GLOBAL BUSINESS REPORTS

CHILE MINING 2019

Pre-Release Edition

Dear Reader,

GBR has a long tradition of providing coverage of South America's mining industry, and we are pleased to present our latest report on Chile — the continent and indeed the world's largest producer of copper.

2019 has been a turbulent year for wider Latin America, which saw the International Monetary Fund (IMF) adjust its growth prediction for the region to just 0.6% this year. Chile, long considered a stalwart of stability in comparison to its unpredictable neighbors, experienced similarly poor performance with GDP growth falling to 1.8% in the first half of 2019. The slowdown in the country's economy can be attributed to a number of both internal and external factors, including a volatile global trade environment, challenging weather conditions and setbacks in enacting a government-led reform agenda.

Furthermore, the second half of 2019 has seen an eruption in civil unrest and mass protests over the country's high rate of inequality and the rising cost of living. While the political and economic implications for the country's mining industry remain unclear, demand for the red metal is projected to grow significantly in the years to come and Chile's centrality in its production will undoubtedly remain.

This pre-release edition provides a snapshot of our findings on the developments occurring in the country this year. As Chilean miners grapple with an increasingly complicated sociopolitical context and an uncertain macroeconomic forecast, they must also navigate an ever-competitive global playing field. Investment into greenfield projects remains critical to the future of the industry, and a host of juniors are finding ways to bring their projects in Chile forward despite a global deficiency in exploration funds. Meanwhile, service providers are finding ways to add value and adjust their business models for the uncertain times that lie ahead.

We would like to thank all of the interviewees that have taken part in the research thus far, and we look forward to continuing our fieldwork from Santiago in the coming months. To participate in our ongoing research or if you have any questions or comments, please contact Project Director Lucrezia Falcidia at lfalcidia@gbreports.com. The final report will be released in April as the Official Investment Guide of Expomin 2020.

Lucrezia Falcidia
Project Director
Global Business Reports

Lucrezia Falcidia

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Table of Contents

Chile Mining 2019 Pre-Release

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Chile: Uncertainty Hits the Stalwart of Latin American Mining

Social turmoil returns to the streets of Santiago after 30 years of calm

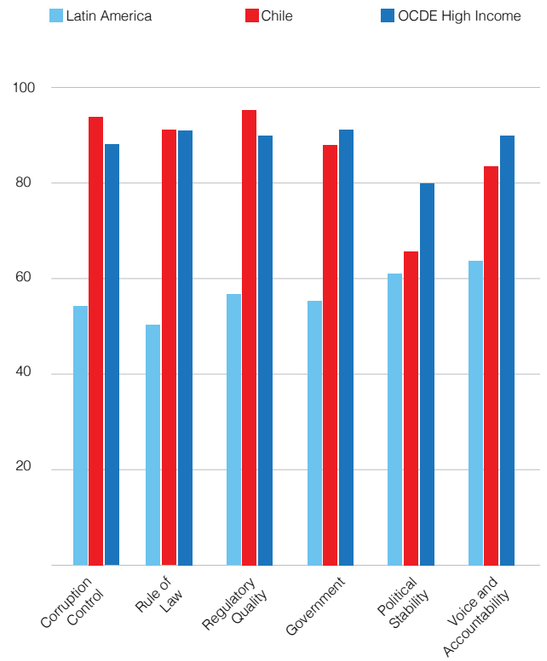
Prior to October 2019, the pervasive view held amongst Chileans and outside analysts was that Chile was immune to political destabilization and unrest. Although populism was spreading across Latin America and several other parts of the world, Chile was viewed as a consistently strong economic performer with relatively moderate politics. At the sustainable mining conference in Santiago in September, the most profound challenges facing the Chilean mining industry were outlined: weakness in the price of copper and lithium, water scarcity, declining ore grades, social license, high energy and labor costs to name a few. One concern absent from that list was internal stability. For the past three decades, Chile has been viewed by investors as a bastion of calm in an otherwise politically precarious region. Chile achieved its status as a leading mining jurisdiction not only because of its high quality and easy to exploit resource base, but also because its policies toward mining were regarded as best in class from an ease of doing business perspective.

In light of October's protests that have shocked the country, questions have been raised regarding Chile's ability to maintain its status as Latin America's most stable and successful country. The civil unrest was seemingly triggered by increased metro ticket prices, but at its core the disorder is fuelled by a gathering sense of economic inequality. Since 1990, the country's restored democracy has maintained the broad outline of free-market policies installed by Pinochet's dictatorship, which have enabled consistent economic success. The poverty rate has fallen from over 40% in 1990 to under 10% today, according to World Bank figures. The middle classes now form a majority, income inequality is below the Latin American average and Chile received the region's highest score on the United Nations Human Development Index, which is predicated on a blend of life expectancy, education and national income per capita.

