

Mining in Chile

This report was researched and prepared by Global Business Reports (www.gbreports.com) for Engineering & Mining Journal. Editorial researched and written by Imara Salas, Kevin Norchi and Meredith Veit. For more details, please contact info@gbreports.com.



Chile, the copper capital. Photo courtesy of Codelco.

Copper Production

Reawakening the sleeping giant

It is no secret that the global downturn in commodity prices has left mining jurisdictions across the world reeling since 2013. Chile, whose mining sector comprised 20% of its total GDP as recently as a decade ago, is no exception. As a country whose economy has historically depended on mining and whose national budget is pegged to the price of copper, Chile serves as a microcosmic representation of the mining industry at large. From 2015 to 2016, the world's top copper producer fell from 11th to 39th in the Fraser Institute's Survey of Mining Companies, the result of which, in this case, correlates directly with investment dollars. According to Sergio Hernández Núñez, executive vice president of the Chilean Copper Commission (COCHILCO): "Since 2013, the portfolio of mining investment projects in Chile has declined significantly, from approximately \$110 billion to \$50 billion."

THE NEXT SUCCESS STORY FROM CHILE



MINERA TRES VALLES

The Tres Valles mining project is based off of two mines: Papomono (an underground mine) and Don Gabriel (an open pit mine), both of which are located in the Manquehua gorge in the Chalinga valley.

Its processing plant has a normal capacity of 5,400 tonnes per day (tpd) of ore, and consists of a copper leaching operation that has a crushing and agglomeration plant, heap leach pads and pools, and a SX-EW plant.

The facility is designed to produce up to 18,500 tonnes per annum (tpa) of thin copper cathodes.

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The purpose of this editorial, however, is not to examine the flotsam of a shipwrecked mining economy. Rather, 2017 is quite an exciting time for the Chilean mining industry. Not only does Chile still produce 30% of the world's copper — Chile produced 5.55 million mt in 2016, representing a year-to-year decrease of only 4%, according to COCHILCO — but it is also essential to recognize that \$50 billion of investment is no paltry sum. Chile's total copper exports in 2016 accounted for \$26 billion in revenue, matching 2009's copper export revenue, which was the low point before the most recent mining boom. If history repeats itself, then the optimism stemming from an expectedly sustainable rise in the price of copper and an imminent influx of foreign investment is warranted. "In my opinion, the price of copper has reached a floor," said Maritza Araneda, KPMG Chile's mining manager and resident copper expert. "By the end of 2017, prices should settle at \$2.65/lb or \$2.70/lb. A more sustained increase is likely to be seen in 2018, with further upside in 2019."

Fortunately for Chilean copper producers, global demand for copper has remained relatively steady. Anticipated infrastructure investments from the United States and China, as well as the looming transition

from fossil fuels to electric batteries in the automotive industry, bode well for copper's inherent application value. The Financial Times reports that Chinese consumption of refined copper is expected to grow at 2% per year over next five years, and according to the Observatory of Economic Complexity, \$13 billion worth of Chilean copper exports were destined for China in 2015. "China consumes approximately 45% of the world's copper," Araneda continued. "At the end of the day, whatever happens in China will heavily influence the price."

Chile's Copper Mines: Survival and Growth

For many copper producers in Chile, production continued at a fairly consistent rate over the past several years despite a relative lack of return for their product. BHP Billiton's Escondida mine, the top-producing copper mine in the world, still produced over 1 million metric tons (mt) of copper in 2016, representing a modest 6.8% decrease in production from 2012. Anglo American and Glencore's Collahuasi mine, Chile's second-most productive copper mine in 2016, produced 506,000 mt, representing an 11.2% increase from the previous year. The Corporación Nacional del Cobre (CODELCO)'s top-producing mine,



Nelson Pizarro, executive director, Codelco.

El Teniente, has increased production every year since 2011. CODELCO's total copper production in 2016 amounted to over 1.7 million mt, representing 31% of Chile's total production. BHP Billiton produced Chile's second-largest amount of copper in 2016 at 1.2 million mt. Mine production is volatile regardless of the state of the industry, but Chile's sustained level of production indicates an absence of any long-term economic health concerns.

