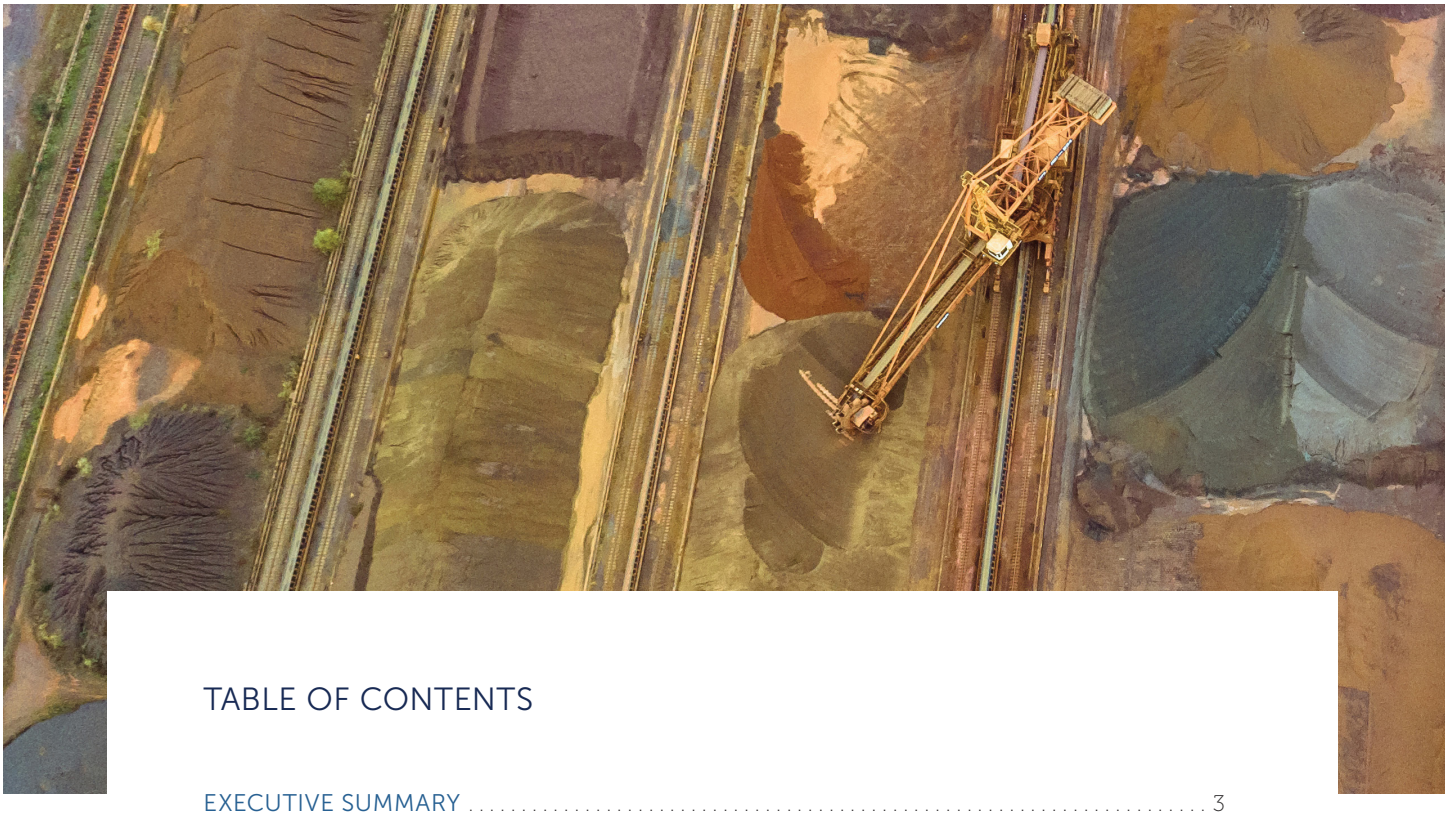
ESG in Mining: A Quiet Revolution is Surfacing