In the context of the region, this performance is strong. However, compared to its OECD peers, Chile ranks highest in economic inequality. UN reporting found that the richest 1% of the population earns 33% of the nation's wealth. This fact is one of the principal reasons why there is such widespread anger. Poor and middle class people, who rely on public transit, feel that the burden of state funding is being unfairly placed on them at a time when middle class wages are stagnating and low skilled jobs are being replaced with technology.

Much of Chile's economic success has come on the back of a robust mining sector that has been and will continue to be the lifeblood of the economy. Chile is the world's top producer of copper, and exports of the metal account for between 10-15% of the

GOVERNABILITY IN CHILE
Source: Organization for Economic Co-operation and Development



CHILE PRODUCTION MAP
Source: Cochilco

nation's GDP. It also possesses the world's largest lithium reserves, based off of a U.S. Geologic Study (USGS) report.

It is unclear what, if any, backlash there will be long term on heavy industries such as mining. The protests have caused disruption to the typically efficient operational environment throughout the country, but strikes within the mines were limited to a few union groups and interruptions were overall minimal. However, the protests effectively shut down many of the country's key roads and ports, which were therefore unable to function at their full capacity. Inevitably knock on effects were felt throughout the mining supply chain as worker travel was limited and logistics networks were disrupted.

It is not just those who have taken to the streets armed with clanking pots and pans that are disappointed in the pace of economic growth in 2019; mining companies also had high expectations going into the year. However, predictions of demand outpacing supply for copper and lithium have not materialized thus far. The demand shortfall for these commodities can be blamed on a variety of global economic factors, but the most salient are the China-U.S. trade war and economic stagnation in Europe. These have taken a toll on global manufacturing activity, and, given copper's critical end usage in everything from car-making and earth-moving to advanced electronic components, a slowdown in manufacturing was bound to put downward pressure on the commodity price. Adding to the pain was the fact that Chilean copper production fell 2.5% in the first half of 2019 on the back of declining copper grades according to a study by the International Copper Study Group (ICSG).

Given these dynamics in the market, it is a testament to the dynamism of the Chilean economy and sound management practices in its mining industry that the economy is still projected to grow at a rate of 2-3% in 2019. Although growth thus far has been below expectations, it is still far better than that of its regional peers: Argentina, which is in recession, and Brazil, whose economy has stagnated.

Chile's history of churning out successfully run local businesses devoted to the mining industry is undoubtedly a positive driver of wealth creation. In describing the advantage Chilean companies have

"Chile is a very stable jurisdiction. The legal system works and levels of corruption are low. The geological potential of the country is huge and, despite claims that Chile is a mature market, we still believe there are significant opportunities. When compared to its neighbors in the Andean cordillera, Chile is a less complicated place to mine."

Timothy J Beale,
President & CEO,
Revelo Resources

over large global enterprises, Ivan Rayo, general manager of Chilean engineering consulting firm JRI, said: "Being a Chilean company means that our clients benefit from increased flexibility. For example, many operations are struggling to stay profitable with a depreciated copper price. Local businesses excel in responding quickly to adjust costs and implement solutions."

Another locally run business, PerfoChile, has 35 years experience as a drilling services provider. General manager Osvaldo Carmona Morales outlined his approach to weathering turbulent times: "We have focused on building our cash reserves over time in order to invest through good and bad economic and political climates."

Although mining is not experiencing its best year, companies continue to invest. Almost US$34 billion has been earmarked for investment in the Chilean mining sector over the next five years, according to the Ministry of the Economy. A report by Consejo Minero revealed 43 mining projects will be built or will begin production by the end of 2023. The biggest project is Teck Resources' Quebrada Blanca phase II, which involves US$4.2 billion in investment over the next five years to extend the life of the copper mine in the Tarapacá region. Antofagasta Minerals, meanwhile, will invest US$3.7 billion to expand its Centinela copper mine, with construction starting in 2021. The third biggest project is Nueva Unión, a joint venture between Teck and U.S.-based Newmont GoldCorp that needs US$3 billion over five years for construction of a copper-gold mine.

These new investments are needed to offset a potential decline in production from some of Chile's largest and most reliable sources of copper. After 104 years of production, Codelco's Chuquicamata, the largest open pit mine in the world, closed its surface operation and commenced its underground phase, and there is uncertainty surrounding the mine's ability to maintain current production levels, particularly in the near term. Codelco is expected to invest US$5.58 billion according to Consejo Minero in order to achieve a production level of 140,000 mt of ore per day, with an approximate mine life of 45 years.

During the 2015-16 downturn in copper prices, companies were devoted to adopting more efficient practices in order to lower their breakeven cost of production, and that trend continues today. By focusing on efficiency, companies can remain profitable while also positioning themselves to capitalize on opportunities when the market recovers. A healthy industry is one in which companies offer products and services to suit client needs in a variety of economic climates. Ricardo Capanema of Solvay, a chemical solutions provider, described how customer demands differ in high and low commodity price environments: "In times when the commodity price is low, our customers look to us to provide chemical solutions to improve the efficiency of their process and lower cost of production. In contrast, when commodity prices are high, that behavior changes, and businesses want us to find solutions that increase throughput and production.

