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Photo courtesy of Glencore

The Chilean Mining Renaissance

Reforms and collaborations set the course for the industry's future

The Chilean mining industry stands at the threshold of an evolutionary era. In 2023, the industry navigated through a period of considerable legal turbulence and transformative change; the long-debated royalty reform was approved, and the constitutional developments set a new precedent, reshaping the legislative landscape that underpins the sector. 2024 was marked by a transformative beginning, as on January 1st, the amendments to Law No. 21,420, refined by Law No. 21,649, came into effect. These revisions represented the first major update to Chile's mining regulatory framework since 1983, ushering in a new era of industry regulation.

From 2023 to 2032, the Chilean mining investment portfolio comprises 49 projects, totaling an investment of US$65.71 billion, according to Cochilco. Six of these projects successfully concluded in 2023, with a cumulative investment of US$7.77 billion. A highlight among those is Vancouver-based producer Teck Resources completed ramp up of its Quebrada Blanca (QB) mine expansion. In Q1 2024, production jumped 74%, amounting to 99,000 t with QB responsible for 43,300 t of that total. The firm's full-year copper production for 2024 is predicted between 465,000 t and 540,000 t, well above the 296,500 t produced in 2023.

Six new projects, amounting to US$6.31 billion, were included in the total, showing the growth of the industry. State-owned Codelco increased its budget by US$4.38 billion for the implementation of both operational and structural projects. In the private sector, investment increased by US$2.33 billion, within that, Los Andes Copper's investments rose from US$1.89 billion to US$2.44 billion for 2023. Los Andes' Vizcachitas project aims to be operational by 2030, "with a daily throughput of 136,000 t, with an annual output of 183,000 t for the first eight years", said the firm's CEO, Santiago Montt.

The US$65.71 billion investment portfolio is, however, a significant US$7.94 billion drop from the 2022-2031 period. Dominique Viera, president of APRIMIN, explained: "In the context of investment, it encompasses far more than just obtaining permits; it is about fostering an environment conducive to investment. In terms of permits, there are numerous actions we can undertake to expedite the process without necessitating new legislation. For instance, simplifying the accreditation of teams and streamlining the approval for exceptional shifts can significantly reduce waiting times."

The government is determined to be proactive. "There is an explicit commitment from the government to reduce permit processing times for mining investment projects in Chile by a third," said Minister of Mining Aurora Williams.

Under the Mining Royalty Law, the government created a public-private working group that proposed 20 actionable measures aligned with this goal. Measures included a reform to Law No. 19.300 to improve the environmental assessment process, implementing modernization projects in institutions responsible for processing permits to review and redesign their processes, significantly streamlining administrative procedures, integrating more critical permits into the unified sectoral permits platform to enhance centralized tracking and reduce delays, and implementing an online permit platform to streamline the application process, among others.

"Chile is a country with a long mining tradition. Most of the uncertainties in the sector have been resolved. There is human capital to make mining possible, stable institutions, and transparency to give foreign investors peace of mind."

Joaquín Villarino,
Executive President,
Consejo Minero

These moves come at a critical time. Copper is trading at its highest levels in over two years. International firms perceive current copper prices and Chile as the perfect marriage. CEO Martin Kostuik of US-based Battery Mineral Resources, which plans to operationalize its new Punitaqui mine in Chile in 2024, explained: "Our commitment to investing in Punitaqui and bringing it into production reflects our confidence in the future of copper."

"Amid political and global instability where others cut back, Odfjell chose to escalate investments in Chile, signaling our aim not just to sustain but to expand our presence and embark on another 50 years in the country," said Diego Rodríguez, general manager of sulfuric acid logistic supplier, Odfjell Terminals Terquim.

Power companies are also forecasting growth: 30% of Chile's electricity demand comes from the mining sector, and by 2030, 50% will be required to come from renewable sources. Sergio del Campo, president of Sonnedix and former Minister of Energy, highlighted Chile's potential: "Our portfolio in Chile stands as the largest within our global operations, reflecting the trust investors place in the Chilean power market."

The regulatory environment also fosters a unique environment said Nelson Batistucci, general manager power technique South America at Atlas Copco: "Chile stands out as a market that readily embraces change and innovation, partly due to its regulatory environment. Stringent regulations, such as those governing light pollution to protect observatories, drive the adoption of advanced technologies."

"Collaboration is essential among all parties involved, including stakeholders, clients, and even competitors. While direct technology development with competitors is not feasible, open communication on various topics is. Collaboration is transversal."

Andrés Costa,
Managing Director
Chile & Peru,
TAKRAF

Lithium: the horses are in the gate

Chile is the world's second-largest producer of lithium. Following the lithium boom of 2021, governmental debates stalled further growth in the industry. The delay came with reason, explained Minister of Mining, Aurora Williams: "Rather than aiming for production numbers or a global position, we aim to develop responsible mining capable of capturing revenue for the state, incorporating technology, and including the Chilean talent. If this places us first in terms of global production, excellent. However, our primary goal is to develop lithium ethically and sustainably."

Racing into development could have meant neglecting blind spots that would have created even larger problems down the road. Instead, the government decided to take the time to consider all the variables to ensure sustainable development of the sector. "The process of awarding Special Operation Contracts (CEOLs)," exemplified Minister Williams, "arises from the previous experience of a failed tender in 2021, when potential impacts were not properly assessed, leading indigenous communities to challenge the process."

In 2024, the government classified Chile's 69 saline environments, identifying 26 salt flats open exclusively to private investors. On April 15th, the country announced a Request for Information (RFI) process. The results will be published in 60 days from that date, in July. The government aims to award permits by the end of the year, if there is no need for indigenous community sign-off, intending to develop three to five new projects

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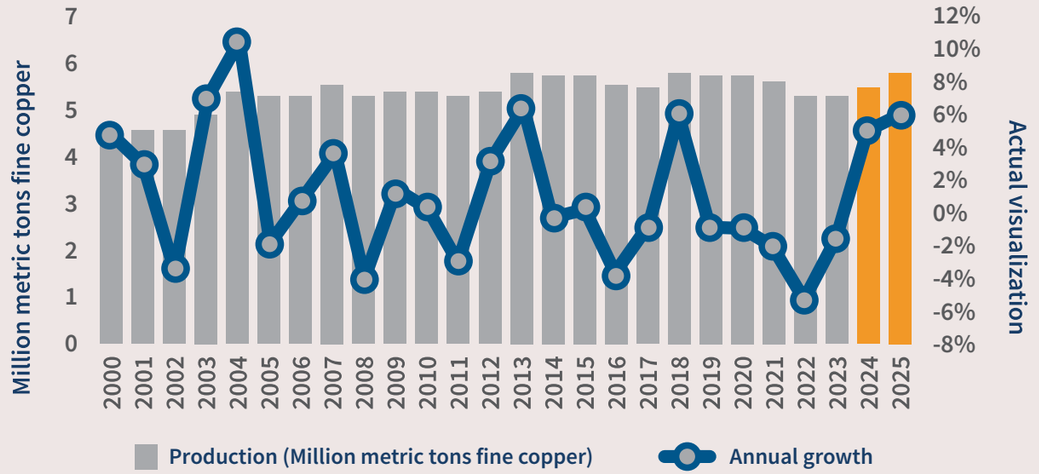
Collaboration is key

Collaboration plays a fundamental role in addressing the mining industry's future challenges, according to Andrés Souper, general manager at Glencore Chile: "Collaboration and strategic alliances to exchange knowledge, technologies, and resources specific to the mining industry, both nationally and internationally will be the primary method to meet the impending copper shortage," he said.

