VOL. 2 | JUNE 2025

# PERSPECTIVE

## SLAG

## SLAG TREATMENT IN THE MINING INDUSTRY

GEM

Paving the way for the future of mining

# INDEX




**VOLUMEN 2**
*June 2025*

# ABOUT GEM

We are an Industrial Engineering company specialized in supporting the mining industry in management and economic matters. With over **15 years of experience** and the successful implementation of more than **400 projects worldwide**, we stand out for our strong track record and commitment to excellence in the sector.
GEM leads the future of mining with innovative solutions.

From climate change management to deep-sea mining and in-situ leaching, GEM is committed to promoting sustainable, collaborative, and responsible practices, always with a focus on social and environmental impact.


Climate Change

Colaboration

Data Science

Decarbonization

Deep Sea Mining

In Situ Leaching

Nature

Social Impact Assesment

Space Mining

# EDITORIAL

**BY**
**ISAAC PAREDES**

In a global mining scenario increasingly challenged by environmental, economic, and social demands, waste management has taken on a new level of importance. Far from being mere discards, copper smelting slags now represent a concrete opportunity to advance toward a truly circular mining industry with high added value.

This issue of Perspectiva focuses on the reprocessing and reuse of slags—a topic that goes beyond technicalities to sit at the heart of the industrial sustainability debate. Chile, with its extensive experience in flotation technologies, has positioned itself as an international benchmark in slag reprocessing. These efforts not only allow for the recovery of valuable minerals but also help reduce the volume of deposited waste. At the same time, research into leaching processes is gaining ground, promising lower water and energy footprints.

But the potential of slags extends beyond copper. Their reuse in the construction industry as artificial aggregate opens new possibilities to reduce pressure on natural resources and contribute to the regeneration of ecosystems affected by waste dumps.

However, Chile's national regulatory framework remains a significant obstacle. While in Europe, the United States, and Australia slags are classified and used as by-products, in Chile they are still considered waste, restricting their industrial-scale application.

This issue analyzes both national and international case studies, explores available technologies, evaluates technical and economic risks, and offers concrete recommendations. At GEM, we are convinced that the shift toward the mining of the future also requires innovation in how we perceive and manage our waste. Transforming slag into a resource is not just a technical goal—it is a clear signal of cultural and industrial evolution.

# INTRODUCTION

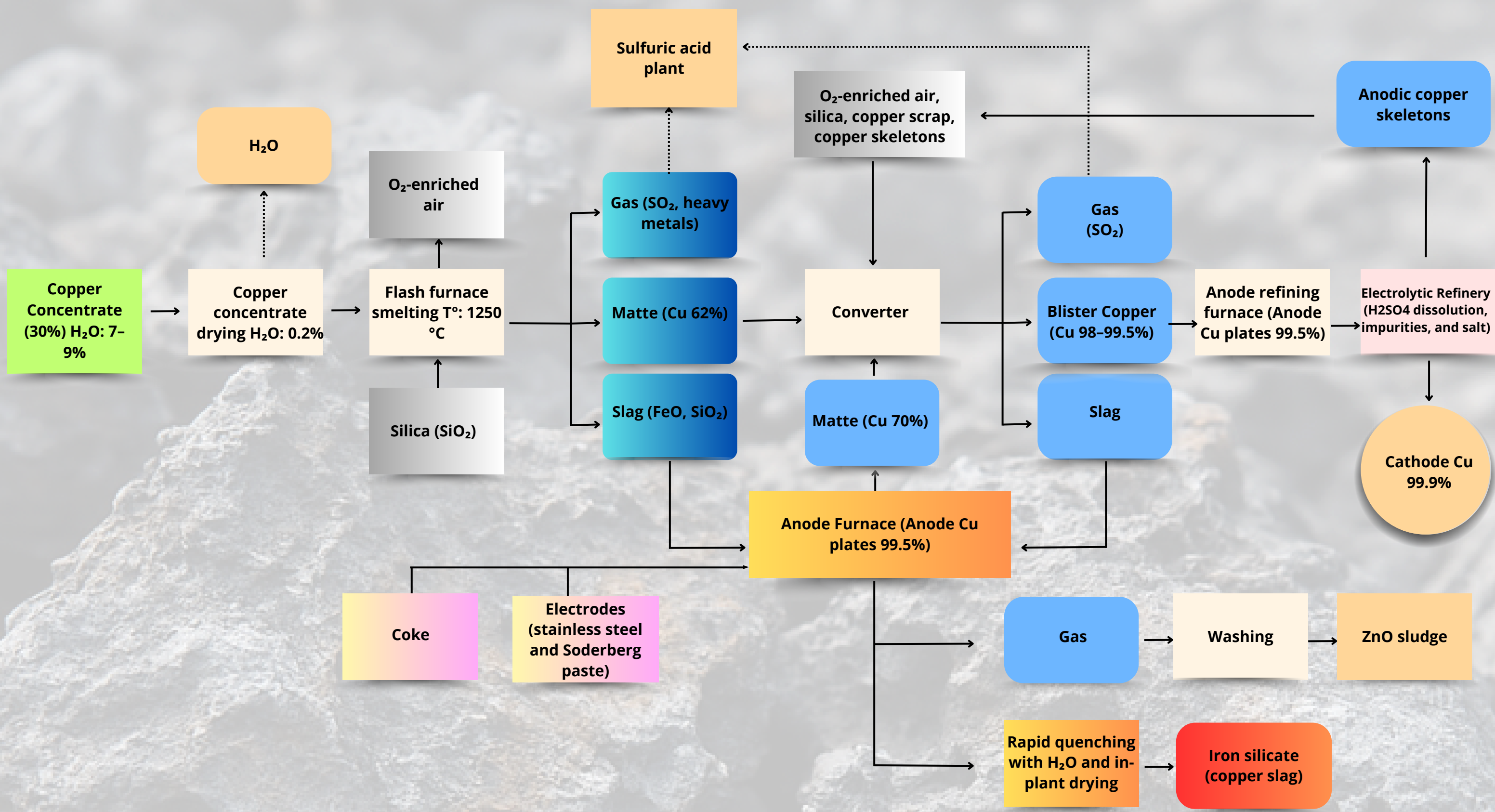
It is estimated that for every ton of copper produced through pyrometallurgical processes, approximately 2.2 tons of slag are generated (Charles et al., 2024). In Chile, around 4.5 million tons of slag are produced annually, with a historical accumulation estimated at over 70 million tons in disposal sites (Cayumil et al., 2022). These slags – produced during the smelting of copper concentrates - solidify through rapid cooling and contain a mixture of metallic and non-metallic oxides. When melted and rapidly cooled, they form a glass-like material (see **Figure 1**) (Charles et al., 2024).

During the smelting process in fusion and conversion furnaces, matte (a metallic phase with high copper content) is obtained along with slags containing between 1% and 2% copper. These slags are reprocessed in electric slag-cleaning furnaces, producing discard slags with approximately 0.7% copper, composed mainly of iron silicate. These are disposed of in slag dumps as final waste (Codelco, 2019). This study focuses on these slags, whose production process is illustrated in **Figure 2**.

**FIGURE 1. IRON SILICATE, COMMONLY REFERRED TO AS COPPER SLAG**

**Source: Own elaboration based on Abrasivos y Maquinarias S.A.**

## FIGURE 2. COPPER CATHODE PRODUCTION PROCESS AND SLAG GENERATION




Source: Own elaboration based on Emgrisa (2021)

As the world transitions to a circular economy, the large-scale accumulation of copper slags poses a significant challenge due to the vast land areas they occupy. In recent years, technologies have been developed to recover the copper contained in these slags and to repurpose them in industries such as construction. To recover copper, techniques such as flotation, leaching, and slag smelting have been explored. However, these face challenges related to high energy consumption and the complexity of chemical reactions, which vary depending on the slag's chemical composition and physical characteristics.

Slags have been used in other industries, such as construction, in countries like the United States, Germany, China, and Japan (MOP, 2025). Their strength and durability make copper slags a viable alternative to natural aggregates, particularly in road construction.

### Advantages and Disadvantages of Slag Reprocessing and Reuse

Slag reprocessing enables the extraction of residual copper and other valuable metals, improving metallurgical efficiency and reducing losses in slag dumps. In recent years, flotation and leaching methods have been implemented, as well as gravity concentration and secondary pyrometallurgy processes to recover metals contained in slags (Charles et al., 2024). Flotation is one of the most widely used techniques, with Codelco's Potrerillos Slag Flotation Plant standing out as one of the most advanced in the world. Its cutting-edge technology has improved the recovery of copper, gold, and silver (Codelco, 2016).