Another strength of the Chilean mining industry is a specialized and technologically savvy workforce that is capable of facilitating the development of suppliers with aspirations to meet world-class standards. Chris Knowles of McLanahan, a minerals processing company based in Australia, said his company chose to move into Chile because: "It has a strong history in mining and minerals, good infrastructure and highly technically skilled workers… Australia and Chile share a strong connection through their minerals technology, and there is a free trade agreement that increases the ease of doing business in the Chilean market."•

Felipe Cabrera, who heads Emerson's innovation center in Santiago, described their experience moving into the Chilean market: "We listened to the big mining companies, and they stressed their need to increase productivity, reduce costs and lessen environmental impacts. Emerson then developed technology and sensors to solve these challenges for them. We were given the opportunity to pilot our technology in Escondida and Minera Los Pelambres. Now we are selling it all over the world."

Many of the top technology providers believe Santiago can be a global hub for mining innovation, and this development is being encouraged as an important driver of economic diversification in Chile.

At the end of the day, it is important to keep in context the sheer size of opportunity the Chilean market represents. It holds 22% of the world's copper reserves, 11% of the molybdenum reserves, 5% of the silver reserves, 7% of gold and 48% of the world's lithium reserves, according to Invest Chile. Furthermore, the quality of these reserves is often described as best in class. In light of the civil unrest, political sensitivities have become a more important part of the discussion regarding mining in Chile, but given the role the mining industry can play in delivering a better future for Chileans, it is important that it prevails in the face of any populist backlash. Jorge Maldonado, general manager of Superex, a leading company in sonic and diamond drilling, summed this sentiment up: "Sometimes Chile forgets how vitally important a strong mining sector is to the health of its broader economy. We must not miss our opportunity to lead in mining."•

"From a macro perspective I am optimistic because electrification of cars and renewable energy growth constitute an unstoppable wave, and the transition will require a lot of metals. On the microeconomic side, there are some regulatory, labor and social challenges that make operating in Chile more difficult. A project that used to take 10 years from start to finish for a new mine is now taking 20 years. We hope to see movement towards a more streamlined process."

Stephanie Ashton,
CFO & Corporate Development,
Griffith Drilling

Chile's Project Development

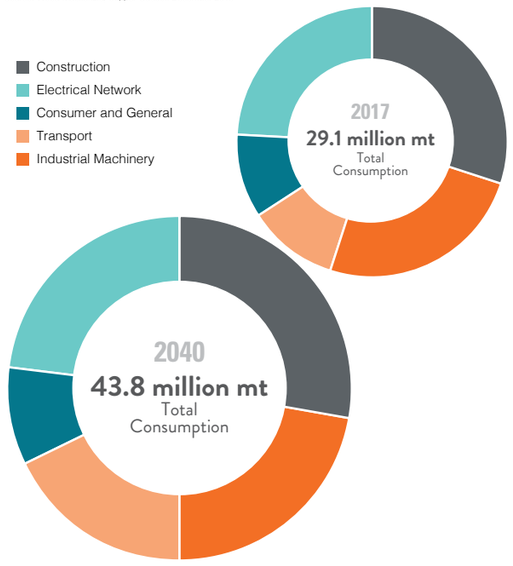
Increasing necessity for new projects today to meet tomorrow's demand

Take a flight to the north of Chile and as the plane descends, you may notice one of the many deep holes in the earth. Of the top 20 highest producing copper mines globally, seven are located in Chile: Escondida, Collahuasi, El Teniente, Los Bronces, Los Pelambres, Chuquicamata, Radomiro Tomic are all stars in the global mining constellation. Maintaining high production from these large mines, along with additional new production, is essential as the world transitions to a new energy economy. Simply put, the green economy is far more metal intensive than the fossil fuel economy. So long as demand continues to rise for electric vehicles and solar and wind energy, demand for copper and lithium will rise synchronously.

Wind and solar energy requires three to 15 times as much copper per unit of output as fossil fuel generation, according to the Financial Times. A report from Deutsche Bank expects the global electric vehicle market to grow 22% annually to 2030, led by China's 25% market growth. Estimates are that copper consumption from electric vehicles, which was 0.9% of the global total in 2017, will rise to 8.2% of total copper demand in 2030. Given these dynamics, it is increasingly important that Chile continues to invest and innovate in order to offset production declines.

