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Emerging Risks Report 2018

Technology

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Risk considerations for a new era of mining

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About Lloyd’s

Lloyd's is the world's specialist insurance and reinsurance market. Under our globally trusted name, we act as the market's custodian. Backed by diverse global capital and excellent financial ratings, Lloyd's works with a global network to grow the insured world –building resilience of local communities and strengthening global economic growth.

With expertise earned over centuries, Lloyd's is the foundation of the insurance industry and the future of it. Led by expert underwriters and brokers who cover more than 200 territories, the Lloyd’s market develops the essential, complex and critical insurance needed to underwrite human progress.

About Satarla

Satarla is a team of risk experts who deliver risk management training, consultancy and research. We have hands-on experience in designing and implementing integrated risk management across a wide range of industries and geographies, including mining. Our approach enables organisations to make and own risk based decisions at all levels based on practical proactive risk management techniques. Our Associates are actively engaged in a number of research projects including improving uncertainty modelling techniques based on increasingly accessible technology; to the exploring of how risk management techniques can be used to better understand and communicate emotive risks associated with climate change and human rights. We have strong links with universities, thought-leader institutes and clients in both the public and private sectors. Satarla can therefore support all four aspects of: research – development – implementation – embedding, ensuring that our techniques have a lasting impact.

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Executive summary

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Executive summary

Events such as the Paris Intergovernmental Panel on Climate Change (IPCC) convention on climate change demonstrate strong political will that the global economy must become more sustainable with a greater focus on recognising externalities.

To achieve this, great reliance will be placed on technologies that incorporate breakthroughs in material science that require increasingly rare earth minerals and metals. Such materials must typically be obtained through mining, often in challenging environments.

Mining, one of the world's oldest industries, is going through a period of rapid change. The upswing in commodity prices coupled with increased demand for novel materials such as lithium, cobalt and rare earth elements has revitalised the sector. Mining projects all over the world are raising funds so that they, too, can be a part of the materials supply chain.

The unique context of each mining operation dictates the exact type and nature of insurance required. The London mining insurance market has been estimated to be between £800m and £1bn per annum in gross written premium, supporting the trillion-dollar mining industry.

This report explores the risks and drivers of current mining trends, and assesses the role insurance can play in the managing of mining risks in the interests of supporting human progress towards sustainability.

Mining and insurance

The history of mining is marred by large-scale disasters from the Benxihu Colliery explosion in 1942 in China that killed 1,549 workers, to Samarco's 2015 Fundao tailings dam failure in Brazil, the civil suit of which is estimated to carry a cost of $41bn. There are also examples of disasters that have been well managed and the potential impacts contained, such as the Kennecott slope failure in the US in 2013.

While larger mining companies use captives for their insurance needs, others buy cover through the regular insurance market. Very few mining projects can achieve full commissioning without insurance. Financiers often require it as a precondition to releasing the funds needed to build the mine. Unfortunately, insurance is sometimes seen as a box-ticking exercise by mining companies rather than as a way they can manage many of their risks. As a result, insurers often get involved in mining projects after the design for the site has been approved, missing the opportunity to optimise site design and lower its negative risk profile.

It is important that insurers view a mine and its risks in its full context, and assess the financial, technological, social, political and environmental drivers of risk in their entirety. While not all risks can be easily insured, they should each be taken into account as they may exacerbate those risks that can be insured.

Important mining risks and trends

There are a number of key trends that are changing the mining sector and the risks it faces. Most important are:

- The shift to a low carbon economy is moving the sector away from thermal coal and other hydrocarbons into materials required for renewable technology such as lithium, cobalt and rare earth elements.
- Increasing demand for novel metals and minerals, many of which lie in undetermined locations, will require unknown extraction and processing methods.
- The exploration of, and mining in, new resource frontiers such as ultra-deep mining (more than 2.5km underground), deep-sea mining and asteroid mining.
- The digitalisation of mines means in the future they could be operated remotely, eliminating risks to humans by removing direct contact with mining's most significant hazards.
- Cyclical commodity prices: Commodities extracted by mining companies tend to over-perform in boom years and under-perform during economic downturns.
- Resource nationalism and relationships between governments, mining companies and workers means that those seen to benefit from a mines operation will be more closely examined to ensure farier distribution of wealth in resource rich countries.
- The social licence to operate is increasingly difficult to build but very easy to lose meaning that mines can struggle to maintain this vital approval.
- The long-term environmental impacts of mining and challenges faced in sustainably closing a mine, means that the end of life mine decommisioning can generate unknown challenges and costs.
- Circular economy and the role of mining within it places new demands on the sector.

Making the most of new opportunities

These trends are creating a number of opportunities for insurers to write new business or expand existing books. To realise these opportunities the following actions could be considered:

1. Include an underwriter relevant risk index in the Terms of Cover which would cover potential environmental impacts, sustainability, maintence levels and other factors pertinent to safety. This will allow companies with consistent global rules, who go well beyond the legal minimum, to demonstrate their superior risk management methods. This would give insurers the enhanced opportunty to include aspects of sustainability and risk management in the calculation of insurance premiums and reward those that manage such risks well.

2. Take an Enterprise Risk Management approach, to assess the full context of a mining operation rather than just the insurable risks. Risks such as losing the social licence to operate, which are less easy to insure, often delay mining projects.

3. Get involved in mining projects earlier to have a greater influence on the design of mines and the operational risks that may be insured in the future.

4. Learn from and build relationships with mining companies to promote greater understanding between insurers and miners, and to identify what both parties want to achieve through the structuring, placement and purchasing of insurance. Both parties currently make assumptions as to how one another operates, some of which are incorrect. This could be addressed through better communication between insurers and mining companies.

5. Help to facilitate safer mine closures and reduce the associated risks by introducing reclamation[a] bonds in jurisdictions where they are currently not the norm.

6. Underwriters could see a significant increase in 'prototypical' technologies being used by companies seeking insurance. Insurers should support such new technology through insurance products thereby allowing mining companies to not only mine the necessary materials but to do it in the most responsible manner possible. To enable this, it will be essential for insurers to understand the design and testing of the new technologies that has been carried out. This will require collaboration and transparency from customers. Greater co-insurance and higher deductibles may also be employed to facilitate risk sharing in this phase of development.

7. Tap into the opportunity for new insurance products that is being driven by companies mining different types of materials in different locations around the world.

[a] A reclamation bond provides a financial guarantee that the land being disturbed for the operation of the mine, or related activity, will be returned back to either its approximate original state or an acceptable condition as agreed between the operator and local community, government or other stakeholders.

8. Take advantage of the increased recognition of the need for cyber insurance as a result of the digitalisation of mining to offer an enhanced and future ready insurance offering to customers.

9. Deploy remote, timely, transparent monitoring of mine sites using technology, such as the internet of things and cutting-edge satellite imagery. This helps insurers proactively monitor risks on site, and provides a better understanding of the retrospective causal factors leading to a loss event. Ultimately this helps insurers to pay claims faster which is better for the customer.

10. Use the increasingly transparent value chain. Blockchain technology, coupled with increased regulation regarding the transparency of commodity supply chains, offers insurers the potential to provide enhanced insurance as products pass along the value chain.