Moreover, reprocessing historic slags - containing copper grades between 0.6% and 1% (Ciencia En Chile, 2024)- could offer an economically viable alternative to mining low-grade ore. This approach helps optimize operational costs. Recovering metals from high-grade slags may prove more efficient than extracting them from primary deposits with lower concentrations. However, it is essential to assess the energy costs involved to ensure long-term viability.

[1] It is a model of production and consumption that promotes sharing, reusing, repairing, refurbishing, and recycling existing materials and products as many times as possible to create added value. In this way, the lifecycle of products is extended, waste generation is reduced, and resource use is maximized (European Parliament, 2023).

# ADVANTAGES OF SLAG REPROCESSING AND REUSE

Slag reprocessing allows for the extraction of residual copper and other valuable metals, enhancing metallurgical process efficiency and reducing losses to slag dumps. In recent years, flotation and leaching methods have been implemented, along with gravity concentration and secondary pyrometallurgical processes, to recover metals contained in slags (Charles et al., 2024). Flotation is one of the most widely used techniques, with the Potrerillos Slag Flotation Plant operated by Codelco standing out as one of the most modern in the world. Its state-of-the-art technology has significantly improved the recovery of copper, gold, and silver (Codelco, 2016).

Moreover, the reprocessing of old slags with copper grades ranging between 0.6% and 1% (Ciencia en Chile, 2024) may represent an economically viable alternative to the exploitation of low-grade ore deposits, optimizing operational costs. The recovery of metals from high-grade slags can often be more efficient than their extraction from primary deposits with lower concentrations. However, it is essential to assess energy costs to ensure the long-term viability of such operations.

On the other hand, the reuse of copper slags allows for the recovery of millions of tons of currently unused material. These materials can be employed in construction applications such as pavements, concrete, tiles and glass, abrasive cleaning agents, soil fill, among others (Alta Ley, 2024). It has been shown that iron silicates pose no environmental impact when in contact with water, air, or soil, and their greater hardness compared to natural aggregates enhances the strength of mixtures with cement, concrete, or other materials (MOP, 2025). This would reduce the demand for natural materials and alleviate environmental stress on river basins such as Chile's Aconcagua, which has been affected by intensive aggregate extraction (Pizzoleo, 2025). Additionally, slag reuse could contribute to reducing CAPEX associated with mine closure costs, by lowering the need for final disposal and dump site management. This would facilitate more efficient resource use and reduce long-term expenses related to waste handling.

Finally, the reprocessing and reuse of copper slags help reduce the environmental impact caused by the large volumes accumulated in disposal sites, which occupy vast land areas. A clear example is the Codelco Ventanas plant, whose closure left behind an estimated 4.5 million tons of slag spread over 15 hectares—a challenging area to manage (Mendoza, 2025). Utilizing this material could free up land, supporting the restoration of nearby ecosystems, such as the wetlands adjacent to Ventanas (Ciencia En Chile, 2024). Moreover, it would reduce dust generation and help mitigate the leaching of heavy metals into the environment.

**DISADVANTAGES**

Leaching and flotation processes for slag treatment require high energy consumption due to the crushing stage, which is significantly affected by the material's hardness. Flotation involves even higher energy demands, as it requires not only crushing but also additional grinding stages to achieve the appropriate particle size. Reducing slag heap volumes can yield economic and environmental benefits. However, high energy demands, and accelerated equipment wear caused by slag hardness can limit the feasibility of reprocessing (Ciencia En Chile, 2024). Furthermore, the infrastructure needed for these processes involves considerable upfront investment, including controlled cooling pots, SAG milling, and pressure filters in slag flotation plants (SMA, 2021).

Additionally, the chemical composition and physical properties of copper slag can vary significantly depending on the characteristics of the ore and the smelting processes used. As a result, recovering copper and other valuable metals is often complex and difficult to standardize, requiring in-depth knowledge of the chemical reactions involved and the physical and chemical nature of the residue (Charles et al., 2024). In general, slag may contain silicon dioxide ($SiO_2$), calcium oxide ($CaO$), magnesium oxide ($MgO$), aluminum oxide ($Al_2O_3$), sulfur ($S$), copper ($Cu$), cobalt ($Co$), manganese ($Mn$), nickel ($Ni$), and zinc ($Zn$).

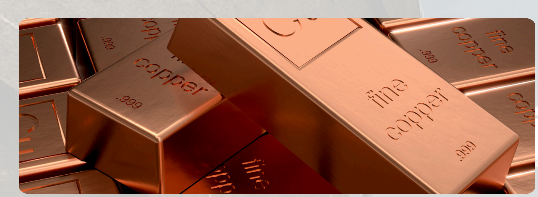
Another key factor to consider is the potential for secondary environmental impacts, such as gas emissions and soil or water contamination. In pyrometallurgical methods, special attention must be given to atmospheric emissions—for instance, mercury released during the processing of copper, gold, and zinc ores. In hydrometallurgical methods, proper handling of leaching agents is essential, such as the destruction of cyanide during cyanidation processes (Charles et al., 2024).

Beyond technical and environmental considerations, regulatory barriers – which vary by country - also play acrucial role in the reuse of copper slags. In Chile, slag is still classified as waste rather than as a by-product, which prevents its reuse. However, regulatory changes are under consideration to demonstrate that copper slag is safe and stable enough for construction applications. Recently, the Mining Center at the Pontificia Universidad Católica de Valparaíso conducted laboratory tests confirming the inert nature of copper slag, thus qualifying it as a suitable material for construction. If adopted, this development could enable the rehabilitation of public spaces and the installation of urban infrastructure by Codelco Ventanas (Mch, 2025). In contrast, countries such as Finland, Germany, and Japan have been reusing slags for decades in the construction of roads, breakwaters, and other civil works (CNN, 2024).

# RISKS LINKED TO THE IMPLEMENTATION OF A SLAG REPROCESSING PROJECT

The implementation of a slag reprocessing project involves a range of risks that may impact its technical and economic viability. Below are some of the most relevant risks:

**1. Copper price volatility**: Copper price fluctuations directly impact projected revenues and introduce uncertainty into project profitability. Since copper grades in slags vary, reprocessing is only viable if market prices justify the associated costs.



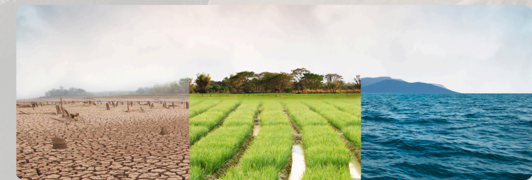

**2. Slag grade variability**: Slags can exhibit highly variable compositions, directly affecting their copper and other valuable metal content. Deviations in copper grades from initial estimates can significantly impact the recoverable quantity and the long-term sustainability of the project.

**3. Copper recovery**: The metallurgical behavior of slags varies depending on their chemical and mineralogical composition. As a result, the efficiency of the copper recovery process can fluctuate significantly, potentially leading to deviations from expected outcomes.

**4. CAPEX**: Estimating CAPEX remains uncertain due to limited experience with reprocessing technologies beyond flotation. This may result in cost overruns during engineering studies, equipment procurement, and plant construction. Furthermore, slag hardness could increase equipment maintenance costs - affecting sustaining CAPEX- and reduce long-term economic viability.

**5. OPEX**: Energy consumption is a critical factor in slag reprocessing, as certain technologies may require high temperatures or intensive comminution. In addition, the material's hardness can affect the efficiency of grinding and crushing equipment. These variables can significantly increase OPEX and reduce the project's profitability.

**6. Environmental Risks**: The emission of polluting gases, as well as the potential leakage of leaching agents into water bodies or soils, represent key environmental risks. It is essential to implement robust containment systems, real-time monitoring, and emergency protocols to minimize these impacts and comply with national and international environmental regulations.



**7. Execution Timeline**: A high degree of research is still required in slag reprocessing to fully understand the chemical reactions and material behavior during processing. This lack of knowledge may delay the project's execution timeline and negatively impact financial planning.

