a significant opportunity given the production of more than 2 million tons of furnace slag per year. While ERW offers significant carbon capture potential, its economic viability relies heavily on carbon credit prices (€50–€400+ per tonne CO_2), and challenges related to environmental performance and impact analysis of the materials, transportation logistics, large land requirements, and carbon methodology are currently under analysis and verification.[11,12,13,14]

Vale S.A.'s Circular Mining Programme: Waste to Value

Vale's Circular Mining Program: Waste to Value is part of its broader efforts to embed circular economy principles into mining. The programme focuses on maximising the use of mineral reserves, reducing the generation of waste and tailings, and lowering carbon impacts along the iron ore value chain.

By 2024, Vale had already produced 12.7 million tonnes of iron ore from circular sources, and the company has set a target for 10% of its annual iron ore production to come from such sources by 2030. More than 100 initiatives have been identified under the program, many of which are already in operation. These include process innovations designed to turn waste into new inputs, demonstrating how circularity can be applied in large-scale mining.[15]

Key examples

- **Reuse of tailings:** At the Gelado Tailings Dam, tailings accumulated since 1985 are being reused to produce high-quality iron ore, reducing the need for new extraction and lowering CO_2e emissions. Magnetic separation, applied in the region for the first time, improves the quality of the material and reduces impurities. The project also extends the lifespan of the dam and enhances safety, contributing to both environmental and operational benefits.
- **Reuse of waste rock:** Waste rock from the Serrinha Mine is being repurposed as Run-of-Mine material, supporting progressive closure of mining structures, reducing geotechnical risks, and optimising resource use.
- **Co-products:** At the Viga and Brucutu iron ore mines in Minas Gerais, Brazil, ore sand is produced by extracting coarse, silica-rich particles directly from processing streams as a substitute for manufactured sand in construction. Production began in 2021 at the Brucutu Mine after seven years of research, offering high silica content and consistent quality. By early 2025, over two million tonnes had been produced, with current production reaching 1–2 million tonnes per year. This sustainable sand reduces the environmental impacts of natural sand extraction and helps preserve river and coastal ecosystems. Studies show that up to 50% of tailings volume could be reduced at some sites using this method. The material can replace 10–40% of natural sand in concrete, depending on performance requirements. In 2023, Vale created Agera, a company dedicated to commercialising and expanding this sustainable sand business. However, economic viability is limited by low margins and the need for nearby markets, as transport distances beyond 50 km often outweigh its value.[16,17,18,19]

Advancing circularity in Brazil's mining sector requires more than incremental recovery—it calls for fundamentally rethinking resource productivity and transforming how mining companies operate and create value. This means valuing every hectare and tonne holistically, shifting from a linear extractive mindset to one focused on stewardship, recovery and regeneration. While current efforts focus on valorising existing tailings, emerging technologies like no-waste mine designs and in-situ leaching hold promise to drastically reduce waste generation. Though these approaches are still developing, ongoing innovation and a shift in business models and corporate mindsets will be critical to unlocking a truly circular future for mining in Brazil.

3

Urban mining

Quantifying the potential of urban mining in renewable energy sector

As Brazil electrifies and urbanises, a second mining frontier is emerging—hidden in cables, networks, and aging infrastructure. Urban stocks offer a high-value, lower-impact complement to traditional mining—but only if Brazil builds the systems to recover them now.

Vast amounts of valuable materials are already embedded in infrastructure, equipment, and products. These in-use stocks represent strategic assets: their recoverable value depends on how they are designed, tracked, and managed today. Materials in buildings, grids, vehicles, and renewable energy infrastructure that can no longer be kept in use through reuse or repurposing can only be effectively recycled if they are built for recovery, clearly inventoried, and accessible.

Brazil has the potential to go further than other resource-rich countries. By influencing how stocks are designed and how business models are structured, the country could position itself as a platform for circular material solutions—creating systems that maximise material recovery while generating economic, social, and environmental value. This is not only about recovering the copper or steel embedded in infrastructure; it is also about developing knowledge, capabilities, and circular design practices. Few countries combine both a rich resource base and the industrial, scientific, and policy capacity to do this. Brazil has shown this potential before in sectors like biofuels and aerospace, and similar approaches could be applied to mining businesses. The true competitive advantage may lie in these capabilities and innovation systems, not just the raw materials themselves.