SMALL STEPS ARE HAVING SEISMIC IMPACTS, RAISING FRESH OPPORTUNITIES FOR INVESTORS

July 2020

By Clive Burstow

BARINGS



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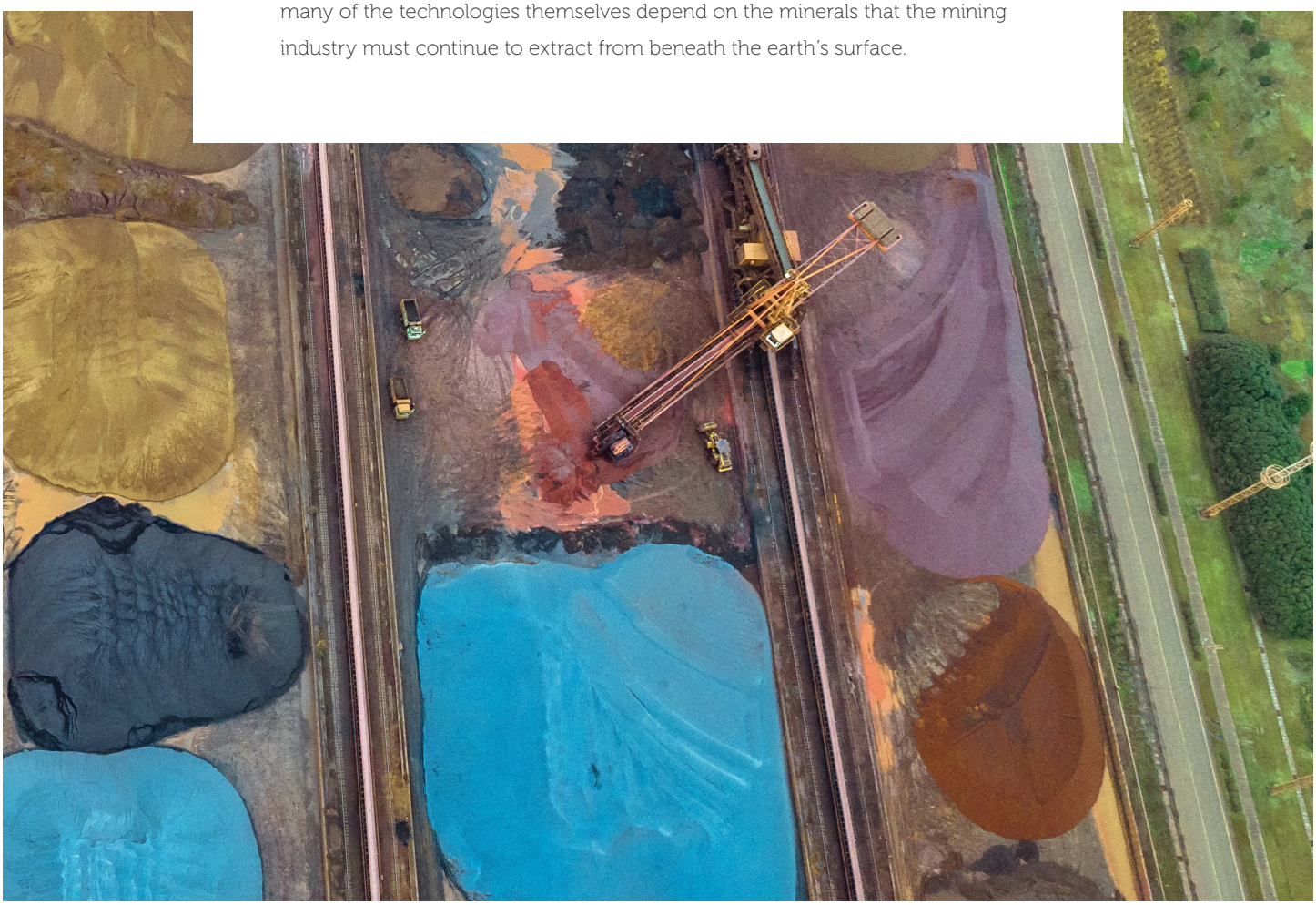
There's a quiet revolution underway in mining that is delivering more change than it has seen in centuries. Investors, like many observers, have long had a negative view of the environmental, social and governance (ESG) records of the mining industry. But the advances underway are rapidly making the industry safer, more efficient and more sustainable.

A change in management culture and crucially the embrace of new technology and working practices are transforming mining at a time when the world is becoming more resource intensive than ever before. Companies are differentiating themselves by transforming an industry that has inherently been regarded as dirty and dangerous.

Ironically, while technology is at the heart of the industry's transformation—just as it remains the driving force in building a more sustainable global economy—many of the technologies themselves depend on the minerals that the mining industry must continue to extract from beneath the earth's surface.



INTRODUCTION

Mining may be the last industry many investors think of when considering ESG issues and the changing dynamics they bring to an investment decision. For most, it likely still conjures an almost Dante-like vision of fire and dark destruction pouring from the earth. Dig a little deeper, however, and many would be surprised at the significant leaps forward in the application of technology and processes. Together, these have revolutionized mining companies' approach to extracting the resources needed to create the sustainable, high-tech world of the future while minimizing the impact on the human element and the natural environment. The industry has made significant strides in all three ESG areas. Ignoring the changing face of a sector once thought of as a necessary evil means ignoring an opportunity to capitalize on investing in an industry that is also undergoing significant change.

Mining continues to innovate at a rapid pace, with advances seen in:

- Artificial Intelligence in mine planning that reduce mine footprints and the impact on the natural environment, while increasing operational efficiencies.
- Driverless trains and trucks that limit vehicle movements and emissions, both on the mine site as well as in the shipment of mineral-bearing rock to customers around the world.
- Safety practices which have even delivered a better record than some online retail giants, including Amazon.
- Alternate fuel sources, such as hydrogen and hybrids, that reduce greenhouse gas emissions onsite.
- Renewable energy sources at remote mine sites that supply clean, inexpensive power which, in some instances, reverts to a trust benefiting the local community.
- Waterless processing methods, which reduces the impact a mine has on local aquifers that might be used by other industries.

It is not a stretch to argue that the generation of mines being developed today, such as Anglo American's Quellaveco copper mine in Peru or Teck Resources' Quebrada Blanca Phase 2 copper mine expansion in Chile, could be the last of what are called 'conventional mines.' By no means is this a journey that is complete. However, the next generation of mines will look very different from their predecessors as technology and working practices make them smaller and more efficient, while also less impactful, less polluting and less intrusive to the communities within which they sit.

SECTION ONE: ENVIRONMENTAL

The mining industry recognized years ago that changing stakeholders' perceptions about its environmental impact would require a substantial shift in operating methods embodied in the wide embrace of technology. From the first exploration, development and operation to eventual closure and rehabilitation, mines are being designed to substantially minimize their impact. No longer is it acceptable for a mining company to find and extract subterranean materials without also taking into consideration the visual legacy that will be left behind. Traditional thinking dictated that an open pit could simply be flooded and grass seed cast over waste dumps—earthen wounds left to heal on their own. This is no longer acceptable. Today, companies go to great lengths to return the closed mine site as close to the natural state it was in when they first arrived. Some physical reminder will always remain in the changed shape of the land after the mine has closed, but careful and considerate reclamation can minimize this substantially.