# REPROCESSING AND SUSTAINABLE UTILIZATION OF SLAG IN CHILE

**SLAG REPROCESSING AND REUSE IN CHILE**
**CONTEXT: SMELTERS IN CHILE**

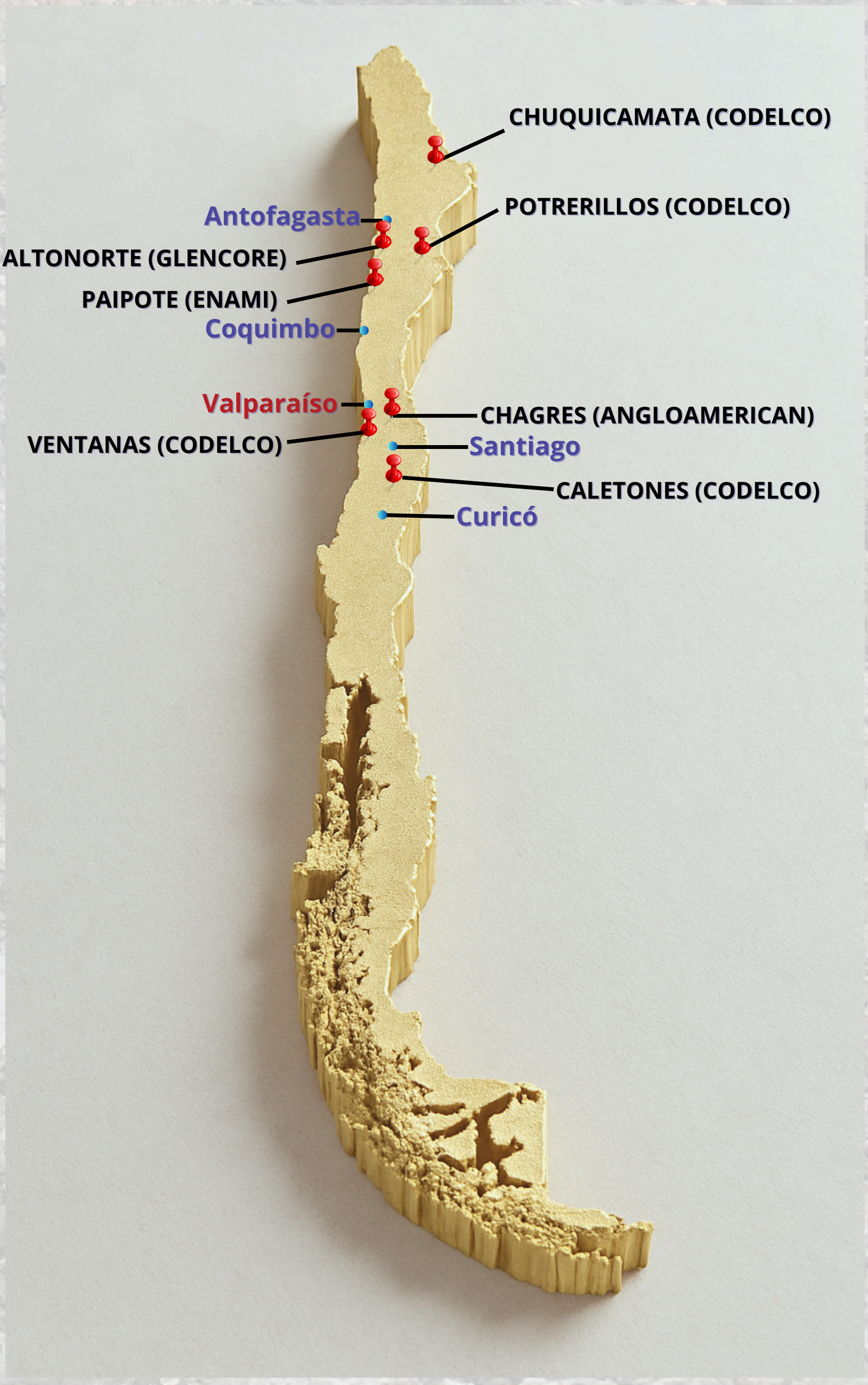
Chile currently hosts seven copper smelters- five operational and two recently decommissioned: Codelco's Ventanas and ENAMI's Paipote (see **Figure 3**). Copper production from smelting has declined by 21% over the past decade, falling from 1.4 million tonnes (Mt) in 2014 to 1.1 Mt of fine copper in 2023. Additionally, its market share dropped from 8.3% to 5.5% during the 2014–2023 period (BCN, 2024) (see **Figure 4**).

This downward trend in smelter production may reduce the volume of slag generated, thereby decreasing the availability of material for reprocessing and reuse. As a result, the lifespan of the slag reprocessing market could also be limited—especially if smelters continue to face operational difficulties and closures.

A review of current operations confirms that all five active smelters in Chile have slag reprocessing systems in place. Flotation is predominant method and remains the only technology implemented at industrial scale. In contrast, leaching technologies remains under development, with ongoing research and pilot tests. One such example is the ammonia-based leaching method for oxidized smelting slags, developed by Dr. Álvaro Aracena of the Pontificia Universidad Católica de Valparaíso and patented in 2022. Studies suggest this technology has demonstrated the potential to recover up to 85% of copper from oxidized slags (PUCV, 2022).

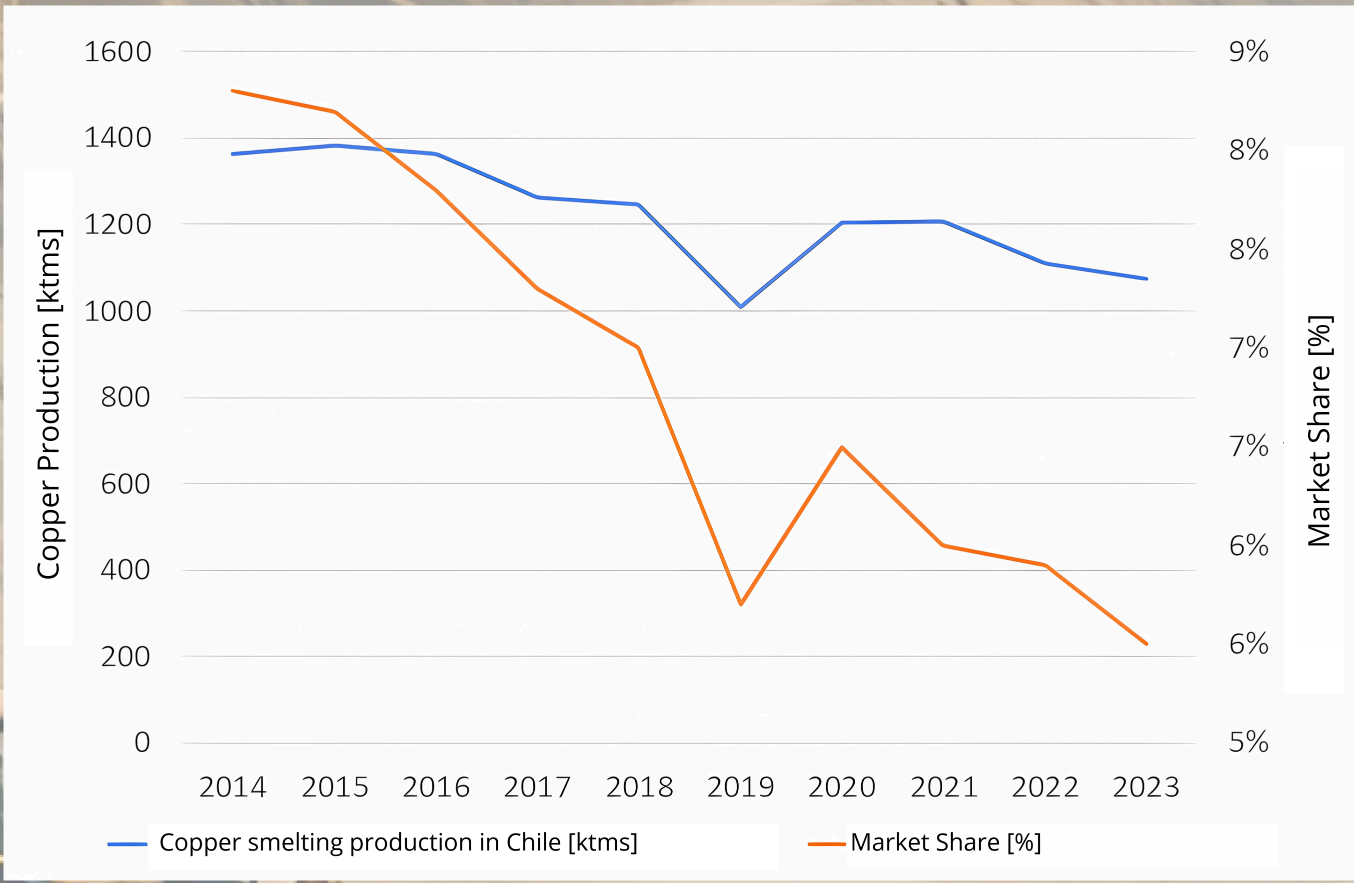
It is worth noting that, in 2013, Chile's Ministry of the Environment enacted Supreme Decree No. 28, which set maximum emission limits and sulfur and arsenic capture efficiency requirements for smelters operating in the country. This regulation required smelters to invest in plant upgrades, incorporating gas capture and pollutant abatement technologies to comply with the standards, which were initially set to take effect by the end of 2018 (Sonami, 2015) and are now fully in force (see **Table 1**).
Pyrometallurgical processes in slag-cleaning furnaces can generate significant emissions of arsenic and sulfur dioxide, depending on slag composition and furnace conditions. In response to these regulations, several smelters began evaluating reprocessing alternatives to mitigate emissions while enhancing metal recovery (Codelco, 2016).