This chapter aims to quantify the potential of urban mining within Brazil's current and **future renewable energy system**. It focuses on the renewable energy sector—specifically **wind turbines, solar panels**, and **power transmission and distribution infrastructure**—and considers **steel** and **copper** as examples of key materials, given the rapid growth of these areas in Brazil's energy landscape.

Details on data sources, assumptions, and estimation methods are provided in appendix A: methodology.

An estimated

19.6 Mt ***of steel*** and

1 Mt ***of copper*** was embedded in Brazil's wind, solar, and power grid infrastructure **in 2022**.

To put this in context, the steel alone represents more than half of Brazil's total crude steel production that year (**34 Mt**).[20]

As Brazil accelerates its energy transition, the rapid buildout of wind, solar, and power grid infrastructure presents an open strategic window of opportunity to **design circularity into emerging systems**. By embedding recovery and reuse into how these assets are planned, installed, and eventually decommissioned, Brazil can lay the groundwork for a future supply of critical materials—particularly steel and copper.

By 2050, the stock embedded in wind, solar, and grid infrastructure in Brazil is expected to grow to approximately:

- **105 to 165 Mt**
  of steel
- **2.2 to 2.5 Mt**
  of copper

— **over 5 times** the stock levels of 2022 for steel, and **more than double** for copper.

While the projected 2050 material stocks in energy infrastructure may seem modest in volume, their economic value is substantial—especially for copper.

If these amounts were imported at 2024 prices:[21]

- 105 to 165 Mt of steel would be worth USD$ 13 – 20 billion
- 2.2 to 2.5 Mt of copper would be worth USD$ 7 – 9 billion

Copper's high unit value underscores the strategic importance of urban stocks, metals that are in use in products and infrastructure, as future domestic resources. But how much of this value is currently being lost or under-recovered? How much copper slips through the system each year—untracked, unrecycled, or exported with little value added? Even a small percentage loss could represent hundreds of millions of dollars in missed opportunity for steel and copper stocks. Moreover, significant urban stocks of Brazilian minerals embedded in products and infrastructure abroad are never recovered—representing a long-term loss of value and resource sovereignty.

To capture value and secure a competitive advantage in a decarbonising global economy, major mining and metals companies in Brazil are already moving to embrace comprehensive circular economy models. These efforts range from increasing resource lifespan through recycling to industrial symbiosis and significant investments in recovered-low-carbon production processes.

- **Decarbonising aluminium production with biofuel**: Hydro Alunorte is co-firing açaí kernel, a byproduct of Pará's massive açaí industry., together with coal. In 2025, 140,000 tonnes of açaí kernels were used, replacing a fourth to a third of remaining coal consumption. This co-firing yields multiple benefits: it utilises local waste that would otherwise go to landfill, reduces reliance on imported coal, and requires no major infrastructure changes. Plans are underway to retrofit existing coal boilers for 100% biomass compatibility.[22]
- **Decarbonisation of aluminium production through electrification**: Norsk Hydro has embarked on a multi-billion dollar investment cycle in Brazil to produce the world's greenest aluminium. The initial phase focuses on radical industrial decarbonisation at the Alunorte refinery in Pará, including switching 13 heavy-oil consuming units to natural gas and installing electric boilers powered by newly secured renewable energy. This strategy positions the company to achieve a 70% reduction in local emissions by 2030, demonstrating pioneering innovation in securing a competitive, low-carbon material supply chain for the energy transition.[23]
- **Scaling scrap metal recycling for low-carbon steel**: ArcelorMittal has become the largest recycler of scrap metal in Brazil, reprocessing millions of tons annually. Aligned with circular economy principles, approximately 54% of its Long Steel production in 2024 originated from scrap recycling, with the remainder produced from pig iron. This commitment includes internal circularity, such as sending metal scrap from the Vega Unit's rolling mill back to Tubarão to be reused as raw material in producing new steels. This strategy embeds the infinite recyclability of steel into the Company's operations, helping reduce reliance on primary production and lowering its carbon footprint.[24]
- **Copper recycling for high-purity metal**: Paranapanema, the largest copper scrap operator in Brazil, is involved in the sourcing, processing, and industrial-scale conversion of copper scrap into reusable metal products, recycling approximately 70 kt of copper annually. The company is able to transform copper scrap back into super-pure copper (99.99%) through the electrolysis process at its Dias d'Ávila unit in Bahia. This advanced process makes the use of secondary copper more cost-effective compared to primary production, drastically lowering energy use by 80 to 90% and simultaneously reducing CO2 emissions.[25]

Need for system-scale recovery infrastructure. Meeting Brazil's growing material demand and unlocking circularity in the energy transition requires developing new business and operating models starting with building a network of hundreds of recovery facilities—and the time to design and implement them is now.