TECHNOLOGY & PROCESSES

Technological progress in mining moves at an almost breath-taking pace, as does the embrace of operating practices from other industries. It is no coincidence, for example, that the chief technology officers of the largest mining companies in the world have experience within, or have studied, the automotive and aerospace fields and use them as examples of how new thinking can apply to an old industry. Just as the Toyota Way revolutionized car manufacturing in the 1950s through the introduction of lean production practices, software development and new management processes that emphasized workforce development, the changes in mining today require a new manner of thinking. Companies want to extract more ore with less waste, and with lower capital expenditures, while minimizing the impact on the natural environment. Global diversified miner Anglo American calls the transformation of the extraction process the "Future SmartMine Concept"[1] while the World Bank refers to it as "Climate Smart Mining."[2]

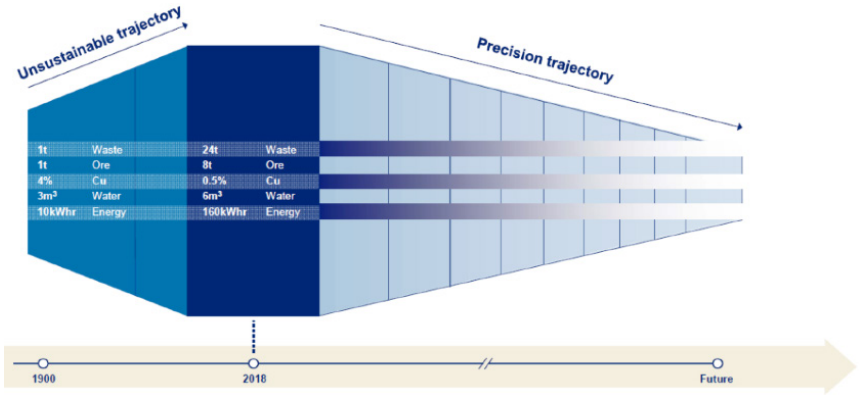
Mining is an increasingly challenging field today, as companies are held accountable in ways their predecessors weren't. There will always be an operational impact, but mining companies are becoming more innovative and finding new ways to minimize this. However, there is still much work to be done.

OPERATIONAL EFFICIENCY

Modern mining operations involve a smaller footprint and more efficient processes that integrate artificial intelligence and automation to maximize extraction value while minimizing operations and, as a result, environmental impact. With the easy ore already extracted in many cases, the task grows harder every year.

- In 1900, to produce 40kg of copper with an average grade of 4% took 1.1 tons (1 tonne) of waste to 1.1 tons (1 tonnes) of ore, consumed 3 cubic meters of water and 10kWh of electricity
- In 2018 those numbers had changed dramatically to 0.5% average grade of copper extracted, 26 tons (24 tonnes) waste to 9 tons (8 tonnes) of ore, consuming 6 cubic meters of water and 160kWh of electricity, all to produce the same 40kg of copper[3]

FIGURE 1: Redefining the Business of Mining



SOURCE: O'Neill, Tony. "Delivering Sustainable Value." AngloAmerican Investor Presentation, 2018 BAML Global Metals, Mining & Steel Conference. Miami, May 15, 2018.

Traditional mining approaches—crush, grind, process, concentrate—have seen little change in several hundred years. What has changed, though, is the increased application of technology to extract more of the finished product with fewer inputs (electricity, water and chemicals for example) and waste. Companies continue tweaking processing flowsheets to achieve incremental gains, aided by technology that helps remove more of the metals and materials needed for a technology-driven future. Put another way: the more copper extracted from every ton of ore through the application of technology, the less rock that is needed to be mined, reducing the industry's environmental impact.

The mine of the future will be a blend of technology and best practices from other industries, shifting thinking from the mine in its traditional sense to one that is part of a larger industrial process. We are already seeing the technology of tomorrow being developed, tested and implemented today, reducing emissions and footprint of future mines. This can be seen today in Rio Tinto's AutoHaul rail technology in the Pilbara mining region of Australia, which is guiding driverless trains across hundreds of kilometers from the mine to the port. Or look at the integrated operations center in Perth, which coordinates BHP Group's iron ore mines, also in Australia's Pilbara region, eliminating the need to maintain a large number of people at remote mine sites or in towns such as Port Headland, where the demand on local services has driven significant cost inflation.

ENERGY SAVINGS

The largest Green House Gas (GHG) emissions at a mine come from transportation and power generation, though power demand from infrastructure and transportation is undergoing a significant change as companies are now building operations with access to renewable power. Both Swedish mining company Boliden[4] and U.K.-listed Chilean miner Antofagasta[5] announced recently that they have signed contracts to be supplied with renewable power to various operations.

Energy transition is an area that is gathering increased attention from corporates, as consumers demand low-carbon intensive products. Corporates are not just looking at emissions within their direct control but also at the carbon footprint of their direct suppliers (like electricity providers) and even firms entirely beyond their reach or control. According to the Greenhouse Gas Protocol,[6] a partnership between the World Resources Institute and the World Business Council for Sustainable Development, this includes:

- Scope 1 emissions: Direct emissions that are under the operational control, such as fleet vehicles
- Scope 2 emissions: Indirect emissions from electricity purchased by the mining operation
- Scope 3 emissions: All other indirect emissions from activities that the mining company does not own or control; these could include emissions associated with the steel industry that is consuming iron ore, for example

To achieve progress, there is growing interest in building renewable power stations at a mine site to supply the operations and the local community with affordable, clean power.