**FIGURE 3. METALLURGICAL SMELTERS IN CHILE**




**Source: Own elaboration based on Reyes (2014)**

## FIGURE 4. SMELTER COPPER PRODUCTION AND MARKET SHARE – CHILE




Source: Own elaboration based on BCN (2004)

## TABLE 1. NEW SULFUR AND ARSENIC EMISSION STANDARD FOR CHILEAN SMELTERS

| SMELTER | $SO_2$ Emission [t/year] Average 2007–2011 | $SO_2$ Limit [t/year] New Standard | As Emission [t/year] Average 2007–2011 | As Limit [t/year] New Standard |
|---|---|---|---|---|
| Caletones | 118.600 | 47.680 | 375 | 130 |
| Chuquicamata | 91.100 | 49.700 | 800 | 476 |
| Potrerillos | 82.200 | 24.400 | 800 | 157 |
| Altonorte | 44.251 | 24.000 | 126 | 126 |
| Paipote | 23.000 | 12.800 | 34 | 17 |
| Ventanas | 18.800 | 14.650 | 120 | 48 |
| Chagres | 13.440 | 13.950 | 95 | 35 |

Source: Sonami (2015)

## CASES OF SLAG REPROCESSING IN CHILE

One of the most prominent examples in Chile is the Potrerillos smelter, part of Codelco's Salvador Division, which has invested in one of the most modern slag flotation plants in the world. Commissioned in 2015, this facility includes controlled cooling pots, SAG milling, and state-of-the-art pressure filters, with a design capacity of 1,700 tonnes of slag per day. The use of cutting-edge technologies has reduced gas emissions into the atmosphere and improved the recovery of copper, gold, and silver. Codelco reports that this plant has enhanced metal recovery and operational performance, turning a previously loss-making unit into a technically and economically efficient smelter through reduced operating costs (Codelco, 2016).

Similarly, the Caletones smelter, part of Codelco's El Teniente Division, has incorporated slag reprocessing technologies. In 2019, it began operations following an investment of approximately US$277 million, aimed at the construction and operation of a milling and flotation plant for processing slags generated in the Teniente Converters. This project arose from the need to replace the slag-cleaning furnaces, whose arsenic emissions levels prevented compliance with the environmental regulations that came into effect in 2018 (Portal Minero, 2015), and which are now fully enforced.

Additionally, the Caletones plant has a slag processing capacity of 3,750 tonnes per day and a projected operational lifespan of 25 years (Contreras, 2019). Approximately 40% of its operating costs are linked to energy consumption, with 60% of that amount corresponding to the operation of the ball mill. To optimize energy efficiency and reduce costs, process improvements were implemented in 2023, specifically reducing the revolutions per minute of the ball mill. This measure resulted in annual energy and cost savings equivalent to US$1 million (Codelco, 2023).

Unlike other Codelco smelters, Chuquicamata continues to rely on slag treatment furnaces and has yet to adopt modern reprocessing technologies. During the 1990s, slags generated in the furnaces—which would otherwise be discarded—were processed via flotation by the external company Minera Cerro Dominador (Arancibia, 2008). However, this contract was terminated in 2009, with the intention of handling these tasks internally (La Tercera, 2010). Later, in 2020, Codelco launched the Flash Furnace enhancement project, increasing its capacity and incorporating gas capture and treatment systems to comply with the emission regulations for arsenic and sulfur set by the Supreme Decree (Pares & Alvarez, 2021).

The Chagres smelter, operated by Anglo American, signed a contract in February 2024 with Minera Punitaqui to process 240,000 dry metric tonnes of slag using flotation, with the commitment to sell the produced concentrate back to Anglo American (De Vicente, 2024). Additionally, Anglo American is developing a slag revalorization project through leaching at the Chagres smelter, aiming to produce commercially viable copper cathodes. However, this initiative is still in the research phase (Consejo Minero, 2023).

Lastly, Glencore's Altonorte smelter commissioned its Slag Treatment Plant via flotation in 2001. This process involves slag cooling, grinding, thickening, and filtration, after which the concentrate is returned to the smelter (Reyes, 2014). In 2021, an optimization project was implemented to improve the ladle cooling system, which significantly reduced water consumption and the copper content in tailings. As a result, water use decreased from 1.3 $m^3$ to 0.4 $m^3$ per tonne of slag—representing a 69% reduction (Glencore, 2024).

## SLAG REUSE IN CHILE

In June 2003, Chile's Ministry of the Environment enacted Supreme Decree No. 148, establishing the Sanitary Regulation on Hazardous Waste Management. Under this regulation, copper slag is considered non-hazardous as long as concentrations of arsenic, lead, and cadmium remain below specific thresholds (see **Table 2**). Should these limits be exceeded, the waste generator must demonstrate to the Health Authority that the material complies with the Maximum Permissible Concentrations (MPC) to avoid its classification as hazardous (BCN, 2004).

A key aspect in the current discussion is the classification of slag as waste, as this determination can limit its potential use in various applications. While Decree 148 does not explicitly prohibit the reuse of non-hazardous waste in construction, its regulation generates uncertainty about the viability of its use in this sector. Materials classified as waste face strict controls on use, transport, and final disposal, limiting their integration into industrial as applications like construction.

## TABLE 2. MAXIMUM PERMISSIBLE CONCENTRATIONS (MPC) FOR NON-HAZARDOUS WASTE

| Substance | MPC [mg/L] |
|---|---|
| Arsenic | 5 |
| Cadmium | 1 |
| Mercury | 0,2 |
| Silver | 5 |
| Lead | 5 |

Source: BCN (2004).

A significant step forward in this area was the approval of the Chilean standard NCh163:2024 "Aggregates for Concrete and Mortar," officially launched in December 2024. This standard allows for the incorporation of recycled and artificial aggregates, including those derived from slag and tailings, in the production of concrete. The goal is to reduce the extraction of natural aggregates and promote the circular economy in the construction industry (Moraga, 2024).

Despite these advances, the classification of slag as waste remains an obstacle to its large-scale reuse. Experts and industry representatives agree that the main challenge is regulatory, not technical. To facilitate its use in construction and other applications, environmental and health authorities must reassess its classification, considering it a mining by-product rather than waste (NME, 2024). This distinction is key: while a by-product can be used without being subject to strict waste management regulations, a material classified as waste faces constraints that may discourage its valorization.

To demonstrate the safe reuse of copper slag in construction and support regulatory change, several initiatives have emerged in recent years. One example is the pilot project by Codelco Ventanas, presented in January 2025 to the Intersectoral Working Group for the Reuse of Copper Slag. This project aims to replace natural aggregates with copper slag in the production of asphalt mixtures for pavement construction (Pizzoleo, 2025).

Similarly, Anglo American signed an agreement with the Ministry of Public Works (MOP) to evaluate the use of mining waste in national road infrastructure projects. This agreement includes the monitoring of pilot projects at the Chagres Smelter and Las Tórtolas Plant, which involve the application of chemically stabilized layers using slag and tailings, as well as a surface asphalt layer (MOP, 2025).

### REPROCESSING AND REUSE OF SLAG WORLDWIDE

The reprocessing and reuse of mining slag are practices addressed in various countries, as similar by-products are also generated during the production of steel, iron, zinc, and nickel. Resource optimization and sustainability have driven both technological and regulatory advancements worldwide, aiming to transform this challenge into an opportunity. This section examines global practices in slag reprocessing and reuse, focusing on widely used metal recovery techniques and the regulatory advances in different countries that have enabled slag reuse across industries, thereby promoting a more circular economy.