At the CRU World Copper Conference and CESCO Week, industry players across the entire copper value chain cited collaboration as the path forward. According to Iván Arriagada, CEO at Antofagasta Minerals, partnerships enable mining companies to employ capital in more efficient ways— sharing the financial burden of constructing a desalinization plant, for example, recycles millions worth of capital. Joint ventures allow

Evolution of Copper Production in Chile



Source: Cochilco (2024 and 2025 figures are estimates)

companies to mitigate financial risk in a time of challenging markets. Collaboration also augments sustainability efforts. Teck acted as a catalyst for the establishment of the North Pacific Green Corridor Consortium, a collaborative effort to decarbonize the supply chain across North America, Asia, and Europe, said its CEO, Jonathan Price.

On the exploration front, collaboration is the key to unlocking a greenfield pipeline said Christian Barra Llano, general manager at Orbit Garant: "It would also be beneficial to promote collaboration between mining companies to standardize operational and safety requirements, like in Québec. This would simplify accreditation processes and reduce costs, allowing a quicker start to new projects."

The year has begun with some of the most significant collaborative, and general, moves the industry has seen in years. On April 16th, 2024, Australia-based BHP made an all-share offer for Anglo American, valuing the company at US$38.9 billion. Should the deal be finalized, the combined entity would surpass state-owned Codelco as the world's leading copper producer.

The Chilean mining industry is not without challenges. An estimated 34,000 skilled workers are needed to meet the supply gap caused by the energy transition, but the number of people entering the industry dwindles. Liquidity for juniors is at an all-time low, while the pressure to make discoveries is at an all-time high. Global lead times to bring mines into production continue to lengthen. Productivity is hampering Chilean miner's production goals. The impacts of climate change accelerate, yet miners are forced to mine more and mitigate their impacts simultaneously. Chilean miners strive to find the way forward for Chile and the general industry. In many respects they have been successful, reviving the sector, and helping to redefine the future of the industry. The succeeding pages serve to reveal a part of those efforts. ■

Mind the Gap

Will Chile be aboard the decarbonization train?

The grunt of the bull

Copper is trading at its highest level since May 2022. Although copper demand continues to increase due to electrification and the green energy transition, recent price shifts are a supply driven story. Following the declaration that First Quantum's Cobre Panama's mining concession was unconstitutional, the mine was ordered to shut down in November 2023. Cobre Panama accounted for 1.5% of global copper production.

In addition to the closure of Cobre Panama, production levels in Chile hit a 25-year low, and dropped 2.3%, slumping to 5.33 million metric tons per year (t/y). Production across Anglo American's operations fell 13.3% and Codelco's by 8.2%. Ramp up at Quebrada Blanca was slower than anticipated, and copper production across Teck's operations totaled 296,500 t/y, down from the 320,000-365,000 t/y range set in production guidance.

Despite predictions of a major surplus, according to the International Copper Study Group, the disruptions in Panama and lower than predicted production rates in Chile flipped the market to a major deficit. "This cascades down into the copper concentrates treatment and refining charges (TC/RC) market. Smelters do not believe they will have the necessary supply of concentrate, leading to a drop in TC/RCs. The fee has fallen rapidly on the spot market as smelters compete for supply", said Aurora Davidson, CEO of Amerigo Resources.

In December, China's Copper Smelter Purchase Team (CSPT) set a buying guidance of US$80/t/ 0.8/lb, equivalent to the agreed upon price between Chinese smelters and miners Antofagasta and Freeport McMoRan. This level was already down 16% from CSPT's guidance for Q4 2023. At the beginning of Q2 2024, TC/RCs hit record lows; the copper market has reached unprecedented tightness. For Chile, this signifies both risk and opportunity. "Chile has seen a reduction in copper output at a time when the market's appetite for it is expanding. This scenario underscores a critical issue but also highlights an opportunity. By reinvigorating production, Chile can capitalize on the copper market's growth," emphasized Juan Ignacio Guzmán, CEO of GEM Mining Consulting.

Chile: a gap filler

To fill the potential supply gap of 8 million t/y by 2034, mining companies will require prices of US$10,000/t, and possibly as high as US$12,000/t, according to Jeremy Weir, CEO of Transfigura, who presented at the World Copper Conference. Chile has the potential to be a 'gap filler', defined by Santiago Montt, CEO of Los Andes Copper. "Chile is a country with the potential and ambition to have a significant role in closing the gap that the energy transition will create between copper supply and demand," he said

Chile holds the world's largest share of known copper reserves, at 21.3%, according to the United States Geological Survey (USGS). The next few years will be a crucial turning point for the industry as demand for copper is forecasted to grow 20% by 2035, according to analysis by S&P Global. If Chile cannot meet demand, the world will turn elsewhere. Investment in the mining sector in Peru has grown to US$54.56 billion for 2024, up 2.7% from 2023. "Regulations need to support jurisdictions in their quest for competitiveness, thus attracting more investments and technological advancements. Otherwise, mining companies may seek opportunities elsewhere," said Augusto Cauti, consultant and strategic advisor at Turner & Townsend.

"The global copper shortage poses significant challenges for the mining industry. Chilean producers, as some of the main copper exporters worldwide, will play a crucial role in addressing this situation."

Andrés Souper, General Manager, Glencore Chile

However, jurisdictions following Chile in terms of reserves, like Peru and the Democratic Republic of Congo, lack the expertise and established, large-scale industry that Chile benefits from. "Mining in Chile has significant opportunities, especially in terms of infrastructure for large-scale mining projects, the use of clean energy, the promotion of gender inclusion, and the integration of technology, given the advanced level of technological development and communications in the country," emphasized Caroline Vender, CEO at Sigdo Koppers Ingeneria y Construccion.

A geological jackpot

Addressing the copper shortage will require bringing new projects online, and exploration is a key part of this. Glencore Chile's general manager Andrés Souper said: "I believe that there is a need to intensify exploration efforts to discover new reserves, which requires investing in advanced technologies and more efficient exploration methods."

The burden of exploration has been placed on junior players, like Filo Corporation, says Jamie Beck, their CEO: "Major mining companies have reduced their exploration spend, leaving room for juniors to fill this void."

With an exploration budget of US$ 832 million, Chile ranks fourth globally trailing only behind the US, Canada, and Australia. There are 226 exploration projects in Chile, and 53.1% of them are copper-focused, according to the Chilean Copper Commission (Cochilco). Copper's dominance comes with good reason; before Chile was a country, it was a mining territory.

Chile's copper deposits are primarily due to its position along the Pacific Ring of Fire, where the Nazca Plate subducts beneath the South American Plate. This subduction produced significant volcanic and magmatic activity, leading to the formation of large-scale porphyry copper systems and iron oxide copper gold (IOCG) deposits. Globally, only four major IOCG belts exist: the Central Andean IOCG belt in Chile, the Olympic Dam region in South Australia, the Carajás Mineral

Province in Brazil, and the Bergslagen district in Sweden. “These deposits offer highly mineralized, steeply dipping deep rooted vein structures with mineable widths, providing favorable conditions for mining operations,” explained Alastair Mcintyre, CEO and president of Altiplano Metals.

Porphyry deposits are associated with extensive hydrothermal systems that alter the surrounding rock and concentrate minerals into economically viable ore bodies. The porphyry systems in Chile often contain sulfide minerals, including chalcopyrite and bornite. The Andes' rapid uplift exposed these deep-seated deposits near the surface, which makes mining operations more technically feasible and economically efficient compared to other countries. “In Australia companies will explore for IOCG deposits below up to 1,000 m of cover,” said Paul Gow, CEO of Tribeca Resources. “For projects like Tribeca’s La Higuera in the Coquimbo region of Northern Chile, the cover is typically much shallower, around 50-80 m of gravel” he continued.

Jamie Beck,
President and CEO,
Filo Corporation

Some projects marry different aspects of Chile unique geology. “Filo Del Sol features a unique oxide cap atop the deposit, which presents a distinct style of mineralization,” started Beck, “However, subsequent drilling revealed a larger sulphide deposit beneath the oxides. This exploration success has positioned Filo Del Sol as one of the world's largest undeveloped copper projects” he continued.