One specific example is copper recycling. Currently, Brazil's largest copper recycling facility is reported to process only about 70 kt of copper per year, which is far below the volume reaching end-of-life.[26] In 2016 alone, 136 kt of copper and 7,063 kt of steel reached end-of-life across all applications.[27] According to the analysis of this report, by 2050 over 9 million tonnes of steel and almost 200 kilotonnes of copper will be decommissioned from wind and solar equipment alone—highlighting both the opportunity and urgency to scale recycling capacity.

Beyond expanding infrastructure, it would be beneficial for Brazil to retain value within the country by maintaining ownership and control over these recovery systems. For example through 'material as a service models'.

4 Recommendations

From vision to practice

Brazil as a leader in driving circularity in mining

As a leading producer of iron ore, bauxite, niobium, copper, nickel and other critical minerals, a shift to applying circularity in mining is essential not only for smarter resource use but also to safeguard Brazil's economic resilience and long-term competitiveness. Circular business models allow Brazil to generate more value from its existing resources, reduce dependence on product imports, and promote domestic industries through innovation and industrial collaboration. The opportunity goes beyond incremental change: Brazil can position itself at the forefront of global efforts to align resource productivity, economic competitiveness, climate and development goals.

This transformation is especially relevant in Brazil, where mining intersects with strategic national priorities—from the Amazon protection to growing clean energy infrastructure. Circular models can support sustainable development, protect sensitive regions, and enable Brazil to participate in the energy transition through both material supply and innovative, circular business models.

National policy priorities for a circular economy applied to the mining industry

As Brazil's National Circular Economy Strategy (ENEC) matures, circularity in mining should be clearly prioritised within national policy frameworks. Brazil's ambition to become a global supplier of critical minerals for the energy transition is reflected in initiatives such as the National Strategic Pro-Mineral Plan and the National Critical Mineral Mission. These must explicitly place circularity at their core—embedding circular practices across the entire mineral value chain, from exploration to processing, use and recycling. Further recommendations include integrating circularity in mining into Brazil's Nationally Determined Contributions (NDCs), strengthening the National Mining Agency (ANM), and formally embedding circular economy principles into its mandate.