GLOBAL COPPER CONSUMPTION BY MARKET SECTOR

Source: Wood Mackenzie, Copper Outlook December 2018



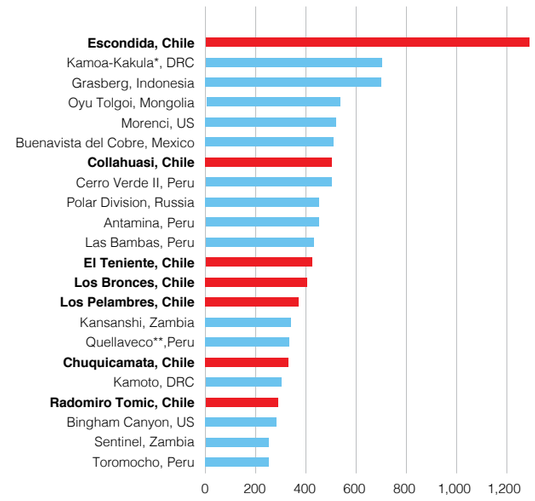
Although Chile is considered a mature mining jurisdiction, Timothy Beale, CEO of Revelo Resources, a prospect generator with a portfolio of copper and gold-silver projects focused in Chile, described the quality of the country's mining assets: "World class means long life of mine and scalability of production, and Chile has several truly world class mines. These huge mining districts in Chile will all be mining for decades into the future."

This perspective is especially welcome in a year when several of Chile's top producers have struggled to boost production and earnings. Chilean state-run Codelco, the world's largest copper producer, saw year-on-year profits plunge over 70% from US$1.235 billion in June of 2018 to US$318 million in June of 2019, according to their earnings statement. This drop in earnings is not expected to continue, but it illustrates the impact weak copper prices coupled with the high cost of investing in future production can have on profitability.

Meanwhile, the story at BHP's Escondida, the highest producing copper mine in the world, was more optimistic, yet still below

LARGEST COPPER MINES BY ESTIMATED PRODUCTION ('000 TONNES)

Sources: International Copper Study Group; Wood Mackenzie



* Company estimate, due to start production in 2021
** Estimated to start 2022

expectations. Copper production at Escondida in FY 2019 decreased by 6% to 1,135 million mt as a consequence of a 12% decline in copper grades. Revenue from Escondida also fell by US$1.5 billion to US$6.9 billion overall for the year. According to BHP's end of fiscal year 2019 (Australian) conference call on June 30th, it is believed that Escondida will continue to be a very good cash returner for the next decade despite the down year. Results amongst the majors operating in Chile vary, however, and 2019 has generally proven to be a difficult year with profit margins being squeezed by low commodity prices and high production costs. Driving the high cost of production in 2019 were falling ore grades, collective bargaining issues and increased water costs.

Given the current dynamics of the market in Chile, there are relatively few greenfield projects being pushed forward today. In a conversation with Claudio Martínez, commercial director at Worley, he confirmed this trend: "There are a lot of greenfield projects, but they are currently dormant due to grades and prices. The mining industry in Chile is thus mostly seeing brownfield expansion at this time."

Projects like Chuquicamata underground and the second phase of Quebrada Blanca, commonly referred to as QB2, dominate the headlines when it comes to investments in the future of mining in

Chile. However, these should not overshadow the progress some of the mid-tier and junior mining companies are making in developing assets that could soon become strong producers.

One company that is leading the development of the industry is Los Andes Copper. Its Vizcachitas project, located in the Rio Rocin Valley of central Chile, is one of the largest advanced copper projects in the Americas not held by a major. The project is currently well positioned to continue its development as it is now in the permitting process for its pre-feasibility study. According to executive chairman Fernando Porcile: "The Vizcachitas project not only has a large resource, but also has some qualities that make it more competitive than many new greenfield projects and even some of the brownfield expansions in Chile."

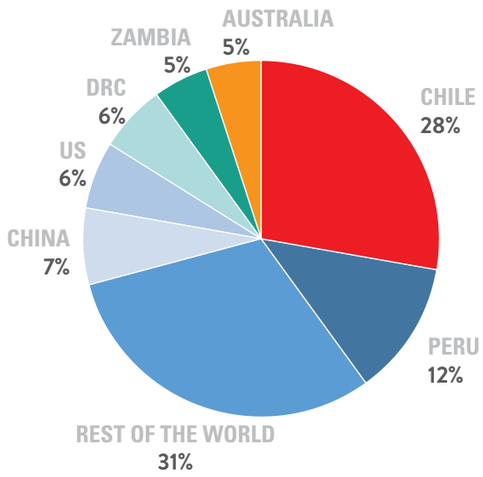
His colleague Antony Amberg, CEO of Los Andes Copper, explained why their project has garnered so much attention from the mining community: "The PEA demonstrated that Vizcachitas is a very attractive and viable copper project. We were able to show a net present value (NPV) of US$1.8 billion and internal rate of return (IRR) of 20.77% at US$3.00/lb copper after tax. We demonstrated a significantly larger resource base and have measured and indicated resources of 1.284 billion mt."