Despite the geology, exploration is not happening quickly enough. Shawn Wallace, CEO and chairman at Torq Resources emphasized: “The key metric to monitor is whether we are finding enough to replace what we are mining, and currently, that balance seems precarious.”

New permitting to permit optimism

Global lead times from discovery to production continue to breach all-time highs. The global average rests at 15.7 years, with most time in the exploration phase. Cristóbal Undurraga, CEO of Ceibo, explained “Heightened regulatory awareness adds complexity to mining operations, extending project commissioning times from six years in the 1950s to around 15 years today—a consistent timeline worldwide.”

With current lead times, a discovery made today would miss the green energy transition entirely and with the global supply gap set to peak in 2027 investors may be tempted to look elsewhere. “On average, in Chile it takes 10 years to approve a project, which discourages investors from coming to the country. In Peru, on the other hand, you can get a project running in 2.5 years,” said Jose Rodriguez Monje, general manager at Aggreko Chile.

However, Chile is making strides. After the royalty bill was passed, a working group under the Ministry of Finance involving the Ministries of Economy, Mining, and Environment, and representatives from Geomin, Sonami, APRIMIN, and Consejo Minero produced two documents: "a baseline analysis identifying the permits with the longest processing times and the areas with delays in project permit acquisition, and a roadmap developed by the Ministry of Finance to address these inefficiencies and bottlenecks," explained Joaquín Villarino, executive president at Consejo Minero.

At the inauguration ceremony for Quebrada Blanca II, President Gabriel Boric committed to reducing lead times by 30%. This action not only will benefit the sector, but also the state says Villarino: “If the approval period is reduced by a third, for every US$1 billion that is invested, the state collects US$240 million.”

Reforms ignite exploration

Starting January 1st, 2024, amendments to Law No. 21,420, refined by Law No. 21,649, came into effect, introducing the first modifications to Chile's mining regulatory framework since 1983. These changes alter the concession system, aiming to enhance mining activity and decrease concession hoarding. Of the current 90,000 concessions that cover 16 million ha of Chile, 40% are held by 10 companies. Of these concessions, only 10% are active. Wallace explained the implications: “Larger companies can secure extensive land holdings and maintain them with minimal activity, which may hinder opportunities for greenfield exploration. Implementing stricter regulations on mineral tenure could stimulate the exploration landscape by compelling companies to actively explore or relinquish their claims.”

Law 21,420 increases patent fees for exploration concessions from 1/50 to 3/50 Monthly Tax Units (UTM) per hectare for both metallic and non-metallic mining fees. For exploitation concessions, the mining fees will increase progressively from 4/10 UTM per hectare for the first five years, up to 12 UTM per hectare from the 31st year onwards. Concessions can qualify for reduced rates (1/10 UTM) by demonstrating initiation of mining operations, obtaining an Environmental Qualification Resolution (RCA), or processing within the SEIA system. “By raising fees, the government aims to deter companies from holding onto licenses without substantial progress or investment. This measure encourages companies to either commit more earnestly to exploration efforts or relinquish licenses, thereby creating opportunities for other groups to engage in exploration and mining activities,” explained Antony Harwood, CEO and president at Montero Mining.

Law 21,420 also increases exploration concessions from two years to four years. However, once the concession term has expired, the concession will be extinguished, unless an extension is requested and supported by a report of the geological information obtained from exploration work or proof of an Environmental Qualification Resolution or ongoing Environmental Impact Assessment to the National Geology and Mining Service.

Off to the races

2024 is off to a promising start. Codelco’s annual production is predicted to rise 1.353 million t, an increase from 2023’s 1.325 million t. In Q4 2023, Quebrada Blanca achieved record quarterly copper production at 34,300 t. In December 2023, Quebrada operated at near throughput capacity and is predicted to deliver on proposed production guidance in 2024.

2023 was a year full of change, which at face value seemed to deter investment. 2024 has seen calmer waters said Brian Miller, CEO at Astra Exploration: “Despite initial concerns, major mining companies continue to invest in Chile, reaffirming its appeal for mining exploration and development, as seen with projects like Salares Norte and Quebrada Blanca 2 (QB2), and ongoing commitments from companies like BHP.”

“The focus of copper mining is on production, with less concern for energy efficiency. This reflects a broader issue within the South American mining industry; the need for energy efficiency, crucial for minimizing environmental impact, has yet to be fully acknowledged.”

Sergio Zamorano,
CEO,
FAM

Chile’s mining sector is at a crossroads. The global energy transition is well underway, but production has yet to see a significant increase in Chile. With reform, investment, and a push for sustainability, the industry has a chance to revitalize production and fill the global copper supply gap. Yet, the outlook is positive with the Chilean Copper Commission (Cochilco) predicting production to reach 5.51 million tons in 2024, a 5% increase from 2023.

However, time is of the essence. As the decarbonization train leaves the station, Chile must act swiftly to remain in the driver’s seat. ■

Photo courtesy of Albemarle

The Lithium Triangle

South America's white gold rush has begun

After reaching peak prices in 2022, the lithium market faces a considerable oversupply, resulting in a more than 75% price drop over 2023, with battery-grade lithium carbonate prices in China collapsing significantly. This price decline reflects an accelerated ramp-up in production capacities, anticipating robust demand growth, which has not materialized as expected.

Current global lithium production has seen substantial growth, with supply anticipated to increase by 30% by year's end. Electric vehicle (EV) batteries are largely responsible for demand increasing. Although EV adoption grows—EV sales in the USA were up 40% in Q1 2024, according to Cox Automotive— the pace is slower than anticipated; Bloomberg New Energy Finance projected sales of 1.7 million plug-in vehicles in 2023, but only 1.46 million were sold. EV giant Tesla's sales were down 41% in Q2 2024, its first drop since the pandemic, a further indication of lower EV adoption. "EV adoption and infrastructure for grid support for EV adoption need to catch up to demand. The energy transition is intricately linked, resembling a spider web connecting various elements. It goes beyond just supplying lithium for EVs; it encompasses a global initiative to facilitate this shift" noted Amanda Hall, CEO and founder at Summit Nanotech.

Declining prices do not mean declining demand: in 2030, global demand for lithium is expected to exceed 2.4 million t/y of lithium carbonate equivalent, doubling the demand forecast for 2025. "If the world wants to evolve into a green energy economy, it will need every single lithium project that is currently on the slate to come into production," said Steve Kesler, executive president at CleanTech Lithium.

Australia is the world's current leading supplier of lithium, producing 86,000 t of lithium in 2023. However, Australia's operations are dominated by hard rock production, causing environmental concerns about their long-term sustainability; lithium derived from hard rock is three times as carbon-intensive as brine operations. With the rise in responsible mining and consumer consciousness, lithium will increasingly need to be sustainably sourced. The lithium triangle—a high-altitude area straddling Chile, Argentina and Bolivia, which holds 56% of the world's lithium reserves — presents itself as the perfect opportunity. "There is enough lithium in Chile alone to satisfy the world's needs, which can be sourced entirely from brine," said Hall.

Chile: the lithium triangle's hypotenuse

Chile is the world's second-greatest producer of lithium, responsible for 44,000 t in 2023. President Gabriel Boric announced Chile's National Lithium Strategy (NLS) in 2023 to enhance private sector involvement across the lithium value chain while maintaining selective state control in public-private partnerships. The signing of the Memorandum of Understanding between SQM and Codelco in December 2023 was a landmark event for Chile's lithium industry, enabling SQM to increase production by 30,000 t/y of lithium carbonate equivalent and extend operations for 30 years. Codelco will own a slight majority share at 50+1%, according to the contract. Mark Wainwright, managing director at Turner & Townsend, said: "These moves within the Chilean lithium industry present potential benefits but may concern investors wary of government involvement because it is clear the present regime sees lithium as a strategic asset. Although it is too early for definitive judgments, the continuation of licenses for existing private companies signals a positive direction. However, market sentiments remain mixed."