### GLOBAL PRACTICES IN SLAG REPROCESSING

Slag reprocessing for the recovery of copper and other valuable minerals is practiced globally, utilizing various techniques such as smelting,flotation, and – more recently - leaching. The selection of the most appropriate technique depends on multiple factors, including available technical expertise, the type of ore, existing infrastructure, local regulations, and the specific composition of the slag.

Notable international companies engaged in slag reprocessing include Aurubis (Germany) and Metso (Finland), the latter known for its Ausmelt TSL technology. Although both companies use furnace-based smelting, their technologies differ by their specific innovations and approaches. In recent years, Aurubis has made significant investments to optimize slag processing at its plant in Bulgaria, focusing particularly on the cooling process. Unlike the traditional pit cooling method, the company plans to implement the use of slag pots—steel containers designed to hold and transport slag—which will improve metal recovery rates and reduce emissions. The new technology is expected to be operational by 2026.

Meanwhile, Metso's Ausmelt TSL technology stands out for its use of fuel injection into the slag, harnessing the energy released during ore oxidation. This significantly reduces fuel consumption compared to conventional processes.

Regarding flotation-based reprocessing, a notable example is Namibia Custom Smelters, located in Namibia. This company recovers copper from slags via flotation when the copper content ranges between 0.8% and 5% (Sibanda et al., 2015). In such cases, copper-rich slags are sent to a specialized plant, where they undergo grinding followed by froth flotation. While most of the copper minerals in the area are sulfides, copper oxides pose additional challenges for this process.

As for leaching, this method has attracted considerable global interest, as it is viewed as a potentially more cost-effective, simpler, and cleaner alternative compared to smelting and flotation. Its lower energy requirements and higher efficiency in processing certain minerals—particularly copper oxides—make it especially appealing. However, despite extensive research in this area, leaching cannot yet be considered an established industrial-scale process. This is primarily due to variability in efficiency and reaction behavior, which depends on the specific mineral composition of each slag.

Despite technological advancements, mineral recovery from slags is not always economically viable. The commercial feasibility of implementing a recovery process depends on the margin between the value of the recovered metals and the associated operating costs, which can vary significantly from case to case. For instance, in scenarios where mineral grades are low and operational costs are high, further slag treatment may not justify the investment.

## REUTILIZATION OF SLAG WORLDWIDE

As mentioned in previous sections, the classification of slag as a by-product rather than as waste has significant implications for its reuse and its potential application in other industries, such as construction.

In the European Union, slags are no longer considered waste and are, in many cases, recognized as valuable by-products. This shift has been made possible by Article 6 "End-of-Waste Status" of the European Union's Waste Framework Directive (2008/98/EC), which promotes a circular economy by allowing certain materials, after undergoing a recovery process, to cease being classified as waste. To achieve this status, the materials must meet the following key requirements: They must have a specific use. There must be a market demand for them. They must comply with relevant technical and regulatory standards. They must not cause adverse effects on human health or the environment.

Regarding the assessment of hazards or potential impacts, the European Union enforces the REACH regulation (Registration, Evaluation, Authorisation and Restriction of Chemicals), which has been in effect since 2007. This regulation provides a clear framework for the evaluation and control of chemical substances. Unlike regulatory models where authorities assign classifications, REACH delegates responsibility to businesses, requiring them to register, evaluate, and manage risks associated with their substances. The companies must demonstrate that these substances are safe for commercialization and use. The European Chemicals Agency (ECHA) oversees this process and has the authority to restrict or ban substances that pose an unacceptable risk to human health or the environment.

Within this framework, REACH classifies substances based on their hazard potential into specific categories, such as carcinogenic, mutagenic, toxic for reproduction, explosive, corrosive, among others. All hazard-based classifications defined under EU regulations can be found in **Table 3**.

This approach enables regulators to set concentration limits based on the combined impact of multiple hazardous characteristics, rather than analyzing each substance in isolation. An example procedure for determining the hazard classification of a particular type of waste is illustrated in **Figure 5**.

A key aspect of REACH is that the evaluation of a substance begins with its original composition. This means that not only is the element in its final state analyzed, but also the compounds from which it originates.

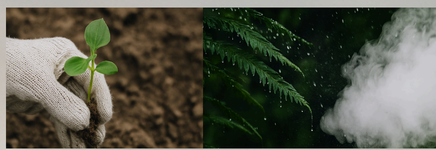
In contrast to the EU's holistic framework, Chile evaluates substances independently, without necessarily considering compound interactions or origin. This can lead to regulations that do not fully align with the actual characteristics of certain materials, potentially hindering their appropriate classification and reuse.

## TABLE 3. CLASSIFICATION OF HAZARDOUS PROPERTIES DEFINED IN REGULATION (EU) No. 1357/2014 ACCORDING TO THE NATURE OF THE HAZARD

| | |
|---|---|
| HP1 | Explosive |
| HP2 | Oxidizing |
| HP3 | Flammable |
| HP15 | Wastes that may exhibit one or more of the hazardous characteristics listed above |

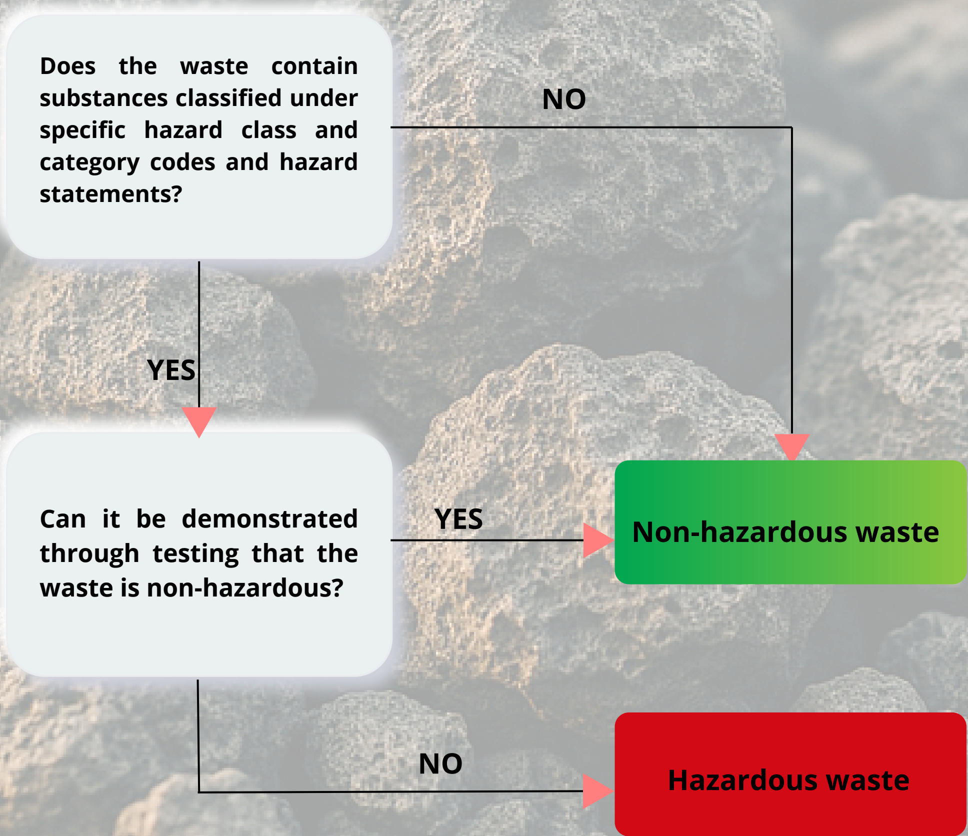

| | |
|---|---|
| HP4 | Irritant: causes skin and eye irritation |
| HP5 | Specific organ toxicity / aspiration toxicity |
| HP6 | Acute toxicity |
| HP7 | Carcinogenic |
| HP8 | Corrosive |
| HP9 | Infectious |
| HP10 | Toxic for reproduction / Mutagenic |
| HP11 | Mutagenic |
| HP12 | Release of an acutely toxic gas |
| HP13 | Sensitizing |

| | |
|---|---|
| HP14 | Ecotoxic |



Source: Own Elaboration based on Gobierno de España (2021)

## FIGURE 5. PROCEDURAL EXAMPLE FOR THE IDENTIFICATION OF HAZARDOUS PROPERTIES HP 1, HP 2, HP 3, HP 12, AND HP 15




Source: own elaboration

A concrete example of regulatory enablement is copper slag (iron silicate), which has been registered under the EU's REACH regulation since 2010 as a safe and valuable by-product. Several smelters around the world (including those in Chile) have demonstrated its environmental and human safety across its life cycle. In this regard, the European approach protects public health and the environment while actively promoting the reuse of industrial materials within a circular economy framework.