Conclusion

The insurance sector could facilitate collaboration between all mining stakeholders to influence outcomes early on in the planning and design phases. This would help insurers design structured and appropriate insurance products that serve the needs of their customers in the context of the mining sector trends discussed earlier.

The innovation that is currently taking place across the raw materials supply chain may result in mining companies adopting new technologies.

Underwriters may therefore see a significant increase in 'prototypical' technologies used by companies buying insurance. New technologies and associated insurance products should be adopted to allow the mining sector to extract and process metals and minerals in the most responsible and least invasive manner possible.

Insurers could use new technologies to allow them to remotely and transparently monitor mines in real time, reducing the time it takes to pay claims. Insurers could benefit from entering new mining insurance markets and writing policies for new commodities that will be increasingly in demand as society moves towards a low carbon economy.

Methodology and research approach

This report was developed through a desktop review and industry consultations. The desktop review identified:

- The mining value chain and how it differs between commodities and geographies.
- The structure of mining insurance in the context of large and small mining companies.
- The drivers behind changes that mining may face in coming years, together with key risk themes.
- Potential opportunities for insurers in the mining insurance market.

Satarla Associates held a number of interviews with mining industry experts from across the value chain encompassing exploration, chemical processing, and financial, sustainability and risk professionals who offered an in-depth understanding of and associated insights on emerging trends within their field. Satarla attended and took part in a number of mining industry conferences and events.

In parallel, Lloyd's organised a series of interviews between Satarla and Lloyd's underwriters to identify how mining risks are changing and are being underwritten. This identified the challenges the mining sector is facing and how they can be overcome in the future.

Lloyd's organised a roundtable involving mining sector experts and Lloyd's insurers to validate the report's findings and gather feedback on insurers' opportunities in the mining sector.

The mining sector

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The mining sector

As of 2017, the top 50 mining companies had a collective value of US$842bn (Els, 2017). One of the oldest industrial sectors, mining activities include the finding, extraction and processing of rocks that house everything from iron ore and coal to copper, nickel, platinum, lithium, rare earth elements and diamonds.[b]

The need for products produced by the mining sector is driven by the requirement for everything from steel and concrete, to smartphones, transportation, and salt for our food. Demand is therefore increasing as the global population continues to grow. The value of each metal and mineral fluctuates in line with economic demand resulting in a cyclical commodities market. Having weathered a prolonged downturn since 2011, the market is now improving, driving increased activity in the sector.

The mix of metals and minerals society requires also changes with shifts in social norms. For example, the move to renewable forms of power generation has reduced global projections for use of thermal coal and increased the requirement for rare earth elements, which form a number of critical components within technology such as wind turbines.

Inherently unsustainable, the extraction of non-renewable resources from the Earth's crust has the potential to dramatically impact on the people and landscapes from where they are mined. Responsible and sustainable techniques can and should be used to ensure that resource-rich countries are able to realise the benefits of their natural commodities in the least damaging way.

Figure 1: Los Bronces Copper and Molybdenum mine 3,500m above sea level in the Andean Mountains, Chile

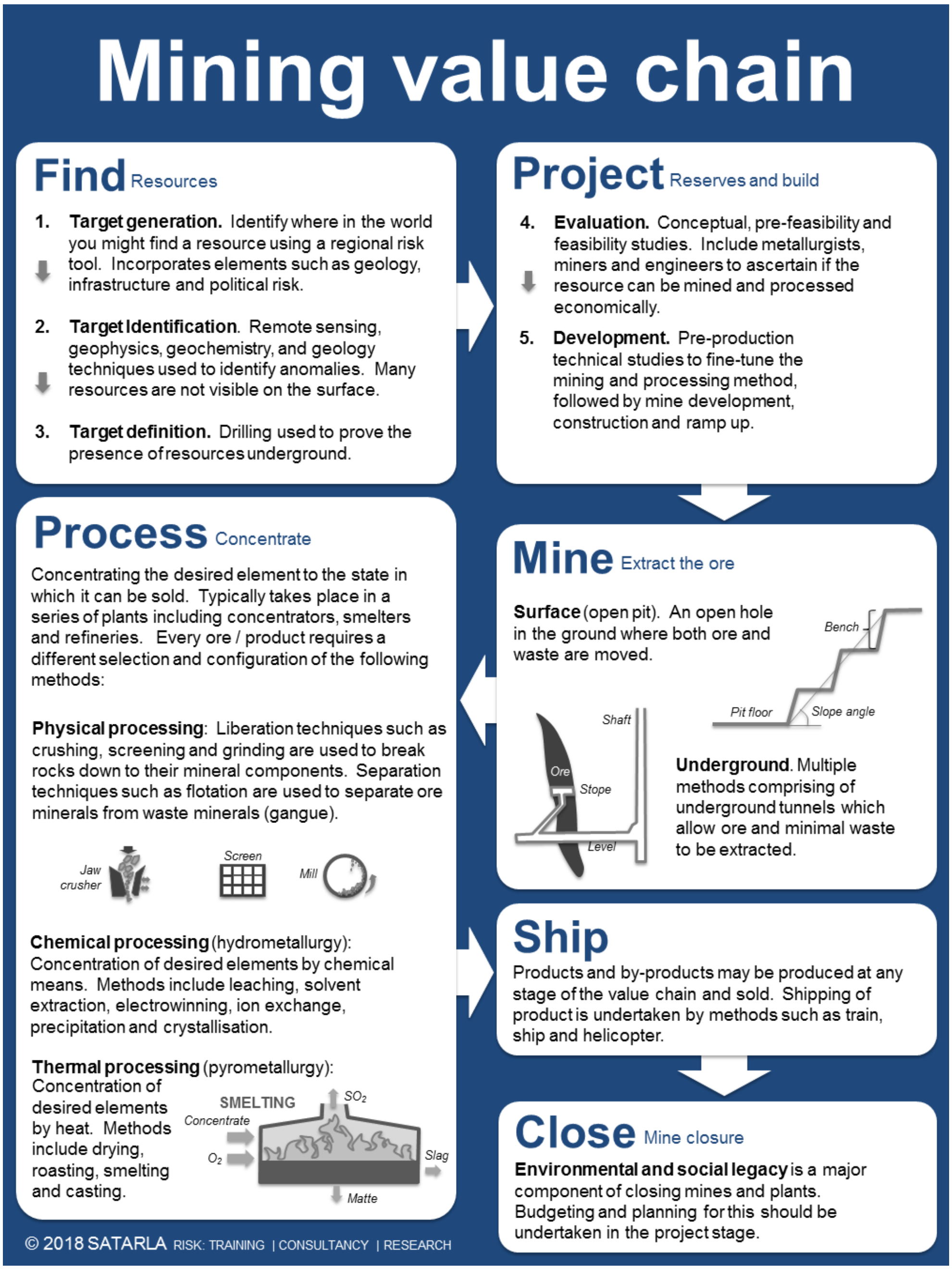
Source: Lloyd’s, Satarla, 2018

[1] The aggregate industry was not included in the scope of this paper and is not discussed elsewhere in the text.