The PEA also demonstrated that there are no fatal flaws and the project can be mined without any significant complications.

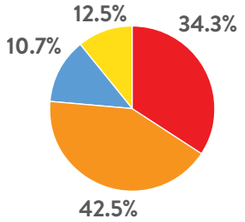
Other important copper projects being advanced by juniors and mid-tier miners are Mantos Copper's Mantos Blancos, Coro Mining's Marimaca, Hot Chili's Cortadera and Aethon Minerals' Arcas. Each of these companies has had to weather a volatile few years, and, given their ability to survive the downturn up to this point, they would all be positioned for success given any uptick in the copper market.

Revelo Resources is a prospect generator, and the company's CEO Timothy Beale outlined their strategy: "The idea is that we generate prospects and then look for industry partners to make joint venture agreements. We are now looking to modify our strategy by continuing to look for option and joint venture agreements with mid-tier or large companies, but also by raising private finance to fund exploration – perhaps by spinning out certain projects, which we will operate."

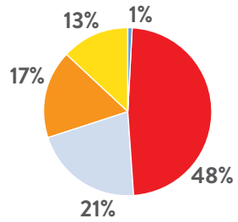
WORLD COPPER PRODUCTION
Source: Cochilco



LITHIUM PRODUCTION
Source: Cochilco



LITHIUM RESERVES
Source: Cochilco



Chile Australia Argentina China Other

"In the past, lithium was left as waste. Only in the last 10 years has lithium become an important mineral for the global economy. It is now clear that lithium will play a big role in the energy and transportation technologies of the future. For this reason I decided that I wanted to contribute to making Chile a leader in lithium production."

Marcelo Awad, Executive Director, Wealth Minerals

Financing has not come easily for juniors in recent years. In 2018, juniors accounted for only 4.5% of the total exploration budget in Chile, while majors accounted for 88.8% according to Cochilco. There are a few reasons for this, but foremost among them is the difficulty juniors are experiencing to raise capital. Dave O'Connor, country manager at Aethon Minerals, said: "There is a lack of investment in junior companies resulting in a lack of activities from them. It has become increasingly difficult for juniors to raise financing on the stock markets. There has also been a slowdown in exploration activity from the majors, making it hard to do joint ventures."

Nonetheless, 2019 has seen some positive developments as each of the aforementioned juniors has received the needed financing and is continuing to progress through the permitting and approvals process.

LITHIUM

Although Chile is known for its prowess in copper, lithium mining is a new frontier in which the country has great potential. In 2018, USGS figures show the country produced 16,000 mt of the mineral, second only to Australia, whose production reached 51,000 mt. Given the global trend towards electrification of transportation, lithium production could be poised to become an increasingly important part of Chile's economy. This would be particularly true if demand ends up meeting expectations to triple by 2025.

Currently the Chilean market is dominated by two major producers; SQM and Albemarle. Canadian-based companies Lithium Chile and Wealth Minerals are some of the most well known juniors operating in the space, and Wealth Minerals in particular has attracted the attention of potential partners and financiers around the world. In October 2019, Uranium One, a subsidiary of Russia's state nuclear company Rosatam, bought a controlling stake in the firm in the wake of China's Tianqi Lithium acquiring a 24% stake in SQM.

The reason Chile is such an attractive jurisdiction for lithium production is largely because of the Atacama salar, which produces the most lithium of any salar in the world. Wealth Minerals has a 46,200-hectare concession in the Atacama salar, and the company's CEO, Henk Van Alphen, described why it is so compelling: "The Atacama salar is the world's highest grade and largest producing lithium brine deposit and currently produces approximately one third of global lithium output from two production facilities operated by SQM and Albemarle. It possesses a very high grade of both lithium and potassium and has a high rate of evaporation and extremely low annual rainfall."

According to Van Alphen, Atacama's finished lithium carbonate is easier and more cost-efficient to process than its peer group globally; a key factor in lithium production costs is evaporation, and Atacama offers the highest evaporation rate in the industry.

It remains to be seen if Chile will be able to fully realize its potential as a leading lithium producer, because there are deep concerns around water usage in the lithium mining process. According to Reuters, Albemarle's plan to build a plant to process 42,500 mt/y of lithium carbonate was rejected by environmental regulators, and this pushback from regulators and communities has inhibited growth in production.

GOLD

In contrast to copper and lithium, precious metals focused companies have not experienced the same level of difficulty in financing their operations. With gold trading at a five year high above US$1,500 per oz and the majority of global central banks devaluing their currencies, there is optimism that gold prices will remain high for a prolonged period. Because of this thinking, the market for new exploration has been reinvigorated.