Chile has 69 saline environments; in 2024, the government declared 31 protected, two strategic—requiring state-owned Codelco or Enami to be a majority partner—and five with Codelco and Enami presence, but not necessarily as a majority partner. This leaves 31 salt flats for exclusive private entity development. "Now that the government has defined the rules of the game and eliminated the elements of uncertainty, investors are starting to make decisions," said Joaquín Villarino, executive president at Consejo Minero.

On April 15th, 2024, the government launched a request for Information (RFI) process for investors and private companies. The process will last 60 days, and the results will be announced in July. Any company can purchase lithium concessions in an area if it does not have other mining claims. The company must be granted a Special Operation Contract for Lithium (CEOL) by the government. "This news will allow us to define the lithium deposits for which the State will begin the process of awarding CEOLs, after carrying out an indigenous consultation process where applicable," explained Minister Aurora Williams in the press release.

This should also help advance late-stage projects like Cleantech Lithium's Laguna Verde and Francisco Basin, which have applied for CEOLs and will contribute a minimum considered annual production of 20,000 t of lithium carbonate each, according to Kesler.

Direct lithium extraction

As part of the National Lithium Strategy, companies are required to extract lithium through DLE, and with good reason; "With evaporation, up to 40% of lithium reserves are lost, whereas with DLE, we can achieve up to 99% extraction efficiency," explained DLE technology company Adionics' CEO, Gabriel Toffani.

DLE technology is relatively new, "Seven years ago, DLE was almost unheard of, with Livent in Argentina operating the only project," said Kesler, who explained the three principal types: "Adsorption involves passing brine through columns of resin, where lithium is adsorbed. After extracting lithium, the brine is reinjected into the aquifer, without altering the brine's original chemistry, unlike ion exchange, which can to a certain extent acidify surrounding soil upon brine reinjection. Solvent extraction, while quick, poses challenges in eliminating organic materials during entrainment from reinjected brine."

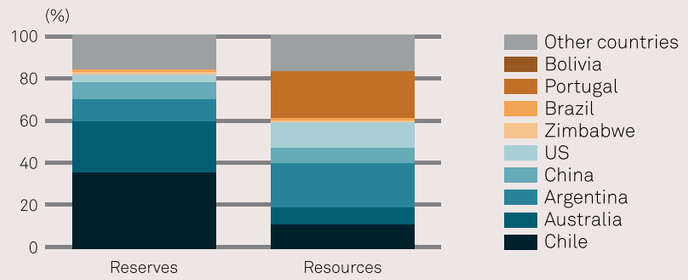
The technology is advancing rapidly. In 2023, SQM partnered with Adionics to pilot their technology. "Initial testing lasted 500 hours", explained Toffani, "subsequently, we conducted an additional 1,000 hours of continuous testing at the Atacama pilot to evaluate the conditions necessary for transitioning to an industrial scale."

In April 2024, Chile's national mining company Enami announced that it would consider 30 proposals from 12 countries to deploy DLE technologies at its US$1.5 billion Salares Altoandinos project in the Atacama region. Summit Nanotech was one such proponent. A committee will choose five technologies that will be compared in terms of lithium recovery and energy consumption.

Argentina

Argentina, currently producing 34,000 t/y of lithium, is on track to become the world's third largest producer by 2027, with the potential to increase output to 260,000 t/y, indebted to the 18 projects forecasted to start production by 2027, according to analysis by CRU.

Global Lithium Reserves and Resources



Source: Argentinian Mining Secretary, based on US Geological Survey (USGS)

In April 2024, Elon Musk and President Javier Milei met at Tesla's headquarters in Texas to pledge cooperation to enhance free-market principles and explore lithium mining opportunities. Despite the buzz, the meeting likely does not signify much. As outlined in the Argentinian constitution, natural resources are the property of the provinces, meaning the provinces manage licenses and grant permits for mining exploration and production. While Milei can set the national mining policy and promote investment, ultimately, decisions are made at the province level. Yet, Milei's enthusiasm will be beneficial. "The current government's commitment to attracting large-scale mining investments is crucial, given the substantial capital required for development," said Ignacio Fernandez, general manager LATAM at Terra Nova Technologies.

Despite growth, the country faces challenges: "One major hurdle in Argentina is the importation of sophisticated mining equipment, which may not be readily available locally, coupled with currency mobility issues," continued Fernandez.

Chile is well-positioned to support Argentina, suggested Filo Corporation CEO Jamie Beck: "The Mining Integration and Complementation Treaty recognizes the necessity of collaboration between the two countries for the development of significant deposits like ours. It allows us to explore across borders, utilizing resources and personnel from both nations. This arrangement also opens avenues for sharing infrastructure such as power, water, roads, and transportation, which will be crucial for future development."

Although Filo is a copper exploration company, the treaty extends to lithium mining.

The rapid development of the sector could also lead to infrastructure and logistics bottlenecks, as many operations are in remote regions of the country. Logistically, Chile can assist neighboring Argentina. "Concerning the lithium sector, an important consideration is the natural suitability of Chilean ports for Argentina's lithium producers, as they are only half the distance from alternative ports in Argentina." offered Tomás Valenzuela Somerville, vice president, mining, energy & regional offices at AGUNSA.

Bolivia

Bolivia possesses the world's largest share of lithium reserves, amounting to 24% of the world's total. Despite vast reserves, Bolivia has struggled to capitalize on its lithium potential compared to its neighbors, largely due to extraction method challenges and conflicts with indigenous communities. Metaproject CEO Manuel Viera Flores, asked: "What is the use of being rich in the subsoil and poor on the surface? Bolivia has one of the biggest lithium deposits in the world, but also immense poverty because it has not been exploited."

The Bolivian government has shown a renewed commitment to the metal, aiming to generate US$5 billion from lithium sales by 2025. In July 2023, Bolivian state-owned Bolivia Lithium Deposits (YLB) identified new lithium resources, bringing the total to 23 million t of identified resource. In January 2024, Bolivia's government signed an agreement with Chinese consortium Catl, Brunp, and Cmoc (CBC) to develop a US$ 90 million pilot plant to extract and process lithium at the Uyuni Salt Flats, with an initial production capacity of 2,500 t/y of lithium carbonate. The plant plans to yield first lithium by year end 2025.

The global white gold rush has begun, and the lithium triangle has ample expertise, reserves, and technologies to meet the world's evolving needs. ■

Climate Change Adaptation

Engineering, consultancy and construction firms prepare Chile's mines for the future

Climate change has magnified its grip on Chile, with central regions enduring a surge in temperatures of 1-2°C above the norm (1981-2010) in 2021—surpassing the continent's average uptick of 0.36°C, according to the World Meteorological Organization. The persistent and proactive adaptation of Chile's mining sector to these evolving climatic conditions has not only fortified its resilience but also established the nation's mining industry as a vanguard in climate mitigation, largely attributable to the innovative strategies implemented by its engineering, consulting and construction firms.

"We are not separate from the environment—we are part of it. Our actions are not just about saving the Earth; they are about preserving human existence. The planet will recover from our abuses, but, without change, humanity may not."

Óscar San Román, General Manager, Yokogawa

Heavy rainfall in 2023 dampened productivity efforts. State-owned Codelco suffered losses of 7,000 t— 2,000 t from the El Teniente mine and 5,000 t from the Andina mine— due to June's heavy rainfall. "The flooding increased operating costs by 10%, and reduced annual production by 5%," highlighted Juan Ignacio Guzmán, CEO at GEM Mining Consulting.

Heavy rainfall is not uncommon in Chile, given the region's exposure to the El Niño phenomenon, which disturbs normal weather patterns, leading to periods of intense precipitation in some areas and drought in others. Yet, 2023 saw heightened effects of the changing climate. "In 2023, recorded rainfall at Minera Valle Central (MVC) was 780 mm, which is around six times more than we experienced in 2019," said Aurora Davidson, CEO at Amerigo Resources.