In the United States, federal law has excluded certain types of slag from regulations related to hazardous waste. A brief historical review shows that in 1978, hazardous waste was defined under Subtitle C of the Resource Conservation and Recovery Act (RCRA). According to the Environmental Protection Agency (EPA), this includes materials that pose risks to human health or the environment due to their toxicity, corrosivity, flammability, or reactivity—thus subjecting them to strict regulations concerning their handling, transportation, and disposal. However, within this classification, a category known as "special wastes" was created, requiring further study to assess their level of risk. Among these were materials generated from mining and mineral processing, including slags produced during the extraction of metals such as copper, lead, and zinc. Ultimately, in 1980, the Bevill Amendment (part of the Solid Waste Disposal Act amendments) exempted wastes derived from the beneficiation and processing of ores and minerals from being considered hazardous waste at the federal level. In 1918, the National Slag Association was founded in the U.S. and continues to this day to promote the use of blast furnace and steel furnace slags.

Following this initiative, the Australasian Slag Association was established in 1960, comprising producers, processors, customers, and suppliers of iron and steel slags. Its name reflects the participation of members from Australia, New Zealand, Indonesia, and Malaysia. The main goal of the association is to conduct research of mutual interest for its members and to disseminate findings and technical information that promote the beneficial use of iron and steel slags in construction materials and other industries with reuse potential. One of the association's priorities is compliance with all state and territorial laws in the member countries (Australasian Slag Association, 2025).

The Australian Standard AS 3582.2 (2016) – "Supplementary Cementitious Materials – Part 2: Slag – Ground Granulated Blast Furnace Slag" defines limits for only four properties: sulfur in the form of sulfide (maximum 1.5%), magnesium (maximum 15%), aluminum (maximum 18%), and chloride ion (maximum 0.1%). While the standard does not mandate performance-based concrete testing to validate the product's suitability, it distinguishes between "proven" and "unproven" slag sources. The latter must undergo frequent testing over a six-month period to ensure quality and consistency. Additionally, while not all properties have defined limits, buyers may request test data for any of them (Cement Concrete & Aggregates Australia, 2018).

It is important to note that both in the European Union and in countries like Australia and the United States, regulations may vary between different countries (in the EU's case) and between states (in the U.S. and Australia). Thus, beyond federal or supranational frameworks, individual jurisdictions may impose additional restrictions.

Aurubis, mentioned previously, is a global leader in non-ferrous metals and one of the world's largest copper recyclers, marketing approximately 1.2 million tonnes of iron silicate annually. In an online seminar organized by Alta Ley Corporation of Chile (2024), which aimed to explore the international landscape of copper smelter slag valorization, Michael Hoppe, project leader at Aurubis, noted that although the material is registered under the REACH system, its use is restricted to specific applications. He also pointed out the challenge of developing applications in one country that cannot be marketed in another, highlighting the need for ongoing dialogue with lawmakers to promote broader global utilization.
This underscores the regulatory fragmentation that still challenges global standardization in slag reuse—and the need for harmonized policies to fully unlock its potential.



**USE CASES AND OPPORTUNITIES FOR SLAG AROUND THE WORLD**

One example of slag that is produced and widely used in various countries around the world is electric arc furnace (EAF) slag, a byproduct of the steel industry that is traded internationally. This type of slag has been used as an alternative to crushed rock in a range of applications, including encapsulated uses (such as in concrete and asphalt) and non-encapsulated uses (as loose material for soil cover, landscaping, and others). However, regulatory agencies - such as the U.S. Environmental Protection Agency (EPA) - are investigating potential health risks associated with the non-encapsulated use of EAF slag, particularly in residential and school environments. It has been found that this material can contain elevated levels of manganese, hexavalent chromium, and other metals, which may pose a risk to human health.
There are warnings about possible adverse effects and recommendations for mitigating exposure, although research is still ongoing. In the United States, the EPA (2024) notes that "EAF slag is used across the country, but its regulation varies significantly from state to state. Some states allow its use in residential settings, while others prohibit it. For more information, it is recommended to consult the specific regulations of each state".

In Australia, the use of iron and steel slag as a substitute for cement began around 1966, primarily in the areas of Port Kembla, Sydney, and Newcastle. However, the increase in its price and the decline of the steel industry in those regions led to a decrease in its usage. Despite these challenges, slag remains in use across Australia, with granulated slag now imported primarily from Japan (Cement Concrete & Aggregates Australia, 2018).

Regarding copper slag, in Singapore, it was originally imported mostly from Japan to be used as an abrasive material. However, with repeated use, the slag loses its abrasive properties, which led to it being discarded in landfills due to the lack of further applications. As a result of this and the potential contamination caused by mining waste deposited in the soil, a local branch of Holcim—the Swiss company and leading global supplier of construction materials—developed in Singapore a concrete that uses washed copper slag, replacing natural sand. It has been demonstrated that this concrete forms denser structures than conventional concrete, which improves its durability, reduces permeability, and increases strength. In addition, there are notable sustainability benefits, as the concrete not only replaces scarce natural resources but also requires less water in its production compared to conventional concrete (Holcim, 2014).

This innovation illustrates how industrial by-products like copper slag can be repurposed in high-performance construction materials, offering a model for circular economy adoption in other urbanized regions.

In relation to the above, the HARARE consortium—made up of 10 industrial partners, including Aurubis, from four European countries—aims to demonstrate sustainable methods for the production of non-ferrous metals, using hydrogen as a key enabler. The project also seeks to use waste as raw material, with a particular focus on copper slag, aiming to validate its use as a supplementary cementitious material that could reduce reliance on clinker and lower carbon emissions. In this regard, the consortium is exploring the use of copper slag as a partial or even total substitute for Portland cement in construction materials (Harare, 2021).

# CONCLUSION

Chile ranks among the global leaders in industrial-scale flotation, with few technological gaps relative to other countries. In the field of leaching, Chile has also made significant progress, conducting research and pilot tests aimed at its implementation. Should this technology be scaled up to an industrial level, it would generate both economic and environmental benefits, as it could lower processing costs and reduce emissions associated with these materials.

In the case of slag reuse, the main barrier in Chile is regulatory, which has delayed its adoption compared to countries like the United States, those in Europe, and Australia. In Chile, slag is classified as non-hazardous waste, which limits its use in construction. In contrast, in other parts of the world, slag is considered a by-product and has been successfully reused for years. Chile could benefit from analyzing these international cases to adopt a more precise regulatory framework aligned with the principles of a circular economy.

Developing more specific regulations regarding usage limits and conducting detailed studies on its environmental and health impacts would not only promote slag reuse but also strengthen environmental protection and public health. In this regard, public-private partnerships have emerged to validate, through studies and pilot projects, the stability and safety of slag in construction, with the goal of driving regulatory change. However, if no progress is made on this front, a viable alternative would be to consider exporting slag to markets where its use is already regulated and permitted.

Ultimately, the reprocessing and reuse of slags represent a significant opportunity from both an economic and environmental standpoint. For smelters, this would mean adding value to their production chain by transforming waste into a usable resource, thereby reducing the costs associated with slag disposal in dumps. At the same time, the construction sector would benefit from the use of artificial aggregates, which offer greater strength compared to natural aggregates.

From an environmental perspective, using slag would help reduce the exploitation of river basins, preserving ecosystems and freeing up space in landfills for alternative uses. Collectively, these actions contribute to a virtuous circle of circular economy practices - reducing environmental impact, conserving natural resources, and transforming industrial waste into a strategic asset.

# BIBLIOGRAPHY

Alta Ley. (17 de octubre, 2024). Expertos coinciden en la importancia de clasificar a las escorias como subproducto minero. https://www.corporacionaltaley.cl/expertos-coinciden-en-la-importancia-de-clasificar-a-las-escorias-como-subproducto-minero/.

Arancibia, A. (2008). MEJORAMIENTO PROCESO DE LIMPIEZA DE ESCORIA EN FUNDICION DE CONCENTRADO CHUQUICAMATA. Pontificia Universidad Católica de Valparaíso. http://opac.pucv.cl/pucv_txt/txt-8500/UCI8576_01.pdf.4

Aurubis. (2023). Investing in sustainability: Aurubis optimizes slag processing at Bulgarian site. https://www.aurubis.com/en/media/press-releases/press-releases-2023/investing-in-sustainability-aurubis-optimizes-slag-processing-at-bulgarian-site.