It's not just the operational side where this change is being seen. In 2019, BHP Group's[7] then-CEO, Andrew Mackenzie, announced that the company was committing $400 million over five years, scaling up low emission technologies that decarbonize its operations to reduce its own Scope 1 and Scope 2 emissions from electricity consumption and diesel use. It will also work with all users of its products to reduce the impact of Scope 3 emissions. Rio Tinto[8] has a similar program, committing $1 billion to reduce emissions from its projects over the next five years to support the delivery of climate change targets and achieve net zero emissions from operations by 2050. Both companies already use a number of low-emission Light Utility Vehicles at their operations and will look to increase this. BHP, for example, is also aligning its executive remuneration with emissions performance, strengthening a program that has been in place for a number of years and encompasses safety as well as financial and operational metrics.

POWER FOR THE COMMUNITY

There are immediate socio-economic spin-offs to protecting the environment. The local 'green' power stations not only support local secondary business opportunities, they are also a natural extension of the micro-finance programs that have been in place for many years, supporting local businesses that provide goods and services to the mine. In Chile, there are trials of solar farms floating on copper mine tailings ponds, where the remains from ore processing, typically in a wet form, are primarily stored in man-made ponds close to the processing site. This reduces evaporation of the pond while also generating clean power from an area that would normally go unused. Renewable power plants are likely to outlast the mine and could end up in a trust to the local community, allowing them to sell power into the state grid, generating a clean income. Think of the changes to local communities.

Access to finance also becomes broader. Renewable energy projects also allow the mining company to access capital through 'green' bonds, improving their social scores with bond agencies. The green bond market now reaches $650 billion and is growing fast, with a large share of projects relating to energy and water. Social impact projects can also access the market for sustainable bonds. Investors support the effort and will accelerate the change in the process of mining.

There are synergies in resource investments with environmental protection. Take the example above of renewable plants reverting back to the community a step further and combine it with a hydrogen fuel cell mine fleet, drastically reducing emissions from the two parts of a mining operation that generate the highest levels of pollution. This may sound like a concept that will take years to put in place, but Rio Tinto is building a 34-megawatt solar plant[9] to supply all the electricity at its Koodaideri iron ore project in Australia today. Combine this with the hydrogen-powered haul truck being developed by Anglo American in South Africa, and the concept becomes reality.

POWER FROM HYDROGEN

This leads us to the generation and use of hydrogen. If generated from renewable power sources, 'green' hydrogen can be a clean fuel source for transportation and power generation. Many companies are looking at the use of fuel cells in utility and haulage vehicles, reducing emissions from diesel-powered trains. Anglo American, in partnership with ENGIE,[10] is developing a hydrogen-powered mine haul truck, the largest conversion of its kind, as a step towards significantly reducing carbon emissions at its operations. The 290-ton truck is scheduled to begin mobility testing this year at the company's Mogalakwena platinum mine in South Africa.

However, it is not just mining companies that use hydrogen as a power source. In Europe, steel producers such as Voestalpine, ArcelorMittal and SSAB are building pilot plants and testing the use of hydrogen as a power source in blast furnaces. Although a hydrogen-powered commercial steel mill is still years away, steps are now being taken in the right direction. SSAB, for example, will heat its North American steel furnaces with renewable energy by 2022,[11] which illustrates again the quiet though broadening revolution in the industry.

Ultimately these measures and more could lead the steel industry to move away from being a high-carbon emitter to a net-zero carbon emitter at best (low-carbon emitter at worst) and significantly change the perception of the industry in many investors' minds—from one of polluter to clean. In the near-term, there will be a trade-off as the industry continues to use carbon credits to offset its carbon emissions. However, the journey towards low-carbon steel is underway, and this decade could produce an industry with emissions falling and a changed, more attractive perception from investors.

WASTE REDUCTION

The reduction in mining waste, or tailings, is an important part in the industry's transition. The mining industry has grappled for years with how best to manage waste handling, with tailings dam design and monitoring having scaled up to current safety levels that were unheard of even 20 years ago.

However, fiber optic cabling and satellite monitoring alone would not have been enough to prevent the tragic accident at Vale's Brumadinho iron mine in Brazil on January 25, 2019, when a dam burst and flooded parts of the neighboring town with nearly 10 million cubic meters of water and mining sludge. The causes of the dam failure appear to have been rooted both in the managerial culture as well as technical reasons, building over time and eventually leading to its collapse and the death of 270 people. But events associated with one company, no matter how devastating, do not reflect the progress across the entire industry. The company has increased efforts to change its internal culture to become one that emphasis oversight and management of its tailings facilities, while increasing monitoring and decommissioning of dams across Brazil. Technology such as satellite monitoring and waterless mining is being applied in new processes to reduce the risk of such events from happening again.

It is almost impossible to eliminate waste entirely from a mining operation, but technology is helping reduce the amount of waste mined from an open pit or underground operation. Even eliminating a fraction of the waste rock hauled to a processing facility will reduce the amount of storage space needed. The next step is the elimination of the water in the waste product, through the application of filter press technology such as that being used at Norsk Hydro's Brazilian alumina plant. This essentially compacts the waste material, squeezing out the water for later reuse in the plant and leaving a compacted cube of material with a much lower water content, which is safer and takes up less room to store. Reducing water use at the mine and processing plant to a minimal level is the vision of many companies that are in the process of developing and testing the waterless mine concept at global operations today. If successful on a large scale, it could lead to a significant change in the safe disposal of waste at operations around the world.

CHANGING INSTITUTIONAL CULTURE

This shifting focus from companies is perhaps the most surprising area for investors who delve into how mining companies are reporting their efforts. Companies have gone from producing literature on sustainability and corporate responsibility as part of the annual reporting suite to now generating independent reports on the impact of climate change on their operations and measures being put in place as part of their commitments to the United Nations Sustainable Development Goals (SDG). They are also holding seminars on technological change and, more recently, presentations on how they will have reduced emissions from their operations to become carbon neutral—in many cases by 2050, with goals set to reduce emissions sustainably by 2030.