Despite the current price of copper, CODELCO appears to have its sights set on the future, investing in projects that aim to extend the company's current mine lives. In fact, in 2016, CODELCO allocated over \$2.7 billion toward development projects as part of an \$18 billion investment plan that will last through 2020. The company's largest development project is at the Chuquibambilla mine, where it is developing an underground mine that is projected to add 40 years to Chuquibambilla's current mine life. The underground mine is expected to be in production in 2019. As Nelson Pizarro, CEO of CODELCO, explained: "We realized that we needed to carry out a plan to replenish the production capacity that had been lost due to the decrease in the reserves, so we formed a portfolio of structural projects, such as the Chuquibambilla new underground expansion, a new haulage level at El Teniente, a potential expansion for Andina, and others."

El Teniente, already the world's largest underground copper mine, is also a recipient of CODELCO's investment funding, as the company is adding a seventh level to it that is projected to add 50 years to its mine life. Also in the El Teniente division, CODELCO implemented the Dacota and Diablo Regimiento projects, which are expected to generate a respective 490,000 mt of refined copper over twelve years and 126,000 mt of refined copper over eight years.

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Antofagasta Minerals (AMSA), the largest privately owned, Chile-based producer, brought their Antucoya mine into production. After having briefly been owned by Sociedad Química y Minera (SQM) and then reacquired by AMSA, Antucoya began producing in 2015 and is still ramping up its copper production totals. Meanwhile, AMSA's Los Pelambres mine is consistently a top-five copper producer in the country, and the company's Centinela mine frequently falls within the top ten.

Apart from Antucoya, CODELCO's Ministro Hales mine, KGHM's Sierra Gorda mine, and Lumina Copper's Caserones mine, also came into production during the height of the downturn, each of which have been able to sustain steady growth in spite of market conditions. "We are currently operating at 90% of our full concentrator plant production capacity, and we are working to close the remaining 10% gap as quickly as possible by identifying and mitigating bottlenecks," said Maciej Sciazko, CEO of Lumina Copper. "Hopefully, this project will serve as an example of how to bring an asset into production during difficult times."

Additionally, in August 2017, Canada-based Sprott Resource Holdings acquired 70% of small producer Minera Tres Valles from the Vecchiola Group, a transaction that may provide hope to any major looking to sell an asset. Minera Tres Valles includes the Don Gabriel open pit mine and the Papomono underground mine. Evidently, Sprott was attracted to the projects due to their potential capacity.

"Right now, Don Gabriel produces 15,000 to 20,000 mt of ore per month with a strip ratio between 3.5 and 4.0. After the mine is fully ramped up, it will produce 78,000 mt per month," said Luis Vega Muñoz, general manager of Minera Tres Valles. "We plan to eventually go public so that we can raise more capital to pursue additional drill targets."

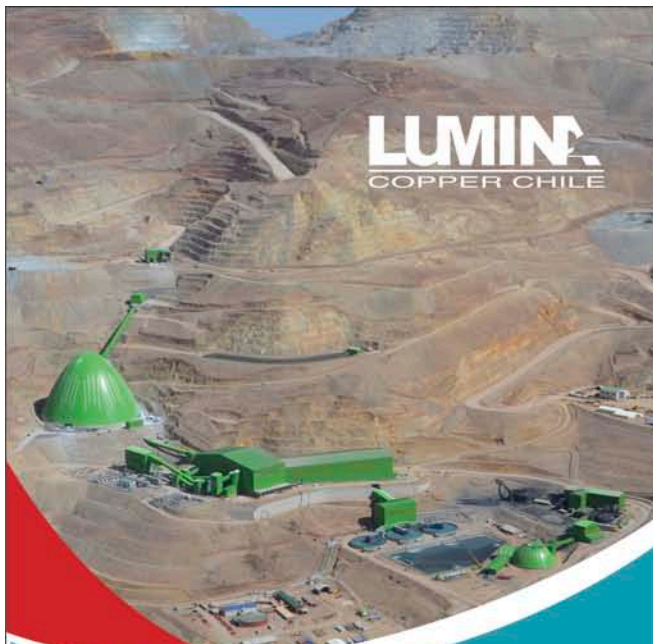
Finally, BHP Billiton has also been negotiating to sell its Cerro Colorado mine since April 2017. Having produced 74,000 mt of copper in 2016, the sale is expected to command approximately \$800 million. Teck Resources, HudBay Minerals, and Lundin Mining, which operates the Candelaria mine in northern Chile, have all been speculated as potential buyers.