Rio2 is a junior led by CEO Alex Black. Black previously turned Rio Alto Mining into a new gold producer in Peru, which was eventually acquired by Tahoe Resources for US$1.12 billion. Rio2's Fenix project, located in Copiapó Province, Antofagasta region, is one of the largest gold oxide resources in the world according to the company. In 2019, it completed an updated pre-feasibility study to reveal an after-tax net present value US$121 million discounted at 5% and an internal rate of return of 27.4%. The study also proved that the project is capable of profitability at prices as low as US$1200 per oz. Now, according to Enrique Garay, senior vice president of geology: "Rio2's business model is to move the large resource at Fenix Gold into development and production as an open pit, gold heap leach mining operation. The strategy is to take the project into production in the shortest possible timeframe based on a staged development strategy."•

"The advantages of developing a project in Chile compared to Peru are that mining regulations are clearly defined and community issues in Chile are far less complex."

Enrique Garay, SVP Geology, Rio 2 Limited

The Services Sector

Building resilient businesses for tough times

Underlying Chile's success as a leading metals producer is a robust ecosystem of service providers. Drilling contractors, engineering firms, mineral processing specialists and consultancies all play an equally important role in contributing to the country's high level of production. Unfortunately, when commodity cycles are in a down phase, service providers are susceptible to tightened margins, falling utilization rates and less ambitious planning for greenfield projects.

According to Stephanie Ashton, CFO of Griffith Drilling, a diamond drilling company capable of drilling at 2,300 meter depths: "There has been little capital for greenfield exploration nor any appetite for it from a timeline and permitting perspective…. The current trend is for companies to do expansions of their existing operations. One of the ways in which the industry is confronting the problem of permitting and not being able to develop new projects is by drilling deeper at their existing operations."

On the engineering side, Ivan Rayo, general manager of JRI Ingeníeria, observed: "Nowadays we have a lower copper price and demand for engineering services has shrunk. There are less opportunities to expand the business, and many engineering companies have been forced to take austerity measures to increase efficiency. It has also meant fiercer competition."

"Social demands are being made as part of the unrest and it is giving Chile the opportunity to start over. Hopefully the silver lining is that regulations and laws will be clearer moving forward."

Carlos Leigh, Regional CEO Latam, DSI Underground

"A great advantage of Chile's system is that our environmental permit system addresses the entire lifecycle of the project. This eliminates the need to obtain temporary permits for each stage of the project."

Hugo Andrade, General Manager, Arcadis Chile

Equipment manufacturer Liebherr is seeing the effects of the downturn manifest through a lack of investment in new equipment. Managing director Dale Clayton said: "Our strategy has been to continue with our maintenance and service contracts while we wait for the market to pick up. Companies are extending the life of their assets, and eventually, it will get to the point where the cost to repair is uneconomical, and they will have to look for replacement equipment."

The strategy in this case is to wait out the downturn long enough to capitalize on companies transitioning to newer, more efficient equipment.

That is not to say opportunities aren't present for service companies. Both a growing lithium industry and an increasing push into underground mining will continue to keep service providers busy for years to come. Furthermore, the mining industry is becoming much more focused on sustainability, so there will be a host of new opportunities and challenges associated with reducing water usage and lowering carbon emissions.

One of the primary demands on service providers in today's market is to lower costs, and that often means careful planning. Claudio Martínez, commercial director at Worley, highlighted his company's success in this area: "Worley has expertise in the designing and reviewing of CAPEX and OPEX estimates. We have been able to support customers with significant reductions (approximately 20%) in their CAPEX investment in brownfield projects."

Another demand from clients is reduced energy consumption. In addressing this need, FLSmidth is working on flotation cells capable of reducing energy consumption by approximately 50% while at the same time improving recovery.

Additionally, there has been a push for service providers to offer tailored solutions to meet specific client needs. McLanahan general manager Jean Pierre Mery outlined his company's experience developing tailored solutions: "The Chile team has in-house capability for design and service. Having a new focus on engineered for spec sampling systems has improved outcomes for clients."

There are also opportunities for Chile's service providers to grow their exports. Despite its reputation as an export-oriented country, only 5.6% (478 of 8,577) of local Chilean mining suppliers are currently exporting their products and technologies, according to Prochile.

One of the biggest complaints among service providers is that regulations are too tight, and that cuts into profits. According to Jorge Maldonado, general manager of Superex: "The rules are not clear. We do not have big communities in the north, but a few people are creating big problems for business. In the Dominga project, they have not been able to begin because of environmental regulations and community issues. If government is

"New mining projects have been slow to develop because it is tough to get approvals and the standards are very high in Chile. Dominga and Pascua Lama were forced to suspend development due to environmental regulations. From a blasting company point of view, our job is to ensure environmental compliance by developing products that minimize environmental impact."

Diego Rodriguez Christensen, Director of Latin America, Maxam

Photo courtesy of Liebherr

granting permits, then the rules should be clear."