The mining value chain

The mining value chain includes everything from exploring for new deposits of minerals and metals, to the mining, processing and shipping of products. All mining projects should culminate in the full closure of the facility. Every commodity follows a slightly different series of processing steps. For example, iron ore can often be loaded directly onto a ship, whereas platinum needs to pass through a series of refineries before it can be shipped in its required form. Figure 2 illustrates the different steps in the mining value chain. Insurance should be involved in as much of this value chain as possible; however, it is typically only introduced in the late project construction stage.

Figure 2: Overview of the mining value chain



Source: Lloyd’s, Satarla, 2018

Mining insurance

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Mining insurance

The current London mining insurance market has been estimated to be worth between £800m and £1bn per annum in gross written premium. The scale of the financial losses that may emanate from a single event within the mining sector underpins the importance of insurance as a risk management tool. Very few mining projects would start without insurance being involved in some way.

Different insurance structures and products are available to companies to protect them against the financial losses associated with the risks they encounter at the different stages of the mining value chain.

Typical structures for mining insurance

Mining companies have a variety of options in terms of how they structure their insurance. Typically, the larger miners such as Rio Tinto, BHP Billiton and Anglo American set up captive insurance companies to effectively manage and mitigate insurable risks. These captives commonly cover events such as business interruption and property damage.

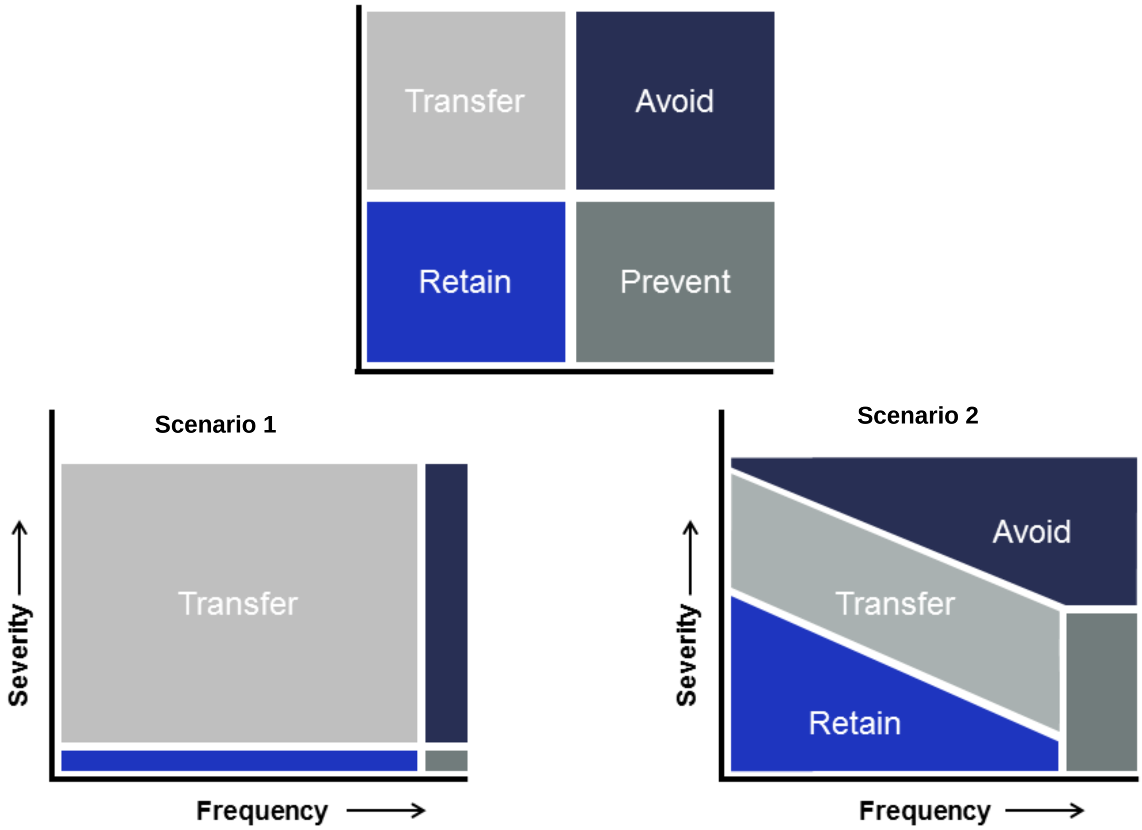
A captive allows a company to pool risks and cover events which are too complex or expensive to insure in conventional insurance markets. Captives also facilitate access to the reinsurance market. If no losses occur, the captive can reinvest premiums into the parent company and realise significant cost savings. These mining companies often seek additional insurance from conventional insurance markets to cover losses above a predefined limit that would be too expensive to cover within a captive, such as catastrophic losses resulting from severe weather events or a tailings dam failure.

Smaller mining companies seek insurance coverage through the regular insurance market. If a mining company does not have a pre-existing relationship with an insurance provider, the company may approach an insurance broker who will attempt to generate interest within the market and find an insurer willing to write the risk. The mining company may select a range of policies depending on the risks their operation faces, and the confidence of investors, governments and themselves in the company's own ability to proactively manage their risks.

Risk transfer

Insurance is a vital mechanism of risk transfer, allowing mining companies to make the most efficient use of their capital while also fulfilling lenders' requirements to manage their risks appropriately. Figure 3 *(below)* portrays the four categories within which risk can be dealt with. Mining companies and their advisors will look to engineer and design out the avoidable and preventable risks; consideration then needs to be given to the retained and transferred portions. Figure 3 represents two different scenarios for risk transfer and retention. Scenario 1 represents a mining company that attempts to manage the majority of its identified risks through insurance whereas Scenario 2 demonstrates a proportion of risk being retained in-house with only the appropriate risks being transferred to the insurance market. Scenario 2 is the profile generally adopted by those companies who have the ability and sophistication to deeply understand their risks, and can quantify and manage those risks effectively as opposed to falling back on insurance. It demonstrates to an insurer that a company has a mature and comprehensive risk management strategy, and is therefore more likely to be lower risk.

Figure 3: Different scenarios of risk transfer and retention



Source: Lloyd's, Satarla, adapted from Richard Lloyd, 2018

The stakeholders involved in determining the most efficient insurance structure and level of risk transfer will include:

- The company’s executive committee and the board of directors, with whom the ultimate decision rests as to the different categories of insurance purchased. These stakeholders often have a fiduciary obligation to the company’s shareholders
- Financiers
- Major contractors
- Key advisors
- Underwriters
- Insurance brokers

For smaller mining companies that don’t have the in-house capacity to research and manage insurance, the insurance process can ultimately be “broker driven” and commonly occurs at a relatively late stage in the project development process. Without careful management, this can lead inadvertently to a Scenario 1 type structure, where risks are not being proactively managed by the mining company for the long-term, and the risk profile of the operation has a greater potential to increase.

Due to the recent period of suppressed commodity prices, many of the mining companies that have survived have become accustomed to operating in a much “leaner” fashion. This means some now operate with a much shorter-term mind-set and a Scenario 1 profile.