Chile's Next Top Mine

In addition to sustained production, Chile's development projects bode well for the well-being of the country's mining industry. In 2015, Teck and Goldcorp announced a 50/50 joint venture to consolidate their Relincho and El Morro projects into a single development project, NuevaUnion, which could become one of the largest mines in the world. The \$3.5 billion copper-gold-molybdenum project could save the companies a combined total of \$4.9 billion, as the Relincho project and El Morro project were expected to cost \$4.5 billion and \$3.9 billion, respectively. The companies expect to have a pre-feasibility completed by the end of 2017.

Teck is also investing in its Quebrada Blanca mine, implementing a development project that aims to extend the life of the mine by 30 years. Also, while the mine has produced fewer than 50,000 mt/y of copper in each of the past three years, Quebrada Blanca Phase 2 is expected to extend the mine's production capacity by 240,000 mt/y of copper and 6,000 mt/y of molybdenum, putting the mine's production total nearly on par with Chuquibambilla.

In 2015, BHP Billiton began a development project focusing on expanding the life of its Spence mine by 50 years. The feasibility study process began at the end of 2015, but the company has yet to decide whether to move forward with its \$2.2 billion of required investment. Spence has produced an average 173,000 mt/y of copper over the past three years.



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In addition to its efforts at NuevaUnion, Goldcorp has also entered into a 50/50 partnership with Barrick Gold to develop the Cerro Casale project. Previously a 75/25 joint venture that featured Barrick as the majority partner and Kinross as the minority partner, Cerro Casale is known to be one of the world's largest undeveloped gold deposits. Like Goldcorp, this is not Barrick's only joint venture in Chile, as the company also owns part of the Zaldívar mine in a 50/50 partnership with AMSA. Large companies entering joint ventures as a means to hedge their bets may be a continuing trend as the market remains in a state of recovery.

Indeed, Chile Does Produce Other Metals

Aside from copper, Chile is also the world's 14th largest gold producer, 4th largest silver producer, and 2nd largest molybdenum producer. Chile's gold and silver reserves comprise 7% and 14%, respectively, of the world's total reserves. Chile also accounted for 23% of the world's molybdenum production in 2016. Notable gold producers in Chile include Los Pelambres and Yamana Gold's El Peñón and Minera Florida mines, each of whom appear to be committed to Chile in the long-term. "We seek to achieve a long life for both of our assets in Chile,"

said Gerardo Fernandez Tobar, senior vice president of southern operations at Yamana Gold. "In general, Chile's geology, infrastructure, suppliers, and regulatory environment make the country a top priority for Yamana's continued presence in Latin America."

Chile is one of the world's largest lithium sources, and the Salar de Atacama alone is responsible for 37% of the world's total lithium carbonate production. Though Chile's lithium market is considerably less mature than its copper and gold markets, the staggering volumes have not gone unnoticed. CODELCO has already expressed an interest in lithium by establishing a lithium-focused subsidiary, Salar de Maricunga S.A., in April 2017, and BYD, a Chinese electric vehicle company, has expressed interest in investing in Chile's lithium supply.

SQM's Salar de Atacama mine, the world's largest lithium brine mine, produced 44,000 mt of lithium carbonate in 2016, up from 33,000 mt in 2015, indicating the global demand for lithium is not slowing down to wait for the rest of the mining economy.

The only other company that has permission from the government to produce lithium is Rockwell Lithium, which was acquired by Albemarle in 2016. In August

2017, Albemarle's lithium carbonate plant received permission from the government to nearly double production from 45,300 mt/y to 88,000 mt/y.