Ashton of Griffith Drilling also pointed to policy issues that were complicating operations: "From a cost efficiency perspective, we have to comply with a significant number of standards, which has increased our operational costs over time. The same amount of work that we used to perform with three crews now requires four to meet the current labor regulations."

OPPORTUNITIES UNDERGROUND

Given Chuquicamata's US$5.6 billion dollar switch to underground cave mining from open pit and El Teniente's new level proposal requiring an additional US$5.5 billion of investment, underground mining is

"Demand for teleoperation has not been affected by the price of copper. Rather, it has been affected by the need to get people away from the worksites. Safety has become the most important concern of our clients. This is even taking precedence over value."

Brian Laroque, General Manager, Hard-Line

one of the more promising areas for service companies. JRI Ingeníeria, ICP Ingeníeria, Worley, Normet, Master Drilling and DSI Underground are all finding lucrative opportunities in this space.

According to Carlos Leigh, head of Latin America at DSI Underground - a company providing dynamic anchor systems and injection resins for underground mining and tunneling – service companies play a critical role in ensuring the safety of mining underground. "Any mine that is deep or located in a country with seismic issues needs bolts and systems with dynamic conditions that absorb energy."

In this case, DSI provides fast setting resins that reduce bolting cycle times and increase safety.

JRI Ingeníeria has a division specifically devoted to providing the most efficient and innovative designs in underground mining. Throughout the downturn in copper prices, JRI has been able to increase market share and since 2017, has experienced 20% per annum growth. A large contributor to this growth came from underground mine engineering and design.•

Innovation that Offsets

Long-awaited disruptive technologies are now arriving to Chile's mining sector just in time to compensate for declining ore grades

Thanks to George Lucas and his Star Wars franchise, as a society, our most popular image of a robot is R2D2. For a small number of visionary thinkers, however, robots are more than science fiction; they are a critical enabler for a safer and more productive mining future.

Marco Ruiz, manager of ENAEX Robotics, is one of the thinkers attempting to bring disruptive change to the mining industry. He said: "We recognized that as ore grades decline there is a need to facilitate access in difficult to reach deposits while protecting the safety of operating personnel."

Within the mining industry, robotics may be considered niche and unready to immediately replace traditional methods, but their development and presence is indicative of a broader trend in which companies are investing heavily in technology. According to a KPMG survey, the highest level of investment in the mining technology space is occurring in data and analytics tools, autonomous vehicles and robotic process automation.

Andrés Costa González, president of the South America division at FLSmidth, an engineering firm that supplies productivity enhancing equipment, has been observing this influx in investment and is positioning his company to capitalize on the trend. He commented: "The future of mining is going to be tough. Deposits are getting deeper, and costs are rising. Mining operators need to maintain productivity in order to be competitive. With technologies and technical support, our clients can offset the degradation of ores and increasing costs."

AUTONOMOUS MINING AND TELEOPERATION

It is no longer an uncommon sight to see a mine truck cabin empty as it is being operated remotely or fully autonomously. Trucks that drive themselves can spend more time working because software does not need to stop for shift changes or to take a lunch break.

Companies at the forefront of this technological transformation in autonomous mining are Finning-Cat, Epiroc, Komatsu, BelAZ, Hard-Line and Liebherr. In speaking about the autonomous future these companies are helping to facilitate, Pedro Damjanic, senior vice president at Finning-Cat, said: "The routine and risky processes will be done by machines, and the focus can now turn to planning, new mine design and new design of the operation. This will aid companies in capturing ores that were previously uneconomical."

Photo courtesy of Hard -Line

One of the added benefits of investment in autonomous solutions is that it also encourages innovation from suppliers. For example, there are several new autonomous trucks being introduced to the market today. Companies such as American Air, which supplies air conditioning, are then encouraged to tailor innovations to complement new fleets. According to Joel Araujo Strul, CEO of American Air, "The challenge (of automation) is that there are not enough qualified people in the industry who are prepared for this rapid change. We are developing the most automated AC unit on the market, and it will require minimum work on installation and maintenance."

Additionally, American Air is developing a predictive maintenance system for air conditioning units to be launched in 2020.

Beyond vehicles, there are also autonomous solutions for other segments of the mining process. Normet, for example, has developed a smart scan technology that senior vice president of sales Marcelo Anabalón, senior vice president Latin America said "improves the quality of the sprayed concrete, securing the concrete in the mine, which supports the tunnel and therefore mitigates the risk of tunnel collapse."

Photo courtesy of Liebherr

Technologies such as this will have big implications for increasing safety in the mines.

When asked about the biggest risks associated with teleoperation and autonomy, Brian Laroque, general manager of Hard-Line Chile, a leading supplier of automation, teleoperation and remote control technology, responded: "The most prominent risk is in companies taking too long to adopt the technology available. The pace of technological adoption in mining is accelerating at an unprecedented rate, and mining operations must partner with support companies to ensure the acceleration in adoption is implemented effectively."