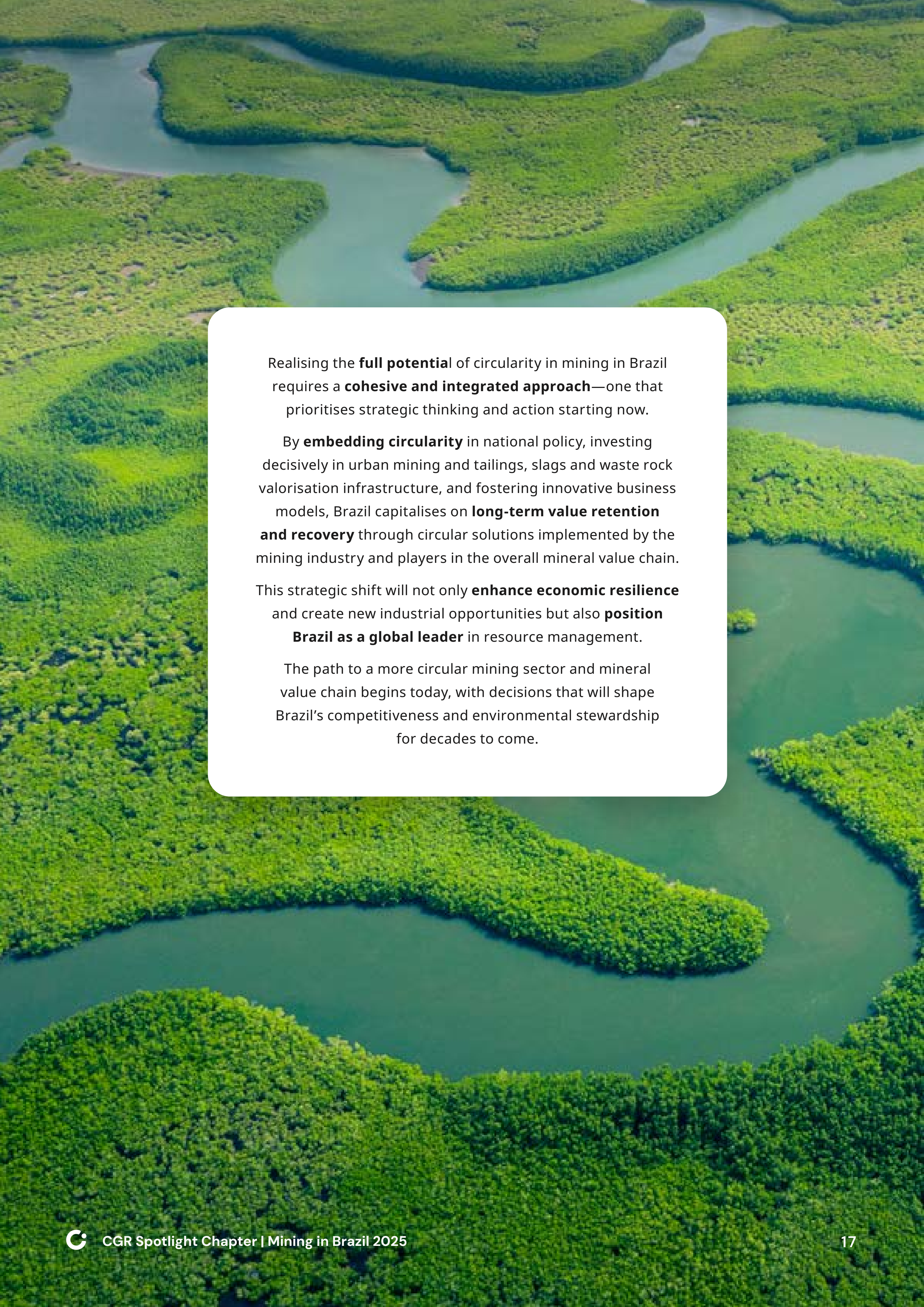
With global steel and in particular, copper demand expected to continue rising, mineral recovery from waste streams (i.e. tailings, slags and waste rock) as well as urban mining presents a major opportunity to mitigate material import dependence and valorise in-country resources. Brazil should invest in system-scale recovery infrastructure—sorting facilities, logistics for design-for-disassembly, and return systems. Recommendations include implementing Extended Producer Responsibility (EPR) schemes for metals, setting national targets for recycled content in renewables (e.g. 30% copper by 2035), promoting urban mining alliances among municipalities and recyclers, establishing traceability standards (e.g. digital material passports), and leveraging and strengthening the existing Brazilian National Solid Waste Policy (PNRS) which encourages the separation of waste at the source (by households and businesses) and promotes selective collection and mandates extended producer responsibility for end-of-life materials streams relevant for urban mining (electronics, batteries).

Business models and industrial collaboration

The Brazilian mining sector is concentrated in large firms, especially in extraction, with smaller actors primarily involved in exploration. Unlocking circular business models requires stronger cross-industry collaboration—such as the initiatives led by the Brazilian National Confederation of Industry (CNI)—to co-develop circular strategies, shared infrastructure, and innovation agendas. Promoting circular industry partnerships, especially between mining firms and downstream sectors (e.g., metals, construction, renewables), is critical to accelerate uptake.

Brazil already has promising pilots in tailings reuse—e.g. examples shared in this report. Scaling these models requires support such as public procurement targets for tailings-derived materials, tax incentives, industrial symbiosis hubs near mining clusters, and upgraded transport infrastructure. Brazil could direct existing funds (e.g. the BNDES/FINEP $5B fund) toward emerging technologies for mineral processing, clean tech integration, and secondary materials recovery and manufacturing. Key financial instruments include blended finance, public-private partnerships, performance-linked loans, and dedicated R&D funding for tailings reprocessing and low-emission materials. A national database of tailings, digital traceability, and a mandated reuse target (e.g. 10–20%) can support environmental safety and market confidence.

Other emerging models include closed-loop supply chain partnerships (requiring traceability and supply chain coordination) and resource-as-a-service models (requiring financial de-risking and tailored instruments). These should be supported through innovation funding, regulatory clarity, and enabling infrastructure.