Amerigo Resources produces copper and molybdenum through its wholly-owned subsidiary MVC, utilizing waste materials from El Teniente. "Given the impact of the rains, MVC saw a 10% drop in production in 2023 in comparison with 2022."

Disruptions at MVC have the potential to be devastating, as it is the direct link between the El Teniente mine and tailings deposit. Adaptive measures, therefore, were implemented. "We installed flotation equipment around the pipes that connect Cauquenes to our plant. We wrapped kilometers of pipe infrastructure in protective equipment. Without these measures, the flooding incident would have necessitated a complete halt in production from Cauquenes," said Davidson.

To operate in the future, climate change mitigation will not be a choice, but a necessity, said Carolina Páez, mining manager at WSP: "Rains and floods are going to happen with higher frequency and intensity. Visible effects of climate change are bringing the industry to agree with our vision; projects must be designed with the effects of a changing climate considered."

At WSP this consideration has become a methodology called Future Ready, said Juan Ignacio Ríos the firm's general

manager: "Future Ready is WSP's global innovation and sustainability framework. It enables us to design to both the current code and for our future world."

The other side of the coin

Floods are not the only climate change induced phenomenon affecting Chile's miners. The country has officially been in drought since 2010— water availability is down 37% in the last 30 years and is predicted to drop by 50% in northern and central Chile by 2060. Lack of water supply led Anglo American's Los Bronces production to drop 32% to 57,200 t in 2023.

Scarcity induces change. "Chilean engineering firms are helping reduce water consumption, using water recirculation in the plant, covering industrial pools to reduce evaporation, and exploring new supply sources such as desalinated water," listed Iván Rayo Villanueva, general manager at JRI Ingeniería. "However," he continued, "these solutions also have limitations in terms of cost and availability."

Desalination has gained traction as a viable solution to counteract the water crisis. Chilean engineering firms are actively integrating desalination projects, with the mining sector set to balance its water usage from fresh and seawater sources by 2031. "More than 20 desalination projects are already underway, and several mining companies are considering new investments in this area," remarked Hugo Andrade, general manager at Shimin.

Anglo American has secured a significant portion of its water needs for the Los Bronces mine from desalinated sources, aiming to meet nearly half of the mine's water requirements by 2025 and to eliminate the use of freshwater by 2030. Anglo also plans to contribute desalinated water to local communities, prioritizing human consumption in times of scarcity.

Chile currently has 28 desalination plants either operational or under construction. These facilities have the capacity to produce 8,200 liters per second of fresh water, and projections indicate that this capacity will likely reach 25,000 liters per second by 2028, potentially tripling the current figures if all projects proceed as planned. The growth of desalination projects aligns with Chile's strategic move to diversify its water sources, as freshwater use is projected to decrease to 53% while seawater use will rise to 47% by 2031 in the mining sector.

The adoption of desalination technology is not without its financial implications. "The cost of seawater at US$5 per cubic meter is 10 times higher than groundwater at US$0.5, significantly raising operational costs," said Guzmán.

However, many miners will not have a choice. "As desertification progresses and water demands increase, the need for desalination is expected to intensify," said Víctor Contreras, general manager at Pares&Alvarez.

Heads or tail-ings

Chile's miners are exploring all alternatives to mitigate water usage. Luis Arcos, mining leader and key account manager of BHP at Stantec, said: "One way is through minimizing the size of tailings deposits. At Spence (BHP), for example, tailings deposits were designed in cells, which reduces the amount of evaporation that will occur."

Chile's miners are also adopting alternatives such as paste, co-disposal, filtered, or thickened tailings. Dry stack tailings permit the recovery of the maximum amount of recycled water. At Anglo American's El Soldado 150,000 cubic meter Hydraulic Dewatered Stacking tailings facility water recovery measured 80%. "However," said Arcos, "a challenge with filtered tailings is their lower production rate compared to standard mining operations. The largest filters can process 20,000 t/d, meaning multiple units are required to scale up to the operational volumes typical of major mines, such as 200,000 t/d."

"Instead," noted Andrade, "large-scale copper mining is exploring alternatives such as thickened tailings – a middle-ground technology that reduces water content by approximately 10%."

Another alternative, being used at Mantos Blancos (Capstone Copper), is tailings treatment plants that use hydro-dewatering screens. Dolores Requena, general manager at ERAL, said: "This circuit offers several advantages compared to conventional methods, such as paste thickeners and belt filters. It is more economical and cleaner, with low energy consumption and maintenance, and enables the recovery of a significantly larger volume of water."

Water recirculation is not smooth sailing: "Water is necessary for many processes in mining, so its quality cannot be understated. The rate of reuse in the mining sector is high, but there is always water that is lost in this recirculation process. Miners must ensure that lost water complies with laws and standards to not bring problems to communities," emphasized Jerome Poujaud, business development director for Chile & Peru at Veolia.

Howden's water treatment system helps ensure water quality. Edson Luis Geraldini, the company's sales director explained: "It injects 80% oxygen into the water, significantly more than the 20% achieved with conventional methods. This technology allows for the rapid recovery of bodies of water such as lagoons and rivers, even eliminating some harmful chemicals… This technology can be particularly useful in northern Chile, where mines face water scarcity, by recycling the water used in mining production and allowing for its reuse in other areas."

Andrea Casciano, Country Director and VP Operations Chile, Worley

Caroline Vender, CEO, Sidgo Koppers Ingeniería y Construcción

Carolina Páez, Mining Manager, WSP

Aurora Davidson, President and CEO, Amerigo Resources

Sustainable solutions in action

Climate change adaptation means taking decisive steps, says Andrea Casciano, country director and vice president operations Chile at Worley, "our ambition to be recognized globally as a leader in sustainability solutions in the next five years, and for that, we have a global target of deriving 75 percent of our revenue from sustainability-related work by 2026," said Casciano.

Equans extends the option of change to their clients. Diego Clavería the company's chief commercial officer, said: "Equans has integrated the option of forest reforestation into all its technical and commercial proposals as a core environmental initiative through tree planting efforts in Patagonia. Every proposal we submit includes a commitment to mitigate CO2 emissions generated by our fleet, which currently comprises 800 vehicles."

Expertise kindled in the mining industry can be used to drive change. Cummins Chile collaborates with the Nature Conservancy Chile on a project for water resilience in the Maipo basin. Miguel Flores, the general manager, said: "Cummins invested US$450,000 over 18 months in this project, leveraging technologies and telemetry to monitor key wetland variables remotely. It involved applying the technology developed for the mining industry to wetland conservation, demonstrating Cummins' dedication to safeguarding vital natural resources."

Mining's climate strategy: more women

Adapting to climate change across the industry requires substantial shifts in its foundational structure, including increasing the representation of women in leadership roles. A study from BloombergNEF indicates that companies with higher female representation on their boards tend to enhance energy efficiency, lower environmental impacts, and invest more in renewable energy. Further, women-led firms are more proactive in reducing emissions and achieve superior ESG scores compared to those led by men, according to a study by the European Investment Bank.

These findings underscore the potential leadership role of the Chilean mining industry in global climate initiatives in mining. In February 2024, copper giant BHP reached 40% female participation across its Chilean operations. The industry-wide average is 12.6%, which is above the global average of 12%. However, in Latin America, women only occupy 11.2% of leadership positions in publicly traded mining and metals companies, according to an analysis by S&P Global. To confront climate change this will have to change, but optimism abounds. "I am very proud to have been chosen as the first female CEO in the company's more than 60-year history. As both the CEO of Sigdo Koppers Ingeniería y Construcción and as national counselor in the Chilean Chamber of Construction, I see a transformation of culture at the national level, with Sigdo Koppers acting as a pioneer," said Caroline Vender. "The company trained nearly 6,000 women, encompassing professionals, frontline leaders, supervisors, and direct labor. Notably, we have initiated female welding programs in Brazil and Chile, along with electrical training initiatives" she continued.