At its February 2020 climate change and water seminar, Rio Tinto published a report[12] detailing its approach to achieving a long-term goal of carbon neutrality by 2050. The report showcased, for example, that through an alliance with Alcoa and Apple, they will replace traditional carbon-containing anodes, which release carbon dioxide into the atmosphere during the production of aluminium, with an inert, oxygen-rich anode that will produce carbon-neutral aluminium. This is a prime example of the old economy working with the new to create a sustainable solution and a more ethical product.

Adopting new technologies and best practices is accelerating the revolution in mining in the same way that the technology industry has undergone its own revolution in processing power and miniaturization. This evolution is far from complete. Ethical and social discussions continue to range over fully autonomous mining equipment, eliminating the need for any human presence on site. But the key is that the industry continues to innovate and adapt technology at pace.

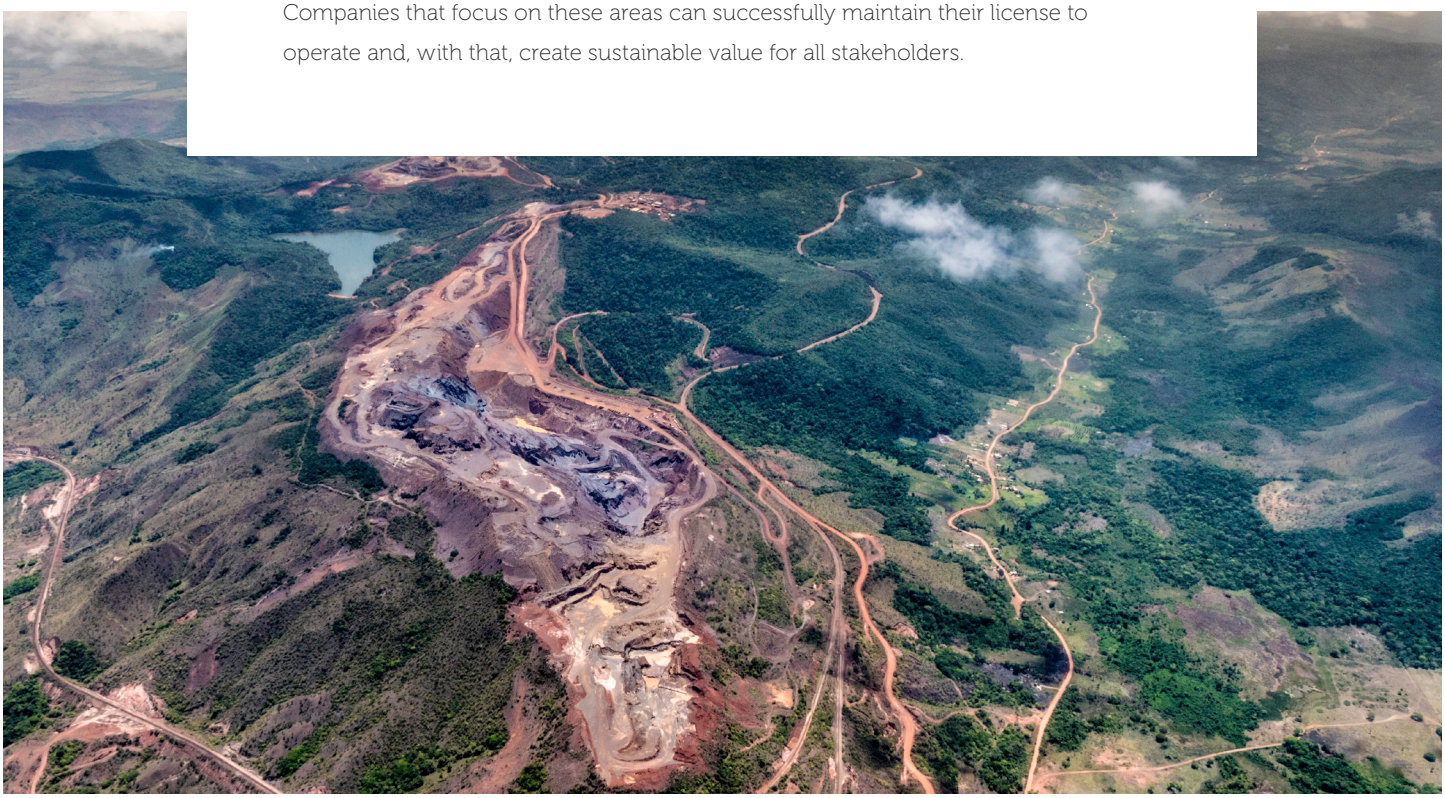
SECTION TWO: SOCIAL

Mining has had a historical dark side, relative to discussions of environmental destruction, child labor and slavery, forcing the industry to take robust action to change. Through initiatives led by the International Council for Metals and Mining (ICMM), the United Nations, Amnesty International and Human Rights Watch, mining firms continue to work towards the eradication of modern slavery and child labor, which still impacts over one million children every year. Many of the largest companies in the world are signatories of various commitments that aim to eradicate child labor from the industry. Openly adopting and advocating these policies shows that they are taking this seriously. The challenge remains that, while many companies are actively engaged in eradicating human rights abuses, there are always those that flout laws and are prepared to operate in the shadows. These are the companies that international agencies and human rights groups are rightly focusing on.

COMMUNITY CONNECTIONS

Sustaining a "social license to operate" remains at the heart of many companies' operating practices. For many years, the focus was on companies gaining a legal license to operate, which invariably took the form of a physical document detailing the requirements and conditions under which the company was able to find, extract and process the ore; essentially this was a contract between the host nation and the mining company. However, this has expanded to include not just national authorities, but also, for example, those indigenous groups close to the mining operation that will be impacted in some form by the extraction process. In essence, mining companies have realized it is not good enough to just have an agreement with federal authorities to operate—they also must ensure that those groups close to the mine site feel that they are represented and that their concerns are being taken into account by the operator. The mining company will work hard to gain and, more importantly, maintain this "social license to operate" knowing that losing this right can have a significant impact on short-term operations and present the company in a detrimental light to investors.