Chris Knowles, global marketing manager at McLanahan, had a similar perspective:

"Our strategy has been to continue with our maintenance and service contracts while we wait for the market to pick up. Companies are extending the life of their assets and eventually that will get to the point where the cost to repair is uneconomical and they will have to look for replacement equipment."

Dale Clayton, Managing Director, Liebherr

"When we talk about automation, artificial intelligence and robotics, there really is not an option to not participate. Businesses will have to accept adoption as a cost of being in the marketplace."

Chris Knowles, Director of Sales and Marketing APAC, McLanahan

"We read a lot about Chile wanting to be lower cost in order to increase competitiveness. When we talk about automation, artificial intelligence and robotics, there really is not an option to not participate. Businesses will have to accept adoption as a cost of being in the marketplace."

DATA AND ANALYTICS

Coupled with development in autonomous mining, data analytics is also quickly becoming an essential tool for operators. Predictive maintenance solutions that address problems before they occur are one of the biggest benefits that digital technologies can offer the mining industry. Maintenance in mining often occurs on a time-based schedule, rather than as needed, leading to a lot of wasted time and money.

Dale Clayton, managing director of equipment manufacturer Liebherr, spoke about the company's approach to data and innovation: "Our LNDS system allows us to monitor vital information on trucks remotely and manage maintenance accordingly."

In Chile, companies such as Emerson, Siemens, Motion Metrics, Hexagon Mining and eBooting all specialize in helping customers to leverage their use of data through software. Although data and analytics tools are still in their infancy in Chile, they represent a significant opportunity, because data has the potential to unlock value in nearly every aspect of the mining process.

BEYOND BLASTING

The market for blasting services is highly competitive in Chile, and this competition is producing some of the most cutting edge technology in the business. Maxam, Enaex, Dyno Nobel and Orica all are all developing products that make blasting safer, more efficient and more environmentally friendly. By investing in the appropriate explosives, the way these explosives are positioned and stabilized, rock within a blast. This produces better fragmentation, thus reducing the overall mining cost for the customer.

While some companies are focused on optimizing the results of blasting, Plasma 4th, a subsidiary of Enaex, is focused on eliminating the need for blasting altogether, by using advanced rock fracturing techniques. Francisco Portilla, general manager of Plasma 4th, the accuracy of the blastholes drilled and the detonation procedure, companies can make a material difference to their bottom line.

Angello Passalacqua, business manager of Dyno Nobel Chile, sums up this realization in saying: "Great benefits can be obtained by adopting new technologies especially given the increase in the cost of labor, inputs and the variability in the price of commodities." He continued: "There is a huge opportunity to improve the drilling and fragmentation processes, minimize exposure of people involved and reduce the amount of equipment used. Optimization of the process of blasting, fragmentation, transport, grinding and supply of the plant can lead to huge cost savings."

This savings opportunity was the driving force behind the development of Dyno Nobel's differential energy technology, which ensures customers deliver the right amount of energy to different layers of

noted that the benefits of plasma are far reaching. Blasting is often unpopular with nearby communities and is also considered harmful to the environment. Portilla said: "To develop a project near a community, you need technologies that are minimally invasive. Blasting creates a lot of pollution, a lot of noise and a lot of vibration. Often this can lead to resistance from communities and the risk of a project being blocked."

In order for any new technology to be adapted, however, the product must be cost effective. Portilla noted that one kilogram of plasma is more expensive than one kilogram of explosives. However, there are other costs to consider. These include community resistance to blasting and the high cost of evacuating the mining site when blasts occur. With Plasma 4th technology, only those within a 150 meter radius of the fracture are required to be evacuated. This guarantees operational continuity and limits downtime.

IMPACT OF TECHNOLOGY ON LABOR

As a byproduct of the push to modernize operations through automation, data and robotics, jobs will inevitably be impacted, both in number and in function. Many of the new jobs created by automation will require different levels of education and skills. This has raised concerns among communities as to how their people will continue to participate in the industry as the automation trend persists. Companies like Liebherr are cognizant of these concerns and feel an obligation to continue hiring and training locals. Dale Clayton, managing director at Liebherr, explained: "We believe that autonomous mining will employ the same amount of people but with a different skillset. The challenge will be finding and training local communities to take these positions."

SANHATTAN VALLEY?

With so much focus on technology development in mining, Santiago has become an important regional hub for many of the leading global technology firms. According to Pascual Veiga, president of APRIMIN: "Chile is being used as a laboratory for experiments with new technology because it offers great diversity and variation in style of operations, height of mines and rock types."

Another reason technology companies find Santiago appealing is because the city has some of the most well educated and well trained workers, an entrepreneurial culture and a good climate for investors – characteristics the city shares with other international hubs for the development of disruptive technology such as Silicon Valley.•

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