Much like the mining industry, the insurance sector is a cyclical industry. It transitions between a hard (insurance is difficult to obtain) and soft (insurance is easy to obtain) market. Mining companies are currently benefiting from the soft insurance market relative to other sectors. However, a catastrophic risk event may cause the market to harden and premiums could increase. Companies may look to retain further risk within their captives but a clear understanding of what they are taking on and the consequences of doing is vital. Stakeholders involved in risk mitigation must be an integral part of the decision-making process to help transfer risk through efficiently designed insurance programmes. Greater interaction between the underwriting community, financiers and future operators of the mines in question is recommended.

Large-scale mining events

Mining disasters can and have been triggered by everything from natural hazards, to managerial negligence, faulty equipment, and design or structural failure. Losses resulting from recent large-scale mining disasters have cost companies hundreds of millions of pounds in fines, clean-up costs and lost profits. Events such as these can also have deleterious effects on a company’s reputation which often translates into a slump in share price, further impacting financial performance. The exact magnitude of the cost on insurers is often confidential; however, a database is being compiled by the Mining Insurance Group (MIG)

Figure 4: A timeline of disasters in the mining industry

1917

Granite mountain copper mine fire, Montana, USA
An accidental ignition of an electric cable 2,500 meters below surface ignited the mine's wooden shaft. The shaft became a chimney which eliminated the mine's primary source of oxygen. Nearly all of the 168 fatalities were due to asphyxia.

1927 – 1932

Hawks nest tunnel disaster, West Virginia, USA
A tunnel was constructed through rock with a high silica content and workers were exposed to silica dust. It is estimated that at least 764 workers died from silicosis.

1942

Benxihu colliery (coal and iron ore mine), Benxi, Liaoning, China
Coal dust explosion where 1,549 workers died, in the worst coal mine accident ever in the world. Later research revealed that most miners died from carbon monoxide poisoning.

1959

Port Griffith Luzerne County, Pennsylvania, USA
Miners dug too close to the underbelly of the Susquehanna River causing a cave-in that flooded the mines. 12 miners died. Cost of recovery ~$5m. Knox declared bankruptcy.

1966

Aberfan disaster, national coal board colliery, South Wales, UK
A waste tip slid down a mountainside into the village of Aberfan, 116 children and 28 adults were killed. Caused by a combination of contravening procedures and heavy rains.

1985

Val di stava tailings dam collapse, prestavel mine, village of Stava, near Tesero, Italy
The upper dam broke first, leading to the collapse of the lower dam. Around 180,000 cubic meters of mud, sand, and water were released into the Rio di Stava valley. An investigation into the disaster found that the dams were poorly maintained and the margin of safe operation was limited. 268 people were killed, 63 buildings destroyed and 8 bridges demolished.

1993 – 1995

Namibia gold mining district disaster, Namibia, Ecuador
A part of the mountain above the countless mines gave way and about 300 people were buried in a landslide. Torrential rains exacerbated the disaster.

Vaal reefs, gold mine, Orkney, South Africa 1995
A runaway locomotive broke through safety barriers and fell down a lift shaft, landing on a cage causing the cage to plummet 1500 feet to the bottom of the shaft, 6900 feet underground. Resulting in the deaths of 104 people.

2011 – 2012

Cyclone Yasi, a category five storm ravaged Queensland's north coastline.
The CAT 5 storm devastated the state, shutting mines, and destroying crops. The storm caused an estimated US$3.6bn damage. Miners declared force majeure on coal contracts. Worldwide supply was disrupted raising prices globally.

Marikana, South Africa 2012
47 people killed during strike of platinum mine workers.

2013 – 2014

Bingham canyon mine slope failure, Utah, USA
145m tonnes of material flowed to the base of the mine pit when the slope collapsed. Largest in-pit slope failure in history. Potential for failure was identified months earlier due to slope monitoring and the mine was evacuated. Nobody was injured.

Soma, Turkey 2014
Coal mine explosion killed 301 people. Protests against mining conditions in 2013 were rejected by Turkish government weeks before explosion.

2015 – 2017

Samarco iron ore mine tailings dam collapse, Minas Gerais, Brazil
19 lives were lost when 60 million m^3 of iron ore waste was released from the dam and covered the town below. Total cost to owners estimated to be $41Bn.

Silicosis in S. Africa 2017
High court ruled that former and current mine workers employed in gold mining since 1965 allowed to proceed with class action against companies. E.g. One South African operator set aside $101m.

Source: Lloyd's, Satarla, 2018

Box 1: Tailings dam failure, Brazil.

On the 5 November 2015, a tailings dam was breached because of drainage and design flaws (Nogueira, 2017). Sixty million cubic meters of iron-rich by-products from the iron mining operation flowed down the valley, burying the town of Bento Rodrigues. The slurry, toxic to much of the environment it encountered, then entered the Doce River where it followed the 650km river course to the Atlantic coast (Garcia, 2017). Nineteen people were killed during the course of this event. The tailings dam failure is now referred to by many as the worst environmental disaster in Brazil's mining history.

The mines' operating and environmental licences were immediately suspended, and the companies involved suffered a drop of up to 9% in their share prices.

Brazilian prosecutors charged 21 individuals with qualified homicide for their roles in the collapse of the tailings dam. Many of the companies involved were charged with environmental crimes.

The federal and state governments have since reached a deal with the mining company involved to carry out restoration and repair work totalling more than US$1bn. Fines levied separately by the state amounting to US$6.7bn have been settled; however, as of early 2018, the 24 environment agencies' fines, which total US$105m had yet to be paid (Phillips, 2018). A civil action suit was lodged by federal prosecutors seeking US$41bn in damages. In June 2018 a two-year extension was granted to facilitate negotiations of the civil suit under an agreement reached between the company and federal prosecutors (Nogueira and Eisenhammer, 2018).

This disastrous failure prompted mining companies to undertake safety and maintenance checks on all of their tailings dam facilities, and review their procedural and operational management strategies. Companies approached this in different ways, including rotating their tailings dam engineers to different facilities to carry out peer reviews.

The tailings dam failure highlights the importance of proactive risk management in mining operations. In 2018, prosecutors submitted previously unreported documents from the mining company which showed that the company carried out a worst-case assessment of the dam nearly six months prior to its collapse, which stated a "liquefaction collapse" could cause up to 20 deaths and seriously impact the land, water resources and biodiversity for more than 20 years at a cost of US$3.4bn (Phillips, 2018). A class action suit was launched by shareholders alleging the company engaged in misleading or deceptive conduct by breaching it's obligation to make continuous disclosures to shareholders. In August 2018, the company agreed to settle the class action suit for $50m with no admission of liability (Godsen, 2018).

Tailings dam failures of this scale have the potential to exceed the indemnity period of a property damage or business interruption policy. This means insurers may be liable to compensate insured clients for between 12-24 months, depending on their deductible limits. This further demonstrates the importance of implementing appropriate risk management strategies that help reduce the risk of catastrophic events.

Understanding mining risk from an insurer's perspective

An open relationship between the insurer and the mining client encourages dialogue and allows the insurers to understand the technicalities of the risks faced by the miner, and the miners to understand inherent operational and design risk from the insurer's perspective. The risks faced by an operation are often unique to the setting and context of that particular operation. For example, an item of equipment that works well at sea level and is regarded as well-proven technology, and is therefore easily insured, may not work as well when installed at 4,000m above sea level in a new mine. This change in context for that item of machinery alters the risk profile and therefore the insurance that can be provided.