It is not uncommon to find mining companies building infrastructure, schools and hospitals local to mine sites as part of the operating license requirement granted by the host government, while also employing indigenous people at all levels. Companies that focus on these areas can successfully maintain their license to operate and, with that, create sustainable value for all stakeholders.



Being a good steward of the environment is also a significant part of the ways in which a company maintains its social connections to the local community as well, including reducing emissions and air pollution that can have a significant impact on indigenous population's health. In South Africa, for example, firms are also addressing the legacy of silicosis caused by the excessive inhalation of dust particles at mining operations. Many of the larger companies have also taken an active approach by providing expanded health care from company hospitals to local communities as well as employees, helping better manage global diseases such as tuberculosis and HIV.

Increasingly, global mine sites are operated by native workforces with a generation of management teams who have developed the skills through company-sponsored programs to take over operational management of a mine. This is particularly evident in many Latin American and African operations with a long history of mining, and corporates have realized the value of having management and operational teams with a high level of integration between the mine and local community. This can yield benefits not just for the mining operation but also for the local community, where there is a better understanding and appreciation of the benefits that a mine can bring. It also allows the community to hold the operators to a higher level of scrutiny than may have been the case in the past.

SAFETY FIRST

Mining is inherently a dangerous industry, placing large machinery, processes and people all in the same operational space. The juxtaposition of a person next to a fully-laden dump truck hauling rock out of an open pit shows just how small and fragile people really are in this environment. Yet in many annual surveys of the most dangerous industries to work in, mining doesn't even make the top ten.

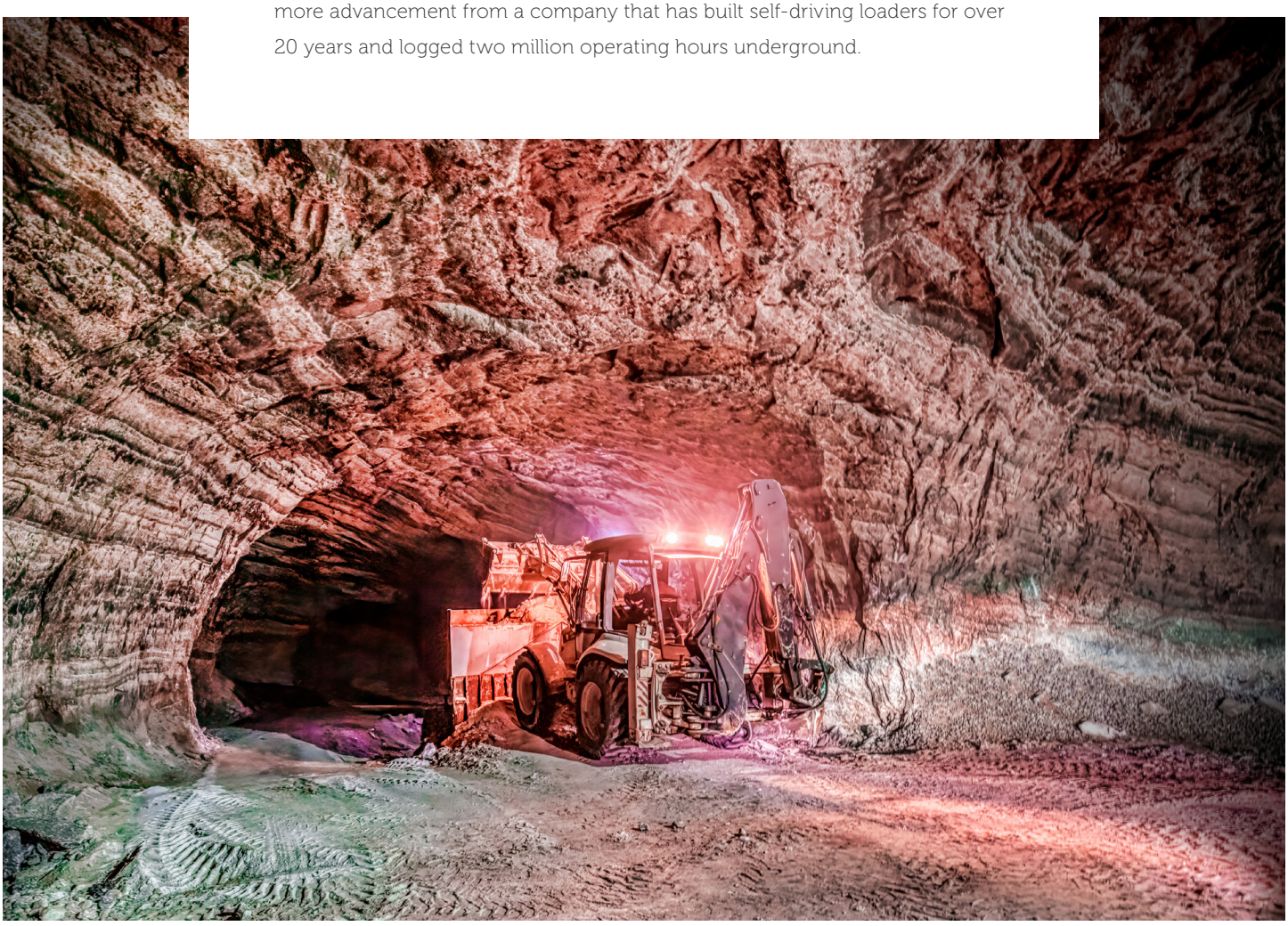
Most mining companies have been on a quest for zero harm for decades, and the strides they have taken to ensure that every employee goes home safely at the end of their shift has been significant. Improvements continue, fatality and injury rates at corporate and industry levels have declined annually due to constant visual and verbal reminders of safety procedures, top-down zero tolerance approaches to safety, and even small technological measures that require a seat belt to be connected before a vehicle can move. In 2019, BHP's then-CEO's annual bonus was reduced by 25% in part due to a single fatality in one of the company's coal mines,[13] showing how seriously the industry takes this.