Realising the **full potentia**l of circularity in mining in Brazil requires a **cohesive and integrated approach**—one that prioritises strategic thinking and action starting now.

By **embedding circularity** in national policy, investing decisively in urban mining and tailings, slags and waste rock valorisation infrastructure, and fostering innovative business models, Brazil capitalises on **long-term value retention and recovery** through circular solutions implemented by the mining industry and players in the overall mineral value chain.

This strategic shift will not only **enhance economic resilience** and create new industrial opportunities but also **position Brazil as a global leader** in resource management.

The path to a more circular mining sector and mineral value chain begins today, with decisions that will shape Brazil's competitiveness and environmental stewardship for decades to come.

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Appendix A: *Methodology*

Resource productivity:
Quantifying the potential of circular mining

The calculation of tailings for iron and copper ore is based on reported data sources and supplementary calculations.

1. **Estimation of mining by products and waste materials: iron ore**

   1.1 The average waste-to-rock (stripping) ratio is derived from three mines in Brazil.[28,29,30]

   1.2 Run of mine (ROM) and metal content (concentrate) is from Brazilian Mineral Yearbook (ANM).[31]

   1.3 Tailings are calculated as the difference between ROM and metal content (concentrate).

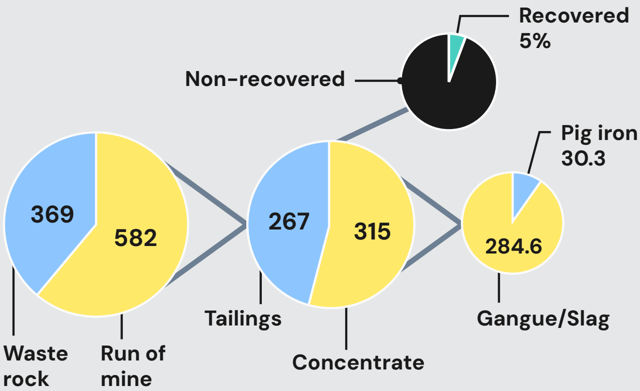
   1.4 After the concentrate is processed into a useful product, the remaining material is considered gangue or slag. This is estimated by subtracting the amount of useful product which is pig iron produced from the concentrate. Pig iron is a crude form of iron obtained by smelting iron ore in a blast furnace.

   1.5 Pig iron is forecasted to 2023 based on reported USGS values from 2015-2019.[32]

   1.6 Tailings recovery rate from IBRAM report.[33]

1. Estimation of mining by products and waste materials

Iron ore, 2023 (Mt)



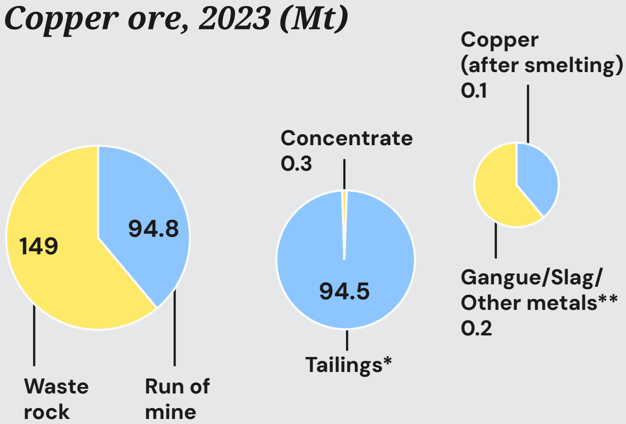
2. **Estimation of mining by products and waste materials: copper ore**

   2.7. The average waste-to-rock (stripping) ratio is derived from four mines in Brazil and the global average.[34,35,36,37,38]

   2. 8. After the concentrate is processed into a useful product, the remaining material is considered gangue, slag or there can still be other metals remaining in the case of copper. This is estimated by subtracting the amount of copper after smelting from the concentrate.