Many risks highlighted by insurers can be eliminated or reduced in severity during the design stage of a mining operation. It is therefore advisable for mining companies and underwriters to engage with one another as early as possible in the design of a mine to identify, discuss and plan for the management of key risks. It is important for both insurers and miners to understand how one another's objectives are being met through insurance. The more open the relationship between the two parties, the more refined the insurance and the more robust the mining operation will be.

Drivers of mining risk

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Drivers of mining risks

Risks faced by the mining sector are driven by economic changes (*is there any demand for what we are mining and can we raise the funds necessary to build the required large-scale infrastructure?*); technological advancements (*do we have the techniques and the equipment through which to extract the elements we find valuable?*); changes in social requirements (*do we have the relationships necessary with governments and local communities to allow us to mine?*); and long-term changes in our environment (*mining seen as stewards of our environment rather than destroyers*). Each of these drivers give rise to a number of risks, some of which have only recently begun to emerge, and many of which can be attributed to multiple drivers *(see Figure 5 below)*. While only some of these risks are directly insurable, all are relevant to understanding the risk profile of the mining sector.

Figure 5: A selection of the dominant drivers and risks within the mining sector as of 2018

Source: Lloyd's, Satarla, 2018

Economic drivers

Cyclicity in the price of commodities

The value of a mining company is more greatly impacted by the cyclicity in commodity prices than other capital-intensive industries such as oil and gas; it tends to over-perform in boom years and underperform in periods of lower prices (McKinsey, 2015). The high degree of volatility in the valuation of mining companies exacerbates the severity of risks which have been insured on site operations. A mining company's ability to implement preventative controls and mitigation measures will vary depending on where the industry is in the commodity cycle.

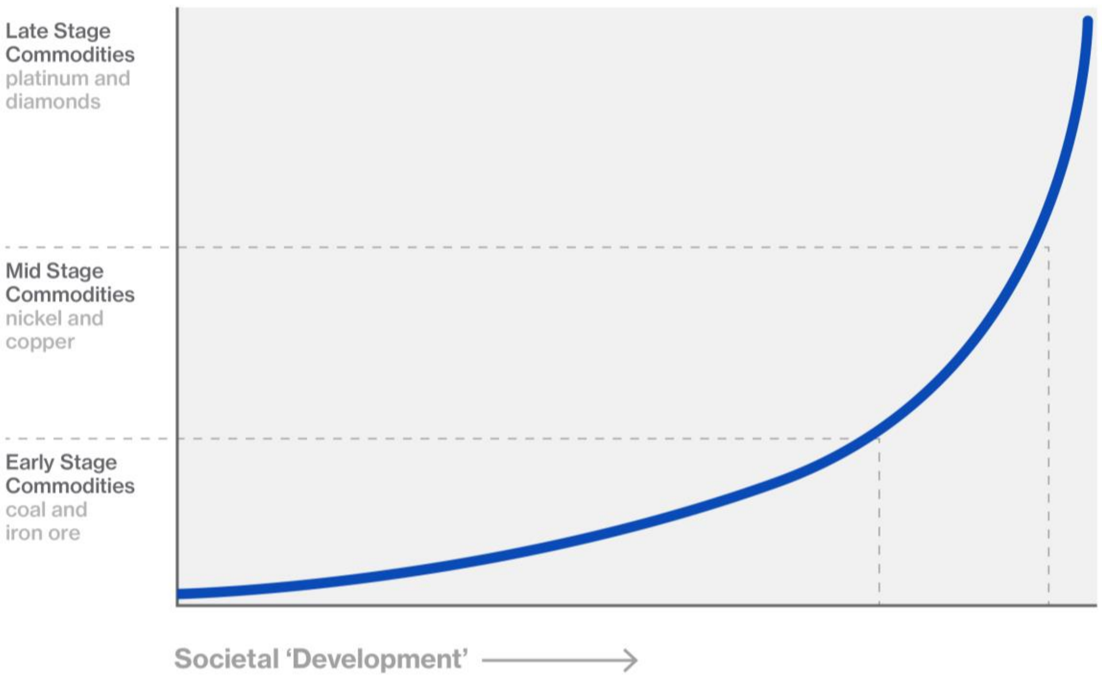
The periodicity of the commodities market is more rapid than that of the mining process. On average it takes 10 years from the discovery of a resource to the point when it is mined. Mining projects are invariably paused when their commodity price falls below the economically viable threshold for extraction and processing. The development of new mining technology is also interrupted during periods of suppressed commodity prices, extending the time required to progress that technology from prototype to tried-and-tested.

The types of commodities demanded by the market are also changing *(see Figure 6)*. Emerging technologies such as those used in electric vehicles (EVs) require materials such as cobalt, lithium and rare earth elements (REE).

While there may be enough lithium present in the earth's crust to service the demand posed by the anticipated requirement of EVs, the technological ability to extract and process enough of it into a useable form does not yet exist (Geological Society of London, 2018). Substitution of one material for another can help to reduce the volatility in the price of commodities. For example, aluminium has for many years been increasingly used instead of steel in car manufacturing because of its lightweight properties (Price Waterhouse Cooper, 2017). In 2018, researchers at Northwestern University successfully created a lithium-ion battery that uses iron instead of cobalt, which would drastically reduce the demand for cobalt (Els, 2018).

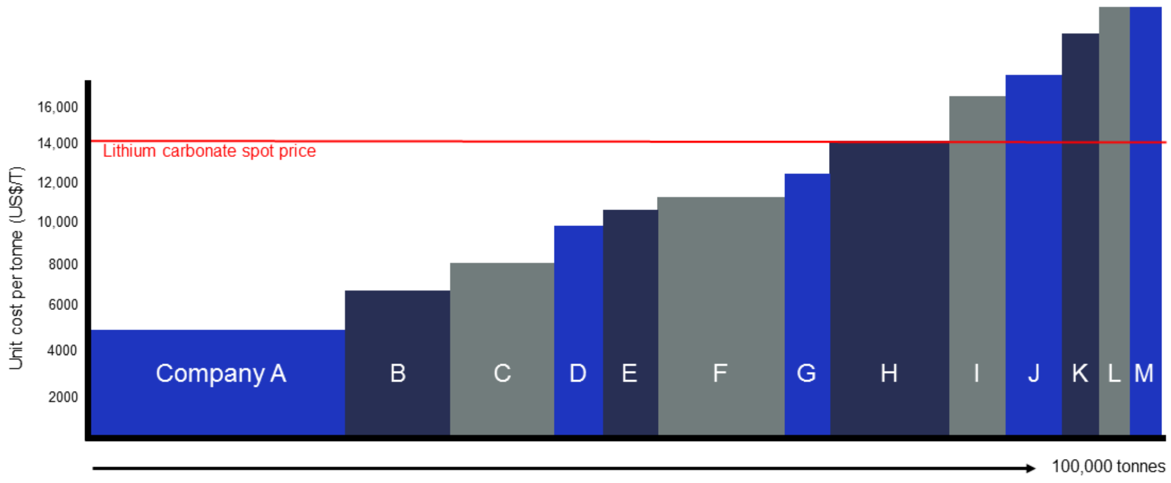
Miners attempt to offset the risk posed by fluctuating commodity markets by diversifying their portfolio of mined commodities; focusing on the extraction of materials for which they perceive there to be a large and stable market (e.g. iron ore, copper); and developing mines they anticipate will be in the lower half of the price per tonne cost curve *(see Figure 7 on page 19)*. Mining companies should focus on those aspects of their operations which are within their control by ensuring, for example, that the mine is in the lower part of the cost curve.