"Increasing female representation is a choice," highlighted Agustín Cabañas, general manager at R&Q Ingeniería, a firm that achieved 25% female participation in 2023. "It involves training and including women in all aspects of operations. In recruitment processes, there always must be a female option. This approach opens the door for either gender to be selected, moving beyond a male-dominated selection process. It is about making a conscious decision to hire a specific number of women. Mining companies, like BHP are openly committing to women constituting 40% of new hires. This policy is not just a statement; it is a deliberate strategy to ensure gender diversity."

The climate will continue to change, and its effects will heighten across the globe. Chile serves as an example to the global mining community: to move forward the industry must adapt. ■

Chile's Circular Economy

A new cycle of growth for the industry

According to the World Bank, an estimated 3 billion t of minerals and metals will be required by 2050 for the implementation of wind, solar, and geothermic energy along with energy storage to achieve temperature reduction below the 2°C reduction mark defined in the Paris Agreement. The Chilean mining industry has the responsibility to achieve production targets to supply the international market while containing its effects on the environment, which implies that the entire value chain makes decisive progress in the reduction of greenhouse gas emissions and conservation of high-stress resources. A circular economy, which promotes restoring and regenerating resources, decoupling economic growth from resource use, and closing material loops in the economy, presents itself as an opportunity to move towards climate change mitigation and adaptation.

Chile's producers are at the forefront. "Amerigo Resources' business model is to generate additional economic value from recovering copper from waste material," Said Aurora Davidson, the CEO.

Battery Mineral Resources is using circular economy processes to fund the production of its Punitaqui mill and mine, set to begin production in Q3 2024. "The partnership with Anglo American involves processing 240,000 dry metric tonnes of smelter waste material from their Chagres copper smelter and providing copper concentrate in return. This not only aids in waste valuation but also generates cash during our ramp-up. It highlights the importance of the circular economy, particularly in Chile," said Martin Kostuik the CEO.

"New value chains are being built in every commodity: green copper, green aluminum, and more. We will also start to see more circularity in the market; clients are creating new value chains and value streams."

Jerome Pelletier,
President and CEO, BBA

The Chilean National Mining Policy 2050 cites a circular economy as a strategic objective, specifically calling on mining suppliers to deliver products that can be recycled and reused.

Waste elimination from design

The circular economy must begin from the onset, said Trinidad Carmona, Co-CEO at Drillco: "Recycling, while important, comes late in the process. The real key is to design products from their origin to minimize waste."

Modular construction has gained traction in recent years partially due to this reason, Jose Luis Spoerer, general manager at Hilti, said: "Modular solutions allow us to work with our clients earlier in the design stages allowing us to optimize our client's predefined solutions, which helps to reduce the amount of materials used."

"Modular construction generates 10 times less waste than traditional methods," said Cristóbal Schneider Guzmán, general manager at Promet. "Steel not only offers superior recycling opportunities compared to wood but also represents a forward-looking choice for sustainable construction," he continued.

However, according to Cristian Goldberg Aichele, general manager at TecnoFast: "Modular construction is more eco-friendly, mainly because it utilizes wood. This material is known for its environmental benefits, including its capacity to store carbon."

In their construction of warehouses for client SQM, Tarpulin introduced another material into the modular construction space. "Our modular floor is made in Chile using recycled plastics (HDPE) instead of traditional concrete slabs," said Pablo Rosales the CEO.

Regardless of the material and the method, all are aligned in aiming for a sustainable circular economy. "Modular solutions can be disassembled, reused, or repurposed, providing sustainable solutions over time," emphasized Tomas Fischer Ballerini, general manager at Edyce.

Use-life extension

Refurbishing equipment before disposal is essential to the principles of the circular economy. One such effort is Haver & Boeker's Niagara rebuild program. "While vibrating screens have coatings made of materials like rubber and polyurethane, their steel structure offers infinite recyclability. Our goal is to refurbish or reuse these steel components before resorting to steel recycling plants, which consume substantial energy," said Roberto Montiglio, managing director, Andean Region. "Not only does this reduce emissions but yields cost savings of 30-50% compared to new screens," he continued.

Delegating capital for new equipment may be a thing of the past, said Andrés Osorio, general manager at STM: "For clients to use a piece of equipment designed with certain characteristics for another job, or in the same job but with increased capacity, it is no longer necessary to remanufacture the equipment. Now we can reuse and enhance current equipment, which extends the use life of equipment and reduces waste."

One way to increase use life is through coating. "ANDRITZ has three global workshops with the capability to extend the useful life of components: Chile, Germany, and India. Chile is a reference for the region in the application of this type of technology," said Fernando Tobar, manager of equipment and services of solid/liquid separation, Chile and Peru.

A second life

"It is estimated that the mining industry recycles only around 7% to 9% of its industrial waste," lamented Edwin Vildósola, president of FLSmidth South America.

Efforts are being made to increase this percentage. "We are implementing a machine in our megaproject in Casablanca to separate steel from rubber, allowing us to valorize rubber and recover steel, which can be reused in our linings or used by foundries through agreements," said Vildósola.

In April 2024, Metso opened a recycling and coating plant in Chile. "This will be the world's largest and will allow us to recycle our mill linings completely, significantly reducing our carbon footprint. We have already initiated the testing phase and have recycled over 200 t of lining, and we plan to recycle close to 600 t/y over the next few years," said Eduardo Nilo, president, South America at the company.

In 2024, the copper industry will release 100 million t of carbon into the atmosphere across the whole value chain. This amount is dwarfed by emissions from steel production, totaling 1.6 billion t/y. Steel and copper can be recycled infinitely, without losing their properties. Equipment manufacturers have capitalized on this to bring new value, without new emissions.

"Our Niagara rebuild program focused on reusing or repairing components. Beyond yielding savings of 30-50%, this initiative facilitated our entry into the realm of circular economy, which is essential for us, our clients, and the broader mining sector."

Roberto Montiglio,
Managing Director, Andean Region,
Haver & Boeker Niagara

For drill component manufacturer Drillco, this has presented a unique opportunity, according to Carmona: "We implement reuse programs where our technicians disassemble consumable products, such as hammers, and evaluate the remaining useful life of each component. Then, we assemble the products using the components that are still in good condition, significantly extending their useful life and minimizing waste. A prominent example is the case of Twin Creeks in Nevada, where a hammer lasted 74,000 feet, which is 10 times more than the average duration."

Steel can be repurposed in completely new ways. "For example, rather than disposing of drill rods as scrap, they can be used as steel fences," said Ignacio Bello Marambio, general manager at Diamantina Christensen.

Magotteaux's Scrap Buy Back program is reinforcing a circular economy for all industry players. "Used balls from our customers melted down and remanufactured," said Enrique Vargas, country manager Chile and Peru. "More than 80% of our raw materials come from recycled products."

Equipment component manufactures are also finding ways to minimize steel waste: "In our contracts for example, we take the used material and direct them to appropriate recycling facilities. We treat and recycle the steel at the suppliers' facilities, reinforcing the concept of the circular economy," said Jean- Paul Droguett, general manager at Mincon.

Tunneling and ventilation companies, such as DSI Underground are pioneering the use of green steel in the industry. "The green steel process is known for its closed cycle: the steel used in mining is collected as scrap, returns to the mill, where it is transformed back into bolts, and other types of raw material. Finally, new systems are manufactured that return to the mine," said Carlos Leigh, regional CEO, LATAM.

"We are exploring the reuse of filtering fabrics in mining once they reach the end of their useful life. Valmet is currently investigating methods to recycle these fabrics in Finland to produce value-added products," said Gonzalo Silva, regional manager flow control business line at piping company Valmet.