   2.9. Copper after smelting is forecasted to 2023 based on reported USGS values from 2015 – 2019.[39]

Copper ore, 2023 (Mt)



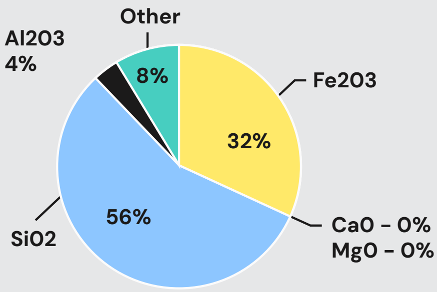
**No data on the current recovery of tailings*

***Other metals can be: gold, silver, nickel, cobalt, zinc, lead ~ 0.18 Mt*

3. Composition of the mining tailings: iron and copper ores[40,41]

2. Composition of the mining tailings

Iron



Copper

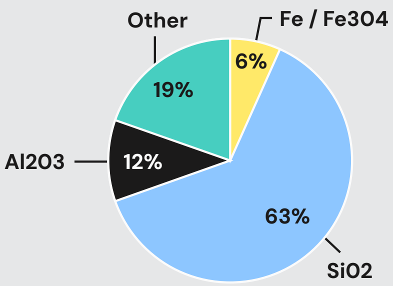


Figure 1. Composition of mining tailings in iron (top) and copper ores (bottom).

Iron: Average of different mines in Minas Gerias region. The region represents 53% of iron ore mining.[42]

Copper: Sossego mine, 2nd largest mine of Brazil. Accounting 5% of the whole production.[43]

Urban mining: Quantifying the potential of urban mining in the renewable energy sector

1. **Estimation of steel and copper stocks in Brazil**

The stock was estimated at 5,600kt of copper and 531 300kt of steel in 2016 in all applications.[44] Although more recent data are unavailable, it is reasonable to assume that the stock has increased significantly since then.

In 2022, Brazil had an installed capacity of 25,600 MW[45] of wind power through onshore wind turbines (offshore turbines are not yet operating in Brazil) and 25 400 MW of solar power[46] mostly through distributed generation (71%). Between 2018 and 2022, Brazil wind capacity went up by 75% (from 14.7 GW to 25.6)[47] and solar capacity was multiplied by 10 (from 2.5 GW to 25).[48]

Based on this data, it was estimated that the wind turbine stock contains 3,100 kt of steel and 64 kt of copper, while the solar PV stock comprises 8,900 kt of steel and 36 kt of copper, using material intensity factors.[49]

Additionally the stock is estimated in the power transmission and distribution infrastructures is 7,600 kt of steel and 920 kt of copper in the grid in Brazil in 2022.[50]

Total steel stock (in scope): 19,600 kt (in 2022)

Total copper stock (in scope): 1,020 kt (in 2022)

2. **Estimation of steel and copper stocks in Brazil in 2050**

By 2050, the stock of copper in these three applications is estimated to increase to approximately in the range 2,200 – 2,500 kt, while the stock of steel is projected to rise to around 105 000 - 165 000 kt[51]

Assumptions include:

- Offshore wind capacity reaching 6% by 2050, based on the World Bank Group's medium scenario for offshore wind development in Brazil,[52] with corresponding changes in steel and copper material intensities.
- Material intensities for turbines and panels are assumed to remain consistent with current values.[53]

- Projected installations were derived from the World Energy Outlook 2024 generation projections.[54] Installation estimates were calculated by applying the 2022 ratio of generation to installation capacity.
- Both the stated policies (conservative scenario) and announced pledges (ambitious scenario) were used to establish a range of projections.
- Data for the 2050 energy grid (distribution and transmission) were sourced directly from existing projections.[55]

3. **Estimation of the value of steel and copper stocks in 2050**

   The estimated value of metal stocks was calculated by applying current market prices to the projected quantities of steel and copper. Market prices were based on 2024 import prices from the Comtrade database for Brazil, specifically:

- Copper price set at USD $3,376 USD per tonne.
- Steel price set at USD $120 per tonne.

These prices were multiplied by the estimated metal quantities projected for 2050 to derive an indicative monetary value of the stocks, assuming they were to be imported at present-day prices.

Table 1. Summary of projected wind, solar and power distribution steel stocks in 2050 (kt)

	2022	2050 stated policies	2050 announced pledges
Wind	3,075	17,766	22,166
Solar	8,922	75,242	130,856
Power distribution & transmission	7,581	11,920	11,920
Total (kt)	19,579	104,928	164,942

Table 2. Summary of projected wind, solar and power distribution copper stocks in 2050 (kt)

	2022	2050 stated policies	2050 announced pledges
Wind	64	389	486
Solar	36	305	531
Power distribution & transmission	922	1,521	1,521
Total (kt)	1,002	2,216	2,538

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