Australasian Slag Association. (2025). About the ASA. https://www.asa-inc.org.au/about-the-asa.

BCN. (16 de junio, 2004). DECRETO 148 | APRUEBA REGLAMENTO SANITARIO SOBRE MANEJO DE RESIDUOS PELIGROSOS. Alta Ley. (17 de octubre, 2024). Expertos coinciden en la importancia de clasificar a las escorias como subproducto minero. https://www.corporacionaltaley.cl/expertos-coinciden-en-la-importancia-de-clasificar-a-las-escorias-como-subproducto-minero/.

Arancibia, A. (2008). MEJORAMIENTO PROCESO DE LIMPIEZA DE ESCORIA EN FUNDICION DE CONCENTRADO CHUQUICAMATA. Pontificia Universidad Católica de Valparaíso. http://opac.pucv.cl/pucv_txt/txt-8500/UCI8576_01.pdf.4

Aurubis. (2023). Investing in sustainability: Aurubis optimizes slag processing at Bulgarian site. https://www.aurubis.com/en/media/press-releases/press-releases-2023/investing-in-sustainability-aurubis-optimizes-slag-processing-at-bulgarian-site.

Australasian Slag Association. (2025). About the ASA. https://www.asa-inc.org.au/about-the-asa.

BCN. (16 de junio, 2004). DECRETO 148 | APRUEBA REGLAMENTO SANITARIO SOBRE MANEJO DE RESIDUOS PELIGROSOS. Apey, A., Ramírez, E., Gumucio, A., & Amunátegui, R. (2017). Agricultura chilena, reflexiones y desafíos al 2030, (1ra ed., pp. 147-178). ODEPA.

BCN. (2021). Colusión de Empresas. Disponible en: https://www.bcn.cl/portal/leyfacil/recurso/colusion-de-empresas.

BCN. (2021). Principales usos del agua desalada a nivel global y estrategias de mitigación de impactos ambientales del proceso de desalinización. Disponible en: obtienearchivo (bcn.cl)

BCN. (2024). Decreto 30 – MINISTERIO DEL MEDIO AMBIENTE. Disponible en: Ley Chile - Decreto 30 01-FEB-2024 MINISTERIO DEL MEDIO AMBIENTE - Biblioteca del Congreso Nacional (bcn.cl)

Cabrera, F. (2023). ClustersMineros en Australia y Chile. Disponible en: https://obtienearchivo.bcn.cl/obtienearchivo?id=repositorio/10221/34387/1/Informe_BCN_Clusters_productivos_en_la_mineri__a_Australia_y_Chile_FINAL.pdf.

Cochilco. (2024). Inversión en la Minería Chilena: Cartera de Proyectos.

COCHILCO. (2024), Proyección de la producción esperada de cobre 2023-2034. Disponible en:https://www.cochilco.cl/Proyeccion_produccion_cobre_2023_2034_vfinal2.pdf.
.

BCN. (2024). Producción de mina, fundición y refinación de cobre. Asesoría Técnica Parlamentaria. https://obtienearchivo.bcn.cl/obtienearchivo?id=repositorio/10221/36566/1/Informe_BCN_mercado_de_FURE_FINAL.pdf.

Cayumil, R., Carrasco, C., Aguilar, C., y Sánchez, M. (17 de octubre, 2022). VALORIZACIÓN DE RESIDUOS MEDIANTE PROCESOS METALÚRGICOS: EXPERIENCIAS LOCALES.Revista Nueva Minería & Energía. 62-64. https://www.litoralpress.cl/sitio/Prensa_Texto?LPKey=G7JGF7DRUZQ5SMZ3VHXOC557NMSNBPAVJ3YLTVEQIOEPUS7PWPDQ.

Cement Concrete & Aggregates Australia. (2018). Ground Slag Properties, Characterisation and Uses. TECH_NOTE_78_-_Ground_Slag.pdf.

Charles, D., Dávila, G., González, A., y Salinas, A. (2024). Revisión sobre la producción, usos y revalorización de escorias. ResearchGate, 76, 221-250. https://www.researchgate.net/publication/380320443_Revision_sobre_la_produccion_usos_y_revalorizacion_de_escorias.

Ciencia En Chile. (22 de mayo, 2024). La problemática de las escorias mineras: pasivo ambiental y potencial de reutilización. https://www.cienciaenchile.cl/la-problematica-de-las-escorias-mineras-pasivo-ambiental-y-potencial-de-reutilizacion/#lectura.

CNN. (3 de agosto, 2024). Escoria minera: Desafíos normativos y avances en reutilización | Minería 360. https://www.cnnchile.com/m360/escoria-minera-desafios-regulatorios-y-avances-en-reutilizacion-mineria-360_20240803/.

Cochilco. (2024). Análisis: Industria Mundial de Fundiciones. Dirección de Estudios y Políticas Públicas. https://www.cochilco.cl/web/otros-estudios-del-cobre/.

Codelco. (14 de noviembre, 2016). Planta de Flotación de Escoria: Sangre, sudor y lágrimas. https://www.codelco.com/sangre-sudor-y-lagrimas.

Codelco. (2019). FUNDICIÓN "Recién salido del horno". 3-11. https://www.codelcoeduca.cl/codelcoeduca/site/artic/20190109/asocfile/20190109005205/fundicion_media_t__cnico_060119.pdf.

Codelco. (30 de enero, 2023). Aurubis y Codelco firman acuerdo para cooperar en una cadena de valor del cobre más sostenible y responsable. https://www.codelco.com/aurubis-y-codelco-firman-acuerdo-para-cooperar-en-una-cadena-de-valor.

Codelco. (3 de noviembre, 2023). Caletones: Planta de Tratamiento de Escorias ahorra 1 millón de dólares anuales en consumo energético. https://www.codelco.com/planta-de-tratamiento-de-escorias-ahorra-1-millon-de-dolares-anuales-en.

Contreras, C. (2019). ELABORACIÓN DE BALANCE DE MASA Y ENERGÍA DEL SISTEMA DE MANEJO DE GASES PARA LA CONSTRUCCIÓN DE UN MODELO PREDICTIVO QUE PERMITA MEJORAR LA CAPTURA DE AZUFRE Y ARSÉNICO EN LA PLANTA DE FUNDICIÓN CALETONES, CODELCO DIVISIÓN EL TENIENTE. Universidad Técnica Federico Santa María. https://es.scribd.com/document/446219676/3560900251245UTFSM

# BIBLIOGRAPHY


Consejo Minero. (5 de diciembre, 2023). Revalorización de Escorias de Fundición Chagres. Innovación y Tecnología. https://consejominero.cl/plataforma-social/revalorizacion-de-escorias-de-fundicion-chagres/.

Emgrisa. (2021). ANÁLISIS DE LA APLICACIÓN DEL CONCEPTO DE FIN DE CONDICIÓN DE RESIDUO DE LAS ESCORIAS DE FUNDICIÓN DE HORNO DE ARCO ELÉCTRICO PARA SU USO COMO ÁRIDO Y OTROS USOS. Gobierno de España. https://www.miteco.gob.es/content/dam/miteco/images/es/estudio_fcr_escorias_vdef_julio21_tcm30-529624.pdf.

EPA Colorado. (2020). Cómo pueden los residentes minimizar el contacto con el material de jardinería de escoria de alto horno. https://semspub.epa.gov/work/08/100008679.pdf.

EPA. (13 de mayo, 2024). Electric Arc Furnace (EAF) Slag. https://www.epa.gov/smm/electric-arc-furnace-eaf-slag.

EPA. (14 de junio, 2024). Special Wastes. https://www.epa.gov/hw/special-wastes.

EPA. (7 de enero, 2025). Comprehensive Procurement Guideline (CPG) Program. https://www.epa.gov/smm/comprehensive-procurement-guideline-cpg-program#content.

Glencore. (8 de marzo, 2024). Fundición Altonorte pone en marcha innovador sistema de enfriamiento de escoria en ollas.https://www.glencore.cl/media-blog/noticias/fundicion-altonorte-pone-en-marcha-innovador-sistema-de-enfriamiento-de-escoria-en-ollas.

Gobierno de España. (2021). Guía Técnica para la Clasificación de los Residuos. https://www.miteco.gob.es/content/dam/miteco/es/calidad-y-evaluacion-ambiental/temas/prevencion-y-gestion-residuos/guiatecnicaclasificacionderesiduosnov_21_tcm30-509157.pdf.

Harare. (2021). Valorisation of copper slags in the construction sector. https://h2020harare.eu/valorisation-of-copper-slags-in-the-construction-sector-why-and-how.