Cable manufacturing company Madeco by Nexans implements a copper recycling program. In 2023, the company recycled 295.3 t of copper, double what was recycled in 2022. Recycled copper reduces water usage by 90% and energy consumption by five times. Camilo Elton, general manager, noted: "The recycling program for copper is of paramount importance, especially given the potential copper shortage in the future. By recycling copper, we not only address potential shortages but also reduce our environmental impact."

Metals are not the only thing being recycled in the mining industry. Rafael Santo, country manager Chile, Peru and Bolivia at tire manufacturing giant Michelin said: "By 2050, our goal is to manufacture tires that are 100% made from recycled or renewable materials. Our intermediate goal is to reach 40% by 2030, and we are currently at 28%."

The bottleneck, he says, is recycling carbon black, which constitutes between 20% and 25% of a tire and is derived from petroleum products, making it non-renewable. The other 80% of tires include natural rubber, which is renewable and has a sustainable cultivation chain, and synthetic rubber, which is moving towards sustainability through methods that use recycled PET bottles. The company is working in partnership with Bridgestone to develop a sustainable carbon black supply chain.

SKF, a bearings provider, has integrated the circular economy, introducing Circular Service Contracts in 2024, to prolong the life of bearings and components through maintenance and remanufacturing, using monitoring to predict failures and minimize new material use, waste, and energy consumption. "Our solutions have demonstrated energy efficiency improvements of up to 30%," said Carlos Lahura, managing director, Andean region.

Recycling, recovery, and renewal

Chile's circularity is indebted, in part, to the nation's legal framework. Enacted in 2016, Chile's Extended Producer Responsibility (EPR) Law, mandates producers to manage and finance the recovery or disposal of waste. "In the mining industry, there are processes of segregation and valorization of the main waste streams. There has been an acceleration of these practices due to the EPR law," remarked Jerome Poujaud, business development director for Chile and Peru at Veolia.

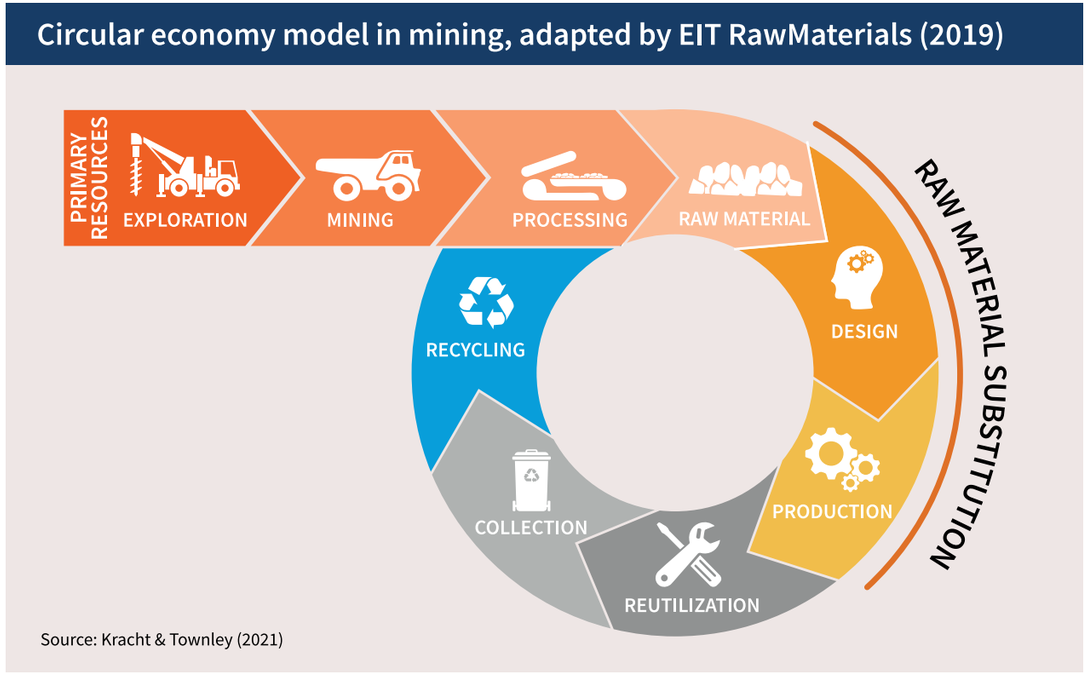
"A challenge is the circular economy and recycling. To address this, we offer a product line called B Cycle, designed to enhance plastic recyclability. This is a complex issue and we know that Governments are putting a lot of effort in this matter, as is the example of the EPR law in Chile," added Felipe Schneider, general manager at BASF Chile.

Construction firm Nexxo incorporates circular economy principles throughout operations. "We are promoting circular economy practices, particularly emphasizing recycling at our headquarters. We have also phased out single-use water bottles at our operations, which became compulsory during the pandemic, providing reusable thermoses to our maintenance operators," said Ignacio Pérez, the general manager.

The impending copper shortage will change the role of copper waste, observed Pedro Urzua, general manager at FastPack: "The industry acknowledges the necessity of both pioneering new mines and leveraging existing resources more efficiently. It is not sufficient to merely open new mines; we must embrace advanced extraction techniques, including chloride leaching and bioprocessing, as seen in BHP's initiatives, and the comprehensive recycling of tailings."

The industry is working towards this goal. "In El Teniente, we worked on a project to recover low-concentration soluble copper. The water that flowed from the lower section of a closed tailings tank had traces of copper and Codelco bid to find a solution to extract, recover, and reincorporate this copper into their processes," said Poujaud.

As proven by Chile's value chain, the path to exponential growth, is a circle. ■



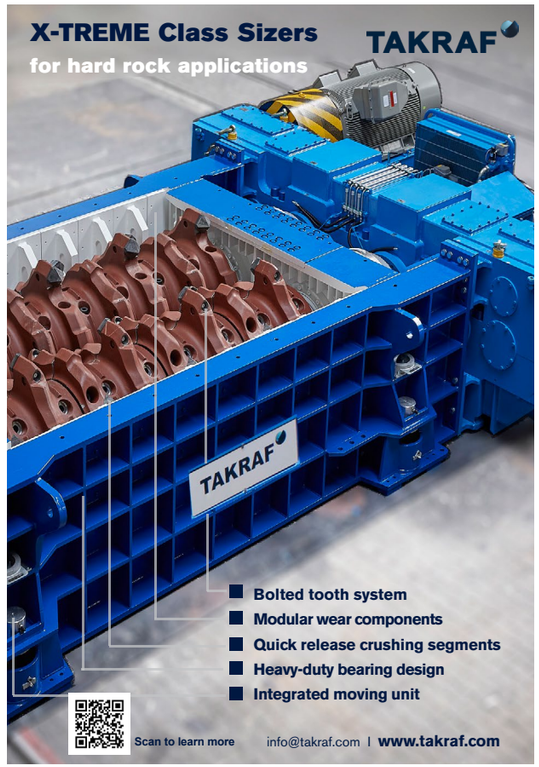


Photo courtesy of ABB

Chile's Digital Revolution

Data, technology, automation are transforming the entire mine lifecycle

Globally, the digital transformation is well underway in the mining industry. Chile is at the forefront of this change, remarked Benoit Richard, associate and director Chile at BBA: "Chile will become a pioneer in digitalization, adopting technology, decarbonization and ESG guidance, not only because the country has the expertise, but also because it is necessary."

The necessity is simple, says TIMining cofounder and CEO, Nicolas Jubera: "In Chile, where we are exploiting copper with grades of 0.3%, inefficiency is not an option. In other places, the pressure is felt in the political sphere, while in Chile all the pressure is on efficiency."