The International Council for Metals and Mining (ICMM) notes that 2018, the last year complete statistics were available, showed the lowest Total Recordable Injury Frequency Rate (TRI) and Fatality Frequency Rate per million hours worked since 2012, the first year statistics for its 27 member companies were recorded.[14] In 2019, diversified miner Rio Tinto recorded its first year of zero fatalities at its operations,[15] a significant achievement for the company and the industry. To put this into context in a similar reporting period (November 2018–October 2019), Amazon recorded six fatalities at its sites globally.[16]

WORKING SMARTER

Technology is driving fundamental change industry-wide, as Artificial Intelligence and battery power aid the development of safer, cleaner and smarter machinery and mines. The use of autonomous equipment at all levels (exploration, haulage, drilling, blasting and processing) is increasing at an almost exponential rate. Safety, specifically removing the person from the danger zone, is increasing productivity and savings to the mining company.

This is not 'moon shot' technology. Swedish mining equipment manufacturer Sandvik has developed technology integrating physical hardware, in this case an 11-meter long, 38-ton mining loader equipped with physical sensors and Artificial Intelligence that can navigate a glass maze, in the dark, without breaking a pane of glass.[17] Testing is currently underway in underground mines and serves as another example of removing the person from potential harm—more advancement from a company that has built self-driving loaders for over 20 years and logged two million operating hours underground.



SECTION THREE: GOVERNANCE

From an investors' perspective, governance can be the hardest of the three ESG elements to define. What is good governance, and how do we analyze it? Corporate governance in the mining industry includes treating all minorities fairly, executive compensation aligned with all stakeholders including workers and local communities and strong policies and processes to combat corrupt practices. It also involves such areas as minimizing tax avoidance schemes and robust cyber security.

This is obviously not an exhaustive list but it does illustrate some of the factors that can be assessed and help determine whether a company has good corporate governance or not. Many investors may be surprised by the rise of cyber-crime targeting the extractive industry, but this has become a greater focus as the industry becomes more digitally connected and data reliant to run its operations. In March 2019, Norwegian aluminium processor Norsk Hydro was targeted with ransomware that caused significant disruption to its European operations.[18] The company was swift to react, bringing in Norwegian police and isolating the problem before it could cause more damage. Within 24 hours of the initial attack, the firm had switched to a manual system wherever possible, partially restored corrupted data from backups, and reported the incident to investors—drawing a positive response from members of the IT community. Ultimately an insurance policy helped offset the cost of the attack to a large degree, but the incident highlighted the importance of cyber security, particularly as technology increasingly permeates the industry.

CORRUPTION & THE "RESOURCE CURSE"

Mining is an industry that has to navigate many challenges encompassing geographic, geopolitical and economically diverse jurisdictions. Manufacturing companies can choose where to locate a factory; mining is constrained by where the orebody is located. This often means that companies have to strike a balance between investing significant capital in developing a new mine and host-nation risk. Developing a mine can sometimes lead to the onset of the "Resource Curse," which suggests that countries with vast, rich natural resource deposits are often those that grow most slowly and struggle with corruption and weak institutions. While many economists have explored these issues, the term itself was coined by British economist Richard Auty in 1993.[19]

The 2018 Fraser Industries annual report[20] highlights the risks many companies face when assessing the risk of investing in a country with its Investment Attractiveness Index or its Policy Perception Index, which rates national governments on the attractiveness of their mining policies. Countries that score poorly in both indexes are more often than not economies that boast rich natural resources and a large mining industry.

So how does a mining company balance the risk to its reputation and its balance sheet with the potential value creation through investing in a new mine in one of these countries? Maintaining the all-important "social license to operate" is a critical step in ensuring that host governments feel they are receiving a fair and equitably share of the reward from the extraction of the resources that lie within their boundaries.

LOCAL RELATIONSHIPS

Managing the relationship with local authorities also involves a direct approach when problems occur. Even when a dispute arises over an operating license, fair and open dialogue or the use of international arbitration can lead to a resolution that is equitable to both sides. However, corruption is one area the industry has had to face around the globe—in some cases at all levels of government. It can take a drastic turn, with dire consequences on the fabric of society. Recent scandals in Brazil resulted in a presidential impeachment and the election of a president out of the system. As an industry, there is a vigorous pushback on corruption with increasing levels of transparency on corporate policies, as well as a zero-tolerance policy where there is concern that some form of infringement may have taken place.

However, this is a very complex issue the industry must tackle daily and can, at times, put the extractive company in a difficult position. Cement company LafargeHolcim was accused by the U.S. Department of Justice and the French judicial system of financing terrorism in Syria in 2013–14.[21] A closer examination revealed the difficult decisions the company faced in the country at that time. As the only meaningful employer in the region when it was overrun by ISIS, the company was faced with a decision: pay the rebels to protect its operation, ensuring that it could continue supporting its employees so they could buy food and medicine, or shut the plant down, creating a potential humanitarian crisis. It was undoubtedly a difficult decision but illustrates the complexity of operating in an ever-changing world. Even more difficult, since these assets have especially long lives, companies must navigate the changing political and economic landscape over extended timeframes, which can bring with it fresh challenges for management teams to face.