The reason why there are only two lithium producers in Chile is largely due to the government's classification of lithium as a strategic metal, which creates a barrier for lithium exploration companies who wish to eventually bring their projects into production. The main limitation is that lithium properties in Chile are not able to become concessions, and the general consensus is that the rules around lithium production are largely unclear.

Looking Forward

In general, while total mining invest in Chile has taken a hit since 2013, production totals have remained relatively stable. In fact, contrary to intuition, 2013 through 2015 copper production totals were the highest in Chile's history, topping out at 5,776,000 total mt in 2013. While this is likely due to companies trying to maintain a certain revenue quota, the overarching message is that Chile's strongest mines were able to withstand the social Darwinian test of an extended down cycle. Chile's mining health should serve as a positive sign of vitality for the global mining industry at-large.



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Investment Challenges

Looking for new opportunities in a mature market

Given Chile's extensive mining history and relative political stability, it should come as a surprise that, in 2016, junior mining companies were responsible for only 7.8% of the country's exploration, while major companies already residing in Chile represented the lion's share of 80.9%. Chile has high-quality infrastructure, significant port accessibility by virtue of its geography, legislative transparency and, according to Transparency International, very little discernible government corruption. This being the case, one would expect Chile to have garnered greater interest from exploration companies around the world.

Land Claims and Mining Licenses

The predominant explanation for an apparent lack of exploration activity in Chile is that land claims and mining licenses do not expire provided that the holders of the concessions pay annual taxes. For the major mining companies that hold the majority of Chile's explorable land, this is a negligible expense. "There is very little turnover of ground com-

pared to other jurisdictions where licenses have limits," said Craig Mackay, managing director of Golden Rim Resources. "There are certain groups in Chile that hold very prospective licenses but are under no pressure to conduct meaningful exploration work. This keeps a lot of ground from the active exploration companies."

According to COCHILCO, the top ten holders in 2015 accounted for 40% of Chile's total exploration concessions. While it has been reported that the government is considering changing the mining code to incentivize concession holders to explore or release land, such an outcome is unlikely because any type of legislative change may deter investment from foreign majors. The government is likely unwilling to trade major investment money for junior investment money. According to Diego Hernández, president of SON-AMI: "Guaranteed land claims is one of the biggest factors that attracted international investment to the Chilean mining industry in the first place. Ideally, we would like to have

more medium-sized exploration companies enter Chile, but any changes that are made must be done cautiously so as not to drive away existing investment."

Water Scarcity

For mines entering the production or development phases, water scarcity continues to be the most pressing issue in Chile. While Chile evidently has plenty of access to water on its coast, transporting water to high-altitude mines has proven very costly in terms of the amount of energy it requires. Underground water is also becoming increasingly scarce and energy-consuming to extract, driving both producers and service providers to devise new water recycling tactics. "Kinross has taken measures to be more efficient with water usage and is using less water to produce the same amount of ore," said Jose Tomás Letelier, vice president of external affairs at Kinross Gold. "We recycle a high percentage of the water we use, we have improved our piping and we have lowered evaporation rates, which is a common issue at such high altitudes."

As a result of the declining underground water supply, mining companies have been investing in desalination plants. Escondida, for example, recently constructed the largest desalination plant in Latin America. "The



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plant's capacity is 2,200 liters per second, and it has a 175 kilometer pipeline," said Mark Venning, business development director of Black & Veatch, the engineering firm tasked with building the plant. "The contract will enable us to build a 1,400 liter expansion. This will supply the water for Escondida and reduce or eliminate its consumption of groundwater."

In recent years, some companies have resorted to using sea water without desalination treatment for their operations, but they eventually learned that this solution can be incredibly corrosive and, consequently, expensive. "If you just use salt water, you reduce your recovery rate and your plant lasts a fraction of the time," explained Venning. "When comparing the cost of using fresh water to the amount of increased capital that ends up being spent on a plant using salt water, it is easy to see which solution is more viable."