Figure 6: Different commodities are desired at different stages of development



Source: Lloyd's, Satarla, 2018

Figure 7: Lithium cost curve with example lithum carbonate spot price



Source: Geological Society of London, Satarla, 2018.

The impact of fluctuations in commodities prices remains a large commercial risk for mining companies as it can result in a mine becoming financially unviable. Insurers are encouraged to incorporate this macro-economic analysis into their portfolio strategy and be prepared to face the effects of commodity volatility on active mining claims. For example, it is possible that during a tough commodity price environment insureds could make claims negotiations more difficult as they are more intent on recovering the most from the policy and may also be slower at releasing information as critical staff may no longer be employed by the business.

As a supplier of services to the mining industry, insurers need to be aware of business strategies that miners are exploring in order to better support their clients. An example of this is the digitalisation of mining operations *(see Technological advancements section).*

Shift towards a low carbon economy

Electric vehicles (EV's), solar photovoltaics (PVs), wind turbines and energy storage batteries require a wide array of minerals and metals including: cobalt, tantalum, lithium, indium, neodynium, copper and nickel. Many of these materials are currently only mined in small quantities, which represents a substantial business opportunity for the mining sector as demand for these materials could increase imminently as society shifts to a low carbon economy. The mining industry could become a dominant player in the energy sector should it choose to move downstream into the more complex processing of these materials.

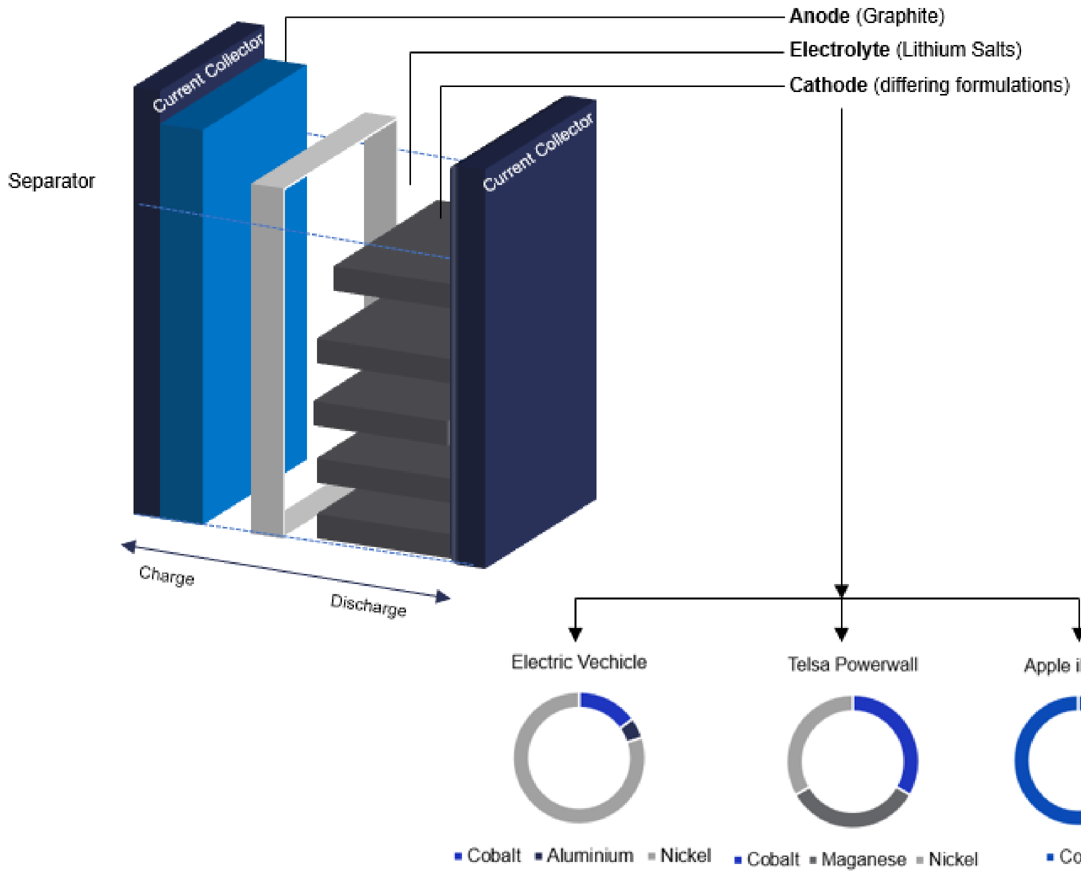
Renewable energy accounted for more than 29% of the UK's electricity generation in 2017 while thermal coal's share of the electricity mix fell by 7%. The UK carbon intensity (emission per dollar of GDP) reduction achieved in 2016 was 2.6%, just short of the 3% average decarbonisation rate pledged in the 2015 Paris Agreement (PWC, 2017). While a great deal is being done globally in an attempt to meet the objective outlined in the Paris Agreement "of holding the increase in global average temperature to well below 2^{o}C above pre-industrial levels" (UNFCC, 2016), continued pressure to reduce emissions and improve clean energy technology is required.

A successful low carbon economy relies on the mining sector's ability to extract and provide the resources necessary to build clean, renewable energy technologies. The following examines the main minerals and metals required for energy storage batteries, solar PVs, wind turbines and the resulting impact on insurance.

Energy storage batteries

The automotive industry is currently dominated by lead acid storage batteries with the global market being worth US$53.32 billion in 2016 (Reuters, 2017). It is estimated that EVs will make up 35% of global new car sales by 2040 (BNEF, 2017), the batteries for which are lithium-ion *(see Figure 8)*. The cost of lithium-ion batteries has fallen by approximately 65% since 2010 and is expected to fall further as the technology improves and EVs become the cars of choice for consumers in the developed world.

Figure 8: Diagram of an energy storage battery and the relative components of different commodities in different types of batteries



Metal	Mined production 2016	Main producers
Lithium	34,000	Australia
Graphite*	2,100,000	China
Cobalt*	128,000	DRC
Aluminium	58,800,000	China
Manganese	51,200,000	China
Nickel	2,001,000	Philippines

*Minerals and metals on the EU's critical raw materials list

Source: Satarla, energy storage battery adapted from Electrek, 2018, table adapted from BGS WMP, 2016.

Lithium

Lithium is found and extracted from an array of geological settings. Approximately 50% of the world's supply of lithium comes from operations in Latin America where it is extracted from brines trapped under salt flats. The remaining 50% is currently extracted from hard rock mines, predominantly in Australia. A large number of new lithium mining projects are beginning to come online globally, including those that will extract lithium from clays in Mexico (Geological Society of London, 2018).