CONCLUSION

There is an irony in the transformation taking place in the mining industry. Technology provides the tools to create a sustainable future, including the extraction of resources and energy transition. And yet, the very technology we need to fight climate change and lead us towards a "net zero" emissions future will not be possible to develop without the copper, aluminium, nickel and other minerals that the mining industry produces.

To satisfy this demand, the mining industry is quietly revolutionizing many of the practices it has used for decades. In 1556, Georgius Agricola wrote De Re Metallica (On the Nature of Metals),[22] considered by many to be the bible of the mining industry and subsequently translated in 1912 by Herbert Hoover and others. Agricola's work included a collection of mining and processing descriptions, as well as a rudimentary assessment of geology. Fundamentally, the process of discovery, development, production and eventually closure of a mine as described in this seminal work on the industry hasn't really changed. And yet, as the industry undergoes an even more profound transformation to become more sustainable and more transparent, it may be on the cusp of change that will make parts of it unrecognizable to the readers of this seminal text.

As this quiet revolution in mining gathers pace, investors are well served to watch closely, identify the early leaders and assess where returns will emerge that are better and more sustainable than peer companies. Elements of this ancient industry are set to become leaders in technological, operational and social change that will set standards mining firms—and all firms—follow for years to come.

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I'd like to thank my colleagues Dr. Christopher Smart and Dr. Agnès Belaisch of the Barings Investment Institute for their guidance throughout the process of bringing this paper to completion. In addition, Amadea Bentheim, Matthew Ward, Colin Moar and Natalia Krol for reviewing the completed manuscript, providing detailed and insightful feedback. A special thanks also to Michael Henry for his patient editing of the manuscript.

ENDNOTES

1. "FutureSmart," Anglo American, accessed June 4, 2020, https://www.angloamerican.com/futuresmart.
2. Kirsten Hund et al, "Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition," World Bank Group (May 2020): 7, http://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf.
3. Tony O'Neill, "2018 BAML Global Metals, Mining & Steel Conference," May 15, 2018, https://www.angloamerican.com/~/media/Files/A/Anglo-American-Group/PLC/media/presentations/2018pres/baml-2018-tony-oneill-slides.pdf.
4. Boliden, April 17, 2020, "Boliden signs agreement for fossil-free electricity supplies," https://www.boliden.com/media/press-releases/?pressReleaseId=1800584.
5. Antofagasta, April 1, 2020, "Centinela signs renewable power contract," https://www.antofagasta.co.uk/investors/news/2020/centinela-signs-renewable-power-contract/.
6. Greenhouse Gas Protocol, accessed June 4, 2020, www.ghgprotocol.org.
7. BHP Group, July 23, 2019, "BHP to invest USD400m to address climate change," https://www.bhp.com/media-and-insights/news-releases/2019/07/bhp-to-invest-us400m-to-address-climate-change/.
8. Rio Tinto, February 26, 2020, "Rio Tinto to invest $1 billion to help meet new climate change targets," https://www.riotinto.com/news/releases/2020/Rio-Tinto-to-invest-1-billion-to-help-meet-new-climate-change-targets.
9. Rio Tinto, February 16, 2020, "Rio Tinto to build first solar plant in Western Australia to power iron ore mine," https://www.riotinto.com/news/releases/2020/Rio-Tinto-to-build-first-solar-plant-in-Western-Australia-to-power-iron-ore-mine.
10. Anglo American, October 10, 2019, "Anglo American partners ENGIE to develop world's largest hydrogen powered mine truck," https://www.angloamerican.com/media/press-releases/2019/10-10-2019.
11. SSAB, November 14, 2019, "SSAB to be first to market with fossil-free steel," https://www.ssab.us/news/2019/11/ssab-to-be-first-to-market-with-fossilfree-steel.
12. J-S Jacques et al, Rio Tinto Climate and Water Seminar 2020, April 21, 2020, https://www.riotinto.com/en/invest/presentations/2020/climate-water-seminar-2020.
13. BHP, 2019 Annual Report, Executive Remuneration, page 140, https://www.bhp.com/-/media/documents/investors/annual-reports/2019/bhpannualreport2019.pdf?la=en.
14. ICMM, accessed June 4, 2020, www.icmm.com.
15. Rio Tinto, 2019 Annual Report, page 12, https://www.riotinto.com/invest/reports/annual-report.
16. Natalie Coleman, "After Deaths, Amazon Lands on List of Most Dangerous Employers," Futurism, October 18, 2019, https://futurism.com/deaths-amazon-list-most-dangerous-employers.
17. Sandvik, September 18, 2018, "Twenty years of self-driving without a single accident involving people," https://www.home.sandvik/en/news-and-media/newslist/news/2018/09/twenty-years-of-self-driving-without-a-single-accident-involving-people/.
18. Norsk Hydro, March 19, 2019, "Hydro subject to cyber attack," https://www.hydro.com/en-US/media/news/2019/hydro-subject-to-cyber-attack/.
19. Richard Auty, Sustaining Development in Mineral Economies: The Resource Curse Thesis (London: Routledge, 1993).
20. Ashley Stedman, Kenneth P. Green, "Annual Survey of Mining Companies, 2018" Frasier Institute, February 28, 2019, https://www.fraserinstitute.org/studies/annual-survey-of-mining-companies-2018.
21. David Keohane, Ralph Atkins, "LafargeHolcim's French arms faces inquiry over Syria claims," Finanical Times, June 28, 2018, https://www.ft.com/content/79d6e5da-7acb-11e8-8e67-1e1a0846c475.
22. Georgius Agricola, De Re Metallica (On the Nature of Metals), trans. Herbert Clark Hoover and Lou Henry Hoover, (New York: Dover Publications, 1950), https://store.doverpublications.com/0486600068.html.

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