Employment and Regulations

Even if the land claims are secured and the water situation is sorted out, it is still important for investors to understand how smoothly their operation will be able to continue. While government expropriation of private mining assets will likely never be an issue in Chile, as it is in Bolivia, Venezuela, and Thailand, for example, mining companies in Chile have had their fair share of hiccups.

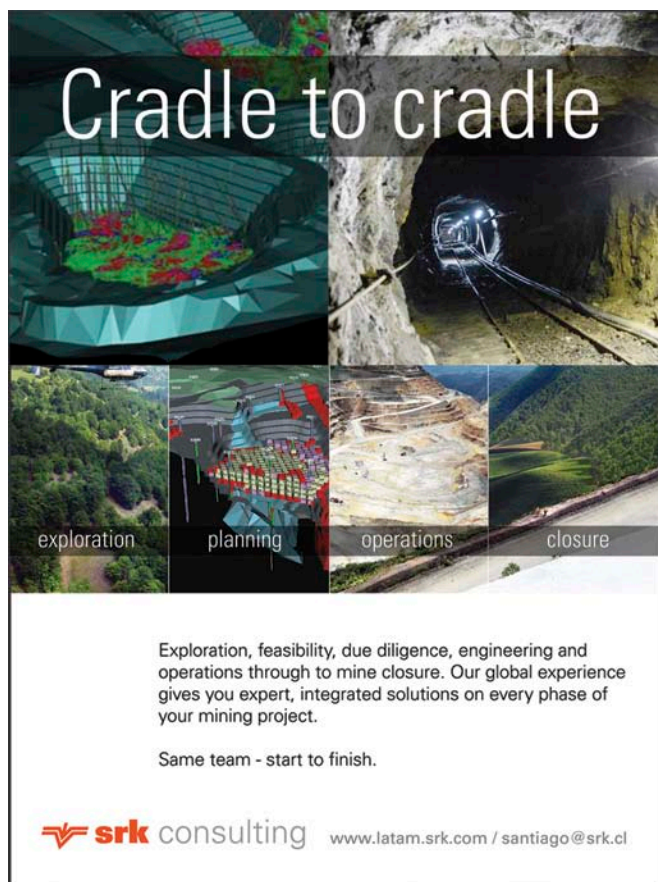
In early-2017, Minera Escondida faced a 43 day, 2,500-employee strike, which was Chile's longest since 1973. As a result, Escondida's Q1 output dropped 63% compared to Q1 2016 output. Antofagasta Minerals also faced strike threats at their Centinela and Zaldívar mines in July 2017. Because of Chile's strong labor union presence, strikes do not simply end once the employees go back to work. "Labor unions are more powerful now than they used to be and recent strikes have had severe consequences," said John Byrne, managing director at Boyden Executive Search. "In the case

of Minera Escondida, in 16 more months, both sides will need to meet again to negotiate." The verdict is still out regarding whether or not Chile's regulatory environment is a substantive deterrent to investment. The general consensus is that the permitting process that was introduced by the current government administration in 2014 is quite time-consuming. According to Pascual Veiga López, president of the Association of Industrial Suppliers of Mining (APRIMIN): "Environmental regulations are affecting more than we had initially expected. Unfortunately, in Chile getting environmental approval does not guarantee that you can go on with a project and it is not always clear which entity gets final approval of a project. Chile has always been respectful of environmental laws, but the processes take too long."

The Chilean government, however, appears to understand how important a smooth permitting process is to stimulating the mining industry. According to EY, after considerable pressure from the private sector, the government is working to overhaul the existing environmental permitting process. "Chile needs to find a way to make regulations more similar to those of the world's most competitive mining jurisdictions, but without jeopardizing what the regulations were originally meant to protect," said Diego Hernández. "An environmental permit that normally takes four years to obtain should only take two years to obtain."

Looking Forward

While efficiencies are being created to combat water scarcity issues, and a robust, albeit bureaucratic, regulatory process is necessary for a mining economy of Chile's scale, land claim and mining license legislation appears unlikely to change in the short-term. Because land availability is scarce compared to Chile's actual exploration potential, junior companies wishing to enter Chile would be practically better off acquiring projects from or joint venturing with existing juniors in the country.