Holcim. (2014). Building on ambition. Corporate Sustainable Development Report 2014. https://www.holcim.com/sites/holcim/files/2022-03/2014_susdevholcim_sd-report2014.pdf.

Hughes, S. (2000). Applying Ausmelt technology to recover Cu, Ni, and Co from slags. JOM, 52, 30-33. https://link.springer.com/article/10.1007/s11837-000-0170-5.

International Copper Association. (2024). Circularidad de las Escorias de Cobre y el Marco Regulatorio de la UE: Habilitando una Minería Sostenible.

https://www.corporacionaltaley.cl/wp-content/uploads/2024/10/Escorias-de-cobre-Economia-Circular-final-publico-2024-10-09.pdf?utm_source=chatgpt.com.

La Tercera. (17 de enero, 2010). Gobierno audita contrato de Codelco con minera de familia Noemi Callejas. https://www.latercera.com/diario-impreso/gobierno-audita-contrato-de-codelco-con-minera--de-familia-noemi-callejas/.

Mendoza, S. (28 de enero, 2025). Innovador proyecto de Codelco Ventanas utiliza 4,5 millones de toneladas de escoria de cobre en pavimentos. https://www.chiletrends.cl/2025/01/28/innovador-proyecto-de-codelco-ventanas-utiliza-45-millones-de-toneladas-de-escoria-de-cobre-en-pavimentos/.

MOP. (24 de enero, 2025). MOP y Anglo American impulsan la reutilización de residuos mineros para desarrollar infraestructura vial. https://www.mop.gob.cl/mop-y-anglo-american-impulsan-la-reutilizacion-de-residuos-mineros-para-desarrollar-infraestructura-vial/.

Moraga, V. (27 de diciembre, 2024). Nueva actualización de la Norma NCh 163 permitirá el uso de escorias y relaves en el hormigón. Centro UC. https://centrohormigon.uc.cl/actualidad/noticias/935-nueva-actualizacion-de-la-norma-nch-163-permitira-el-uso-de-escorias-y-relaves-en-el-hormigon.

NME. (15 de octubre, 2024). Expertos coinciden en la importancia de clasificar a las escorias como subproducto minero. Nueva Minería y Energía. https://www.nuevamineria.com/revista/expertos-coinciden-en-la-importancia-de-clasificar-a-las-escorias-como-subproducto-minero/.

Pares&Alvarez. (25 de septiembre, 2021). Potenciamiento del Horno Flash, Fundición Chuquicamata. https://pya.cl/potenciamiento-del-horno-flash-fundicion-chuquicamata/.

Parlamento Europeo. (24 de mayo, 2023). Economía circular: definición, importancia y beneficios. https://www.europarl.europa.eu/topics/es/article/20151201STO05603/economia-circular-definicion-importancia-y-beneficios

Pizzoleo, J. (28 de enero, 2025). Subsecretaria de Minería conoce avances de inédita pavimentación con escoria de cobre. Reporte Minero y Energético. https://www.reporteminero.cl/noticia/noticias/2025/01/subsecretaria-mineria-avances-pavimentacion-escoria-cobre.

Portal Minero. (26 de octubre, 2015). Inician tramitación ambiental de Planta Tratamiento de Escorias de El Teniente. https://www.portalminero.com/pages/viewpage.action?pageId=104465887&utm_.

PUCV. (12 de octubre, 2022). Tecnología PUCV que utiliza método de lixiviación amoniacal para la recuperación de cobre desde escorias obtiene patente de invención por parte de INAPI. https://www.pucv.cl/uuaa/tecnologia-pucv-que-utiliza-metodo-de-lixiviacion-amoniacal-para-la.

Mch. (20 de mayo, 2025). PUCV certifica estabilidad de la escoria de cobre de Codelco Ventanas. PUCV certifica estabilidad de la escoria de cobre de Codelco Ventanas - Mch.


GEM
Paving the way for the future of mining

# BIBLIOGRAPHY

Pizzoleo, J. (28 de enero, 2025). Subsecretaria de Minería conoce avances de inédita pavimentación con escoria de cobre. Reporte Minero y Energético. https://www.reporteminero.cl/noticia/noticias/2025/01/subsecretaria-mineria-avances-pavimentacion-escoria-cobre.

Portal Minero. (26 de octubre, 2015). Inician tramitación ambiental de Planta Tratamiento de Escorias de El Teniente. https://www.portalminero.com/pages/viewpage.action?pageId=104465887&utm_.

PUCV. (12 de octubre, 2022). Tecnología PUCV que utiliza método de lixiviación amoniacal para la recuperación de cobre desde escorias obtiene patente de invención por parte de INAPI. https://www.pucv.cl/uuaa/tecnologia-pucv-que-utiliza-metodo-de-lixiviacion-amoniacal-para-la.

De Vicente, A. (21 de febrero, 2024). Anglo American firma acuerdo con Minera Punitaqui para recuperar cobre de escorias. Reporte Minero y Energético. https://www.reporteminero.cl/noticia/noticias/2024/02/anglo-american-acuerdo-minera-punitaqui-recuperar-cobre-escorias.

Reyes, G. (2014). EVALUACIÓN DEL PROCESO DE FLOTACIÓN DE ESCORIAS PROVENIENTES DE LA FUNDICIÓN ALTONORTE. Universidad de Santiago de Chile. https://es.scribd.com/document/358206738/Evaluacion-Del-Proceso-de-Flotacion-de-Escorias-Provenientes-de-La-Fundicion-Altonorte.

Sibanda, V., Sipunga, E., Danha, G. y Mamvura, T. (2020). Enhancing the flotation recovery of copper minerals in smelter slags from Namibia prior to disposal. Heliyon, 6, 1. https://www.sciencedirect.com/science/article/pii/S2405844019367945.

Sipunga, E. (2015). Optimization of the flotation of copper smelter slag from Namibia Custom Smelters' Slag Mill Plant. University of the Witwatersrand, Johannesburg. https://wiredspace.wits.ac.za/server/api/core/bitstreams/e6aea972-2416-4f61-9b5b-3aeb01920780/content.

SMA. (30 de abril, 2021). FORMULA CARGOS QUE INDICA EN CONTRA DE CORPORACIÓN NACIONAL DEL COBRE DE CHILE. https://snifa.sma.gob.cl/General/Descargar/20601043485.

Sonami. (2015). Fundiciones de Cobre en Chile. https://www.sonami.cl/v2/wp-content/uploads/2016/07/FCM-20150610-Com-Miner%C3%ADa-y-Energia-Senado-Fundiciones.pdf.

Vernon, P. y Burks, S. (1997). The application of Ausmelt technology to base metal smelting, now and in the future. The Journal of The South African Institute of Mining and Metallurgy. https://www.saimm.co.za/Journal/v097n03p089.pdf.

Your Europe. (2024). Registro de sustancias y mezclas químicas en la UE (Reglamento REACH). https://europa.eu/youreurope/business/product-requirements/chemicals/registering-chemicals-reach/index_es.htm.

# AUTHORS


**MARÍA JESÚS OVALLE**
Project Engineer
mjovalle@gem-mc.com

**MARÍA FRANCISCA REBOLLEDO**
Project Engineer
mfrebolledogem-mc.com


# EDITION


**MERY-ANN GIESE**
Head of Marketing and Administration
magiese@gem-mc.com

**JAVIERA ALEMPARTE**
Press Coordinator
jalemparte@gem-mc.com


# Commercial contact by practice area


**Sebastián Faúndez**
Analytics Practice Leader
sfaundez@gem-mc.com

**Patricio Faúndez**
Economics Practice Leader
pfaundez@gem-mc.com

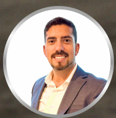
**Pablo Faúndez**
Environment and Society Practice Leader
pmfaundez@gem-mc.com

**Isaac Paredes**
Evaluation Practice Leader
iparedes@gem-mc.com

**Manuel Cordero**
Planning Practice Leader
mcordero@gem-mc.com

**Catalina López**
Strategy Practice Leader
clopez@gem-mc.com


# Commercial contact for Australia and the Asia-Pacific region

**Cristóbal Olave**
Business Development Manager
colave@gem-mc.com


# Commercial contact


**Felipe Guzmán**
Partner - Chief Financial, Administration and Marketing Officer


## OFFICES


**Chile: Las Condes Avenue 12.461, tower 3, officess 805-806, Las Condes, Santiago**

**9 Straits View, Marina One West Tower, #05-07, Singapore 018937**