A great deal of speculation surrounds the near and long-term supply and demand requirements for lithium. It is not a commodity in itself as it is sold in different forms of acid. It is not therefore currently traded via the likes of the London Metal Exchange, making it difficult to determine accurate price trends. It is anticipated that a number of the new lithium mining projects will not therefore make it to full production, as they will be positioned too far to the right on the lithium cost curve *(see Figure 7)*.

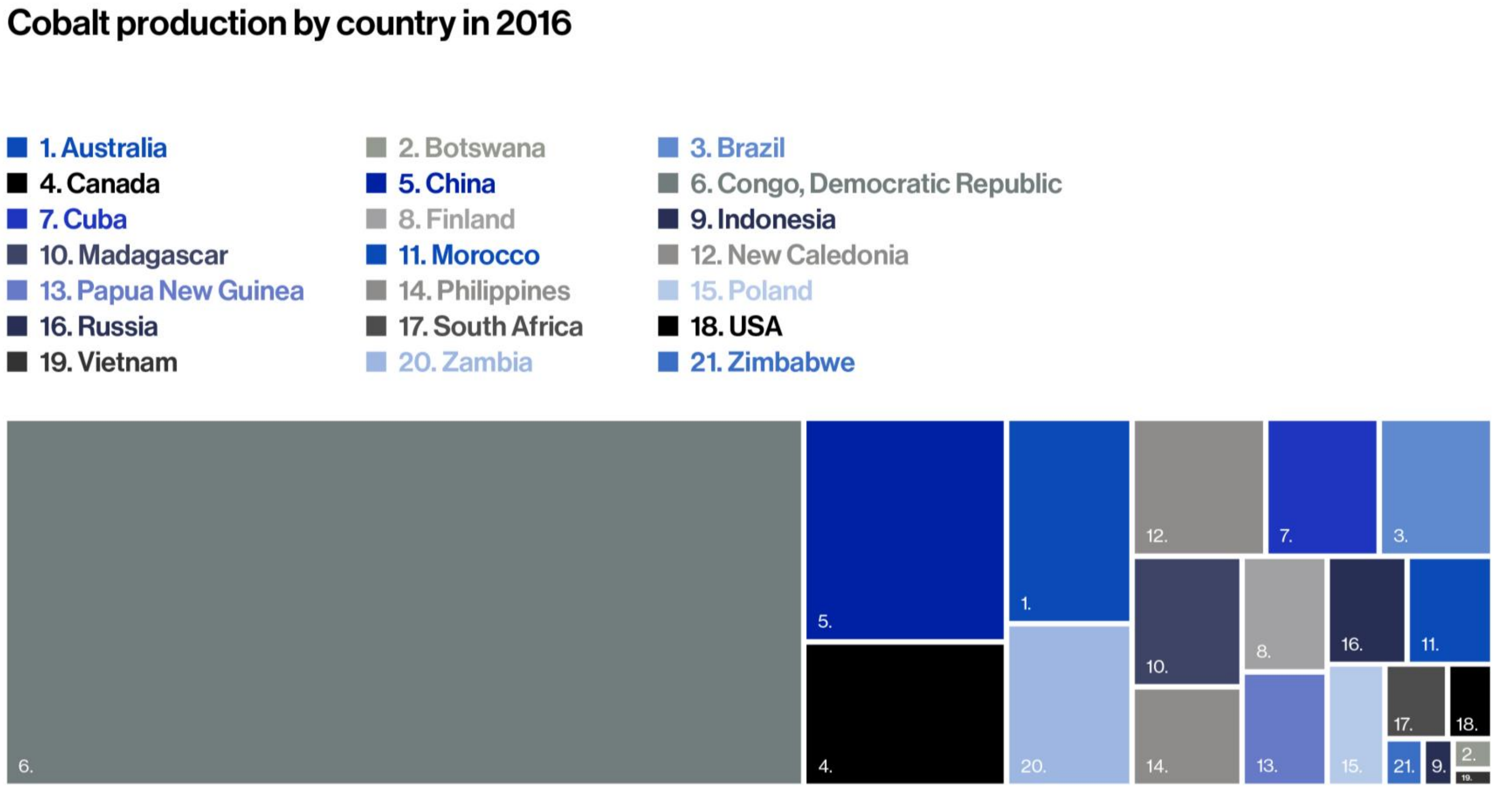
Many of these new mines will use novel mining and processing techniques, many of which may be considered as "prototypes" for the purposes of insurance. If the long-term demand for lithium is to be met, these technologies will have to be used, even if they involve great risks.

Cobalt in the Democratic Republic of Congo

Cobalt is required in the majority of lithium-ion batteries. More than 60% of the world's cobalt is currently mined in the Democratic Republic of Congo (DRC) (BGS WMP, 2016), *(see Figure 9)*. The DRC is regarded as having a "high" political risk (Control Risks, 2018) and has a history of conflict that is funded by mining (Global Witness, 2017). This creates cause for concern, both due to the opaque nature of the material supply chain in the country, and potential breaches of human rights, but also because the Government may alter its regulatory regime and impose export restrictions on certain metals, increased royalty rates or nationalise mines *(see box 8)*; all of which would severely alter the amount of cobalt produced by the DRC and would disrupt global supply.

State-owned mining companies have expressed an interest in renegotiating partnerships with international mining companies (Wilson, 2018). Insurance claims for business interruption, delay in start-up, mobile asset and commodity expropriation cover (MACE), which are often sought as a result of reputational damage and cover for those lending to mining operations, could be impacted as a result of changes to contracts and partnerships for companies working in the DRC. Mechanisms to improve the transparency of the value chain - through using blockchain, for example - will greatly alleviate some of the risks faced by mining companies in the DRC.

Figure 9: Global cobalt production in 2016, highlighting how susceptible supply is to disruptions arising from the main cobalt-producing country, the DRC



Source: Satarla, BGS WMP, 2018

Solar photovoltaics

Solar photovoltaic (PVs) panels use semi-conducting material which becomes energised when exposed to sunlight and produces electricity. Solar PVs are expected to produce about 11% of global electricity supply by 2050 (Low Carbon, 2018). The metal components of four of the most widely used solar PVs are explored in Table 1 below. Crystalline silicon cells comprise 85% of the current market share for PVs and it is expected this type of cell will continue to dominate the market (The World Bank, 2017).

Cadmium-telluride solar PVs are the world's second most-used type of solar panel. While cadmium is a highly toxic metal, the safer Cd-Te compound is used in the production of PVs.

The PVs are designed to last for 30-40 years. The Cd-Te compound is encapsulated between thick sheets of glass and is unlikely to leach out over time; however, it is recommended these panels are recycled at the end of their lives to ensure they do not pose a risk to the environment (Bleiwas, 2010).

The majority of the metals required in PV technology are by-products of other forms of mining. As the demand for PVs grows, so does the demand for these metals. Currently, 390 metric tonnes of tellurium are required to produce about 1GW of electricity; however, only 385 metric tonnes of tellurium was mined in 2016, meaning there is a significant supply gap (BGS WMP, 2016).