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Innovation and the Future of Mining

Chile as a hotbed for technological development

Perhaps clouded by some of the challenges the country faces both internally and as a global player, Chile remains an exciting mining jurisdiction. If a silver lining could be drawn from the downturn in the price of copper, it would be that Chile has essentially been forced to become a global nucleus for technological innovation and engineering expertise. As mining companies focus on cutting costs while maintaining their levels of production, engineers have been tasked with developing efficiencies and fabricating creative solutions. While this is the case in mining jurisdictions around the world, Chilean mining engineers have a particularly high reputation and are considered on par with those in Canada and Australia. "The Chilean engineer is well recognized around the world in the mining industry," explained Juan Pablo González Toledo, president of the Chilean Institute of Mining Engineers. "In general, the perception of Chilean engineers is very strong in mining and in other industries."

The Rise of Autonomous Mining

Chile's mining expertise and the industry's call for creating efficiencies have coalesced into a perfect storm of innovation. There is a general consensus around the mining industry that autonomous mining is the most exciting of these innovations due to its positive financial, environmental, and security implications. "One of the positive things about automation is that it is steady, which reduces variability and saves millions of dollars," said Felipe Cabrera, general manager of Emerson Automation Solutions. "Automation also greatly reduces the risk of people working in the mines being injured."

CODELCO's Gabriela Mistral mine is thus far Chile's most advanced mine in terms of automation, implementing autonomous haulage systems (AHS) supplied by Komatsu. Beginning in 2007, the mine's automation was a response to a qualified labor shortage throughout Chile. The mine can now be operated by lower-level workers, but without any apparent loss of productivity. "An example of this is SMART construction," said Darko Louit Nevistic, executive vice president of Komatsu Cummins Chile. "This system is a combination of intelligent machines and operation planning methods that can significantly increase productivity in a construction operation. All of the more complex tasks of the operations are managed by the machine automatically."


While mining companies generally appear to be quite receptive to the idea of automated operations, labor unions are much more skeptical. While it is reasonable to conclude that autonomous mining will replace human workers with machines, it does not necessarily imply fewer jobs available in mining. On the contrary, many believe the new technology will, in fact, result in new employment opportunities. As Pedro Damjanic, senior vice president of mining at Finning Chile, stated: "Some people are scared that autonomous mining will result in a loss of jobs, but what they forget is that it creates opportunities to open many other mines that are otherwise too expensive to pursue."

Process mechanization also plays a major role in increasing safety measures. Mining inherently involves a considerable deal of risk, and limiting human involvement in the more dangerous aspects of the mining process can mitigate this concern. "In Chile, the explosive loading process is not yet mechanized," said Marcelo Anabalon, general manager of Normet. "We are working with Chilean explosives companies to further develop this technology."

Autonomous mining addresses the fact that thousands of workers can be living on a mine site at one time, which is costly in terms of both accommodations and employee morale. Remote operations is an increasing popular technological focal point, as it would allow employees to tele-commute to a mine from a control center at the company's headquarters. ABB, for example, has already developed this technology and uses it to monitor their operations at their clients' mine sites, as opposed to sending their employees back and forth. According to Jorge Abraham Canales, ABB's industry lead for mining: "The opportunity to work on mines remotely is going to be the next big demand trend, and that is something ABB is pushing for."


Alternative Energy Sources

Mining operations and developments in northern Chile have long regarded high energy costs as one of the major detriments of operating in the country. In 2012, Consejo Minero predicted Chile to have the second-worst energy costs in the world, after the Democratic Republic of the Congo, from 2014 to 2020. Since then, however, the Chilean government has taken steps toward reducing the prices of electricity supply tenders and promoting renewable energy operations, resulting in a 34% decrease in the average marginal energy cost from 2013 to 2015. The increased presence of renewable energy in the mining industry would be a significant step toward a further reduction in both cost and carbon emissions. "The key issue with mining