This pressure is multifold. Chile's existing operations have exploited the same deposits for decades. On the other hand, the world is demanding more of the minerals that Chile has in abundance, which increases pressure to not only locate the deposits but also exploit them quickly and efficiently. Yet exploration and production must be done responsibly. Globally, for the third year in a row, ESG is EY's top business risk and opportunity in the mining sector.

For Chile, a solution has presented itself, and the industry is capitalizing on it. Digitalization is being used to enhance every aspect of the mining operation, from exploration to production to processing. Digitalization is being used to improve performance and efficiency through automation, robotics, and integrated management systems, advance models with AI, increase safety, and reduce downtime, with real-time monitoring, predictive alert systems, and reactive detentions.

Exploration

In Chile, traditional exploration methods are being overtaken by digital tools, such as artificial intelligence and machine learning, to meet the urgent needs of the global energy transition, said Ignacio Torresi, executive vice president, LATAM at Seequent: "It is fundamental for junior exploration companies wanting to enter Latin America to be disruptive and use techniques such as drones for faster/cheaper geophysical surveys, horizontal drilling, optimization of drilling and targeting core logging and geochemical survey solutions, and continuous modeling. Those are options that will speed up the process of advancing an exploration portfolio pipeline."

According to S&P Global, for the 127 new mines that began operations worldwide from 2002 to 2023, the average time from discovery to commercial production was 15.7 years. For copper mining, exploration averages two to eight years and can cost from US$500,000 to US$15 million, according to the University of Arizona. On top of that, "With traditional methods, only 1 in 1,000 exploration projects become a mine," emphasized Amitai Axelrod, COO and Cofounder at VerAI.

New methods are necessary; "VerAI can shrink the traditional targeting window from three or four years to two months, while significantly cutting costs," Axelrod continued.

Efficient capital use is crucial in exploration due to reduced liquidity, as evidenced by the TSX-Venture Exchange index, which has halved since early 2021 amid a three-year decline. "By leveraging AI, we offer the industry a way to de-risk exploration investments and improve the odds of success, benefiting not only juniors but also mining financiers and investors seeking more efficient and reliable methods for mineral discovery," said Axelrod.

AI is also being used to better analyze exploration results at technology firm Veracio. "Data captured undergoes preparation for analysis by AI within our cloud system, followed by validation by Veracio's geoscientists. This process ensures the delivery of results to our clients within 24 hours," remarked Eduardo Molina, the firm's commercial vice president LATAM. "Currently, AI is being used to assist in data analysis; in the future, it is expected to be able to collect and process information autonomously. This will require extensive learning and proper education by the industry. It will allow for faster and more accurate decision-making, as well as greater real-time knowledge of the mining deposit," he continued.

An explosion of digital technologies

"As pit depth increases, challenges arise because the rocks are harder, and the ore grades are lower. In Chile, since the biggest mines are old, ore grade is decreasing more rapidly," said Cristian Cifuentes, general manager Chile and Argentina at ORICA.

This is where the digital transformation works its magic, Cifuentes continued: "Our new 4D technology, an advanced explosive product that enhances energy distribution, makes explosive use more efficient and cost-effective. In parallel, our digital solution, Rhino, has been pivotal in improving rock mass recognition and optimizing our blasting designs for better client outcomes."

Maxam has its own wand, said Jorge Blazquez Hernandez, regional manager: "Our X-Energy solution allows us to adjust the energy of explosives based on rock characteristics. Through data collection and mathematical modeling, we determine the exact quantity of explosives required for fragmentation."

Pablo Wallach, vice president technology, innovation and marketing explained Eneax's approach: "In 2023 Eneax developed a new version and tools of Enaex Bright, a platform that utilizes machine learning to predict bench hardness based on data from previous benches. This information allows for optimized blast designs, improving efficiency and reducing maintenance costs for crushers and sag mills."

OEMs digitize

For Chilean OEMs, 2023 and the beginning of 2024 delivered unprecedented digitalization and automation orders. John Smith, managing director Chile and Argentina, at Epiroc highlighted: "We received our largest digital order in our history from Codelco."

The order, aimed at optimizing fleet management and ore production, providing visibility of people and machines underground, collecting machine performance data, and helping avoid vehicle collisions, will be deployed in Codelco's El Teniente mine. It is a five-year project valued at approximately US$ 23.3M.

In parallel at El Teniente, Sandvik is helping Codelco advance, says Ricardo Pachon, vice president sales area Andean and south

"The mining industry is at the forefront of digitization, remote operations, and autonomy. Remote integrated operation centers, used by companies like Teck, Anglo American and BHP, show how technology has gained ground in the mining industry."

Fernando Ares, Operations Director South America, Wood

cone: "Codelco is developing its largest automation project to date. This project, Andesita, is part of a process to increase production at El Teniente. Sandvik will implement an advanced automation system and deliver an automated LH621i loader to Codelco's operations in 2024. We are currently in the implementation phase, and we expect the first stage of development to reach production level by the end of this year."

Both orders are a part of Codelco's expansion of El Teniente's LOM at Andes Norte, Diamante and Andesita, requiring investments of US$1.93 billion, US$730 million, and US$513 million respectively. Andesita will include 25 km of tunnels and will feature autonomous LHD equipment operated from the Integrated Operations Center in Rancagua.

"Over the last two years, there has been a significant increase in the number of mining sites adopting autonomous equipment. We expect this trend to continue in Chile in the near future, with further growth of the autonomous truck fleets," said Darko Louit Nevistic, CEO at Komatsu Chile.

Julio Piña Alegría, commercial director at XCMG agrees: "Although automation faces obstacles such as resistance to change and the high investment required to renew equipment, it is an unstoppable process."

In-process digitalization

Digitalization can significantly enhance the efficiency of ore extraction and transportation. In extraction, digitally based tools, like Minesense's ShovelSense, are demonstrating results. "It resulted in metal production increases of 5% to 20%, averaging 12% across all installations," said Jeff More, Minesense CEO. "By

scanning each extracted bucket, Minesense's datasets surpass traditional methods like blast hole sampling, offering information down to every 50 to 90 t in the pit," he continued.

After extraction, industry player Fourthane utilizes digital tools to identify conveyor faults, reducing unexpected stoppages. Fourthane general manager Alfredo Serrano explained: "We started services with X-ray equipment for inspecting conveyor belts with steel cords, enhancing our diagnostic capabilities. This modern technology now allows us to use X-ray filming equipment to examine the condition of steel cords throughout the entire conveyor belt in about 20 minutes. This process may be displayed on a screen, enabling operators to identify the belt's condition remotely."

SAG mills, the most energy-intensive components in the mining industry, can be managed digitally to minimize energy use, said Óscar San Román, general manager at Yokogawa Chile: "We developed an advanced control algorithm that predicts mill behavior, considering various inputs like the type of mineral, the amount of water added, and the amount of grinding media used. By adjusting these parameters, our automatic control system can regulate the mill's speed efficiently. Operating at optimal speeds reduces the consumption of water, grinding media, and, most importantly, energy. The algorithm must control dozens of variables, and how they correlate, in seconds. This task is impossible for a human being."

Every flotation circuit is unique. "Digitalization enables us to analyze historical data to understand how various mineralogies react to different chemicals, allowing us to identify the most effective formula for a specific operation's mineral," said Ricardo Capanema, global marketing and business development director mining solutions at Syensqo.

"The journey towards autonomous operations encompasses more than just autonomy itself; it necessitates the prior automation and transformation of data."

Rodrigo Couto, President LATAM, Hexagon

For providers focused digitizing the industry, the path forward will not only be paved by digitization: "Real progress is achieved by adapting sustainable practices throughout mining operations," said Jorge Abraham, division manager, process industries at ABB. "Therefore," he continued, "ABB is focusing in more efficient, responsible and safe technologies, to support our customers meeting environmental challenges in terms of decarbonization."

Digital solutions will be one of the main factors allowing the industry to meet its goals. As the world goes digital, the Chilean mining industry has proven it will be at the forefront of this change.

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