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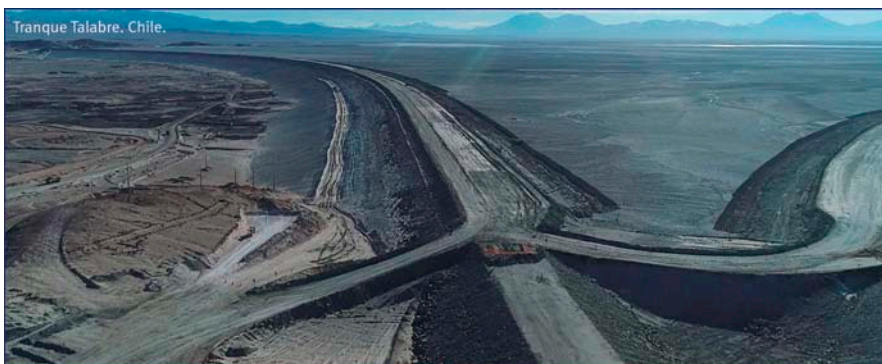
companies was that they wanted to know if renewables could provide power 24 hours per day, seven days per week, and we have proven that renewables can do so,” said Bart Doyle, general manager of Mainstream Renewable Power. “There is a big tender going on right now with a major mine, and that will be announced between October and December.”

Mainstream Renewable Power operates Cuel, a 33 MW wind project in Chile, and their joint venture, Aela Energía, began construction on two additional Chile-based wind projects that are due to begin operations in the second half of 2018. Acciona Energy also

hopes to one day provide renewable energy to the mining sector. Currently, the company operates the El Romero solar project, 30% of which is dedicated to supplying Google Chile. According to Jose Ignacio Escobar, general manager of Acciona Energy: “We are fairly confident the renewable energy sector will be able to compete with the more conventional offerings. Some mining companies are now mandated to reduce their carbon emissions, so they have become more open to the renewable approach.”

Looking Forward

As the state of the mining industry has repeatedly flashed its hazard lights over the past several years, mining companies across the world have no choice but to consider the future. Whether it is a response to companies cutting costs or environmental challenges, Chile and its talented pool of engineers are prepared to lead the charge toward more efficient mining practices as commodity markets are poised to rebound. According to Maria Eugenia Parot, general manager of Golder Associates: “Chile has the opportunity to become global leaders in developing a mining industry that is innovative in the way it solves key challenges related to productivity, water, and community relationships.”



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Conclusion

As commodity prices continue to recover, so will Chile's mining industry. The combination of expected infrastructure projects in the United States, China, and India and the world's transition from fossil fuels to electric vehicles and lithium ion batteries indicates that Chile's natural resources will play a more critical role than ever. Both the public and private sectors are confident Chile will remain an important player in the global mining industry, particularly in the event of a commodity deficit.

Mining is a cyclical business. Commodity prices over the past decade have become increasingly volatile, and as great as the mining boom was for most companies involved, the past few years were equally painful. Going forward, it is imperative for companies to examine the mistakes that were made at the onset of the downturn in order to avoid them when the next one inevitably comes. In the opinion of Nelson Pizarro: “During the mining boom, mining companies produced the maximum possible amount of copper due to the high price. This triggered an excess demand of engineering and construction services for new mines, and the cost for critical supplies for the mining activities increased dramatically during that period.”

Sustainability will be an important weapon in the fight against volatility, and cost-conscious productivity is a key element of a sustainable business model. Perhaps another boom would not be ideal for the health of the mining industry. According to Gonzalo Fanjul, director of corporate finance at Asset Chile: “When the copper price was up to \$4 per pound, the average cost to produce was nearly \$3 per pound. Mining companies are hoping for the price to recover slowly. They want a long-term, sustainable copper price. A stable and healthy industry is much better than the alternative.”

The mining industry in Chile is confident it will remain a top jurisdiction in terms of production and investment. According to Aurora Williams, the Chilean Minister of Mines: “Chile's investment portfolio is projected to increase from \$50 billion in 2016 to almost \$65 billion in 2026, representing an increase of 30%. The government has been protecting and improving the maintenance of solid institutionalism, clear rules, and competitiveness conditions. By March 2018, we will double assistance to small mining with over \$100 million in resources within the next four years of government and create more focalized mechanisms for its sustainable development.”