Table 1: Minerals and metals contained in the four most dominant types of solar photovoltaic cells, with the country primarily responsible for producing each metal

Metal	Crystalline silicon	Cadmium telluride	Gallium selenide	Amorphous silicon	Main global supplier
Aluminium	X				China
Copper		X	X		Chile
Indium*			X		China
Iron	X				China
Lead	X				China
Nickel	X				Philippines
Silver	X				Mexico
Zinc		X		X	China
Silicon *	X	X	X	X	-
Gallium*			X		China
Cadmium		X			China
Tellurium		X			China
Germanium*				X	China

*Minerals and metals on the EU's critical raw materials list

Source: World Bank, BGS WMP, 2016

Wind technology

In 2016, 11.5% of electricity used in the UK was generated by the wind (Evans, 2017). The energy generated by a wind turbine varies between 85kW to more than 5MW, and is dependent upon the wind speed and the swept area of the blades. Two different types of wind turbine are widely used today. Geared turbines are coil driven and dominate the market as they make up approximately 85% of all installed turbines. The remaining 15% is made up of direct drive turbines which use a low speed generator composed of magnets containing rare earth elements (REEs). Table 2 highlights the different types of metals required by both turbines.

Table 2: Different inputs into the two main types of wind turbines

Metal	**Wind turbines**		**Main global supplier**
	Direct drive turbines	**Geared turbines**	
Aluminium	X	X	China
Copper	X	X	Chile
Iron	X	X	China
Lead	X		China
Zinc	X	X	China
Steel	X	X	China
Manganese	X	X	China
Nickel	X	X	Philippines
Chromium	X	X	South Africa
Neodymium*	X		China

*Minerals and metals on the EU's critical raw materials list

Source: The World Bank, BGS WMP, 2018

Offshore wind turbines, mostly of the direct drive design, will represent 50% of total installation by 2050; therefore an increase in the amount of mined neodymium will be required to support these installations (The World Bank, 2017). This could become a cause for concern for insurers as the mining of REEs only takes place in few places across the globe. This means expertise of this type of mining is very limited (Elshkaki, 2013). The technology required to extract these elements is complex and may be viewed as prototypical by the insurance market.

As highlighted in Figure 10 *(below)*, depending on the type of technology used, between 400kg and four tonnes of copper are required in each turbine. Of the 20.2 million tonnes of copper mined in 2016 (International Copper Study Group, 2017), approximately 1% of it went into wind power. Ironically, the mining and processing of copper requires significant energy, and is projected to be up to 2.4% of the global energy demand by 2050 unless less energy intensive methods of copper mining are used (European Commission Science for Environment Policy, 2016). This puts pressure on miners to test new types of mining and processing technology, and therefore, the type of insurance required to support them.

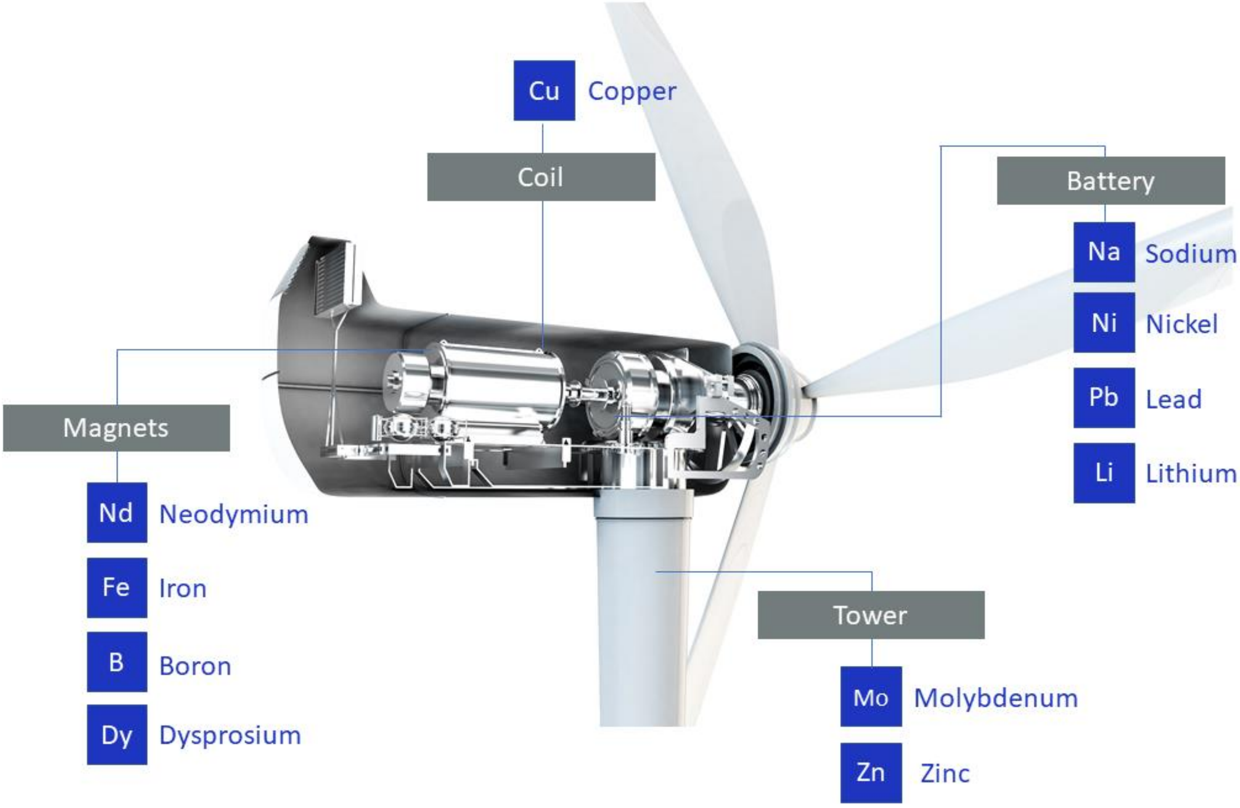


Figure 10: Diagram of a wind turbine

Source: Satarla 2018; Adapted from International Council for Minerals and Metals, 2018

Coal mining

While mining will see a boost from the need to mine metals needed in the various forms of renewable power generation, the sector has seen increasing challenges in coal mining.

The primary use for thermal coal is its combustion in power stations to create electricity. The burning of thermal coal provided 9% of the UKs energy demand in 2016 (Energy-UK, 2017). Coal is also a vital component in the manufacturing of steel with 74% of steel produced today using metallurgical coal and the remaining 26% of steel being produced in an electric arc furnace (EAF) (World Coal Association, n.d.). When used to produce non-alloyed steel, an EAF requires between 350-370kWh to produce one tonne of steel; this amount of energy is sufficient to power 100,000 houses per day (Industrial Efficiency Technology & Measures, n.d.).

In 2017 the Chinese Government announced it would invest US$360bn in renewable energy by 2020 and scrap plans to build 85 thermal coal-fired power plants (Kejun, 2017). Similarly, India's government announced plans to build 175 gigawatts of renewable energy generation by 2022 reiterating the desire of these rapidly evolving economies to use renewable energy to support their continuing growth (Reuters, 2017), and reduce their dependence on thermal coal and other fossil fuels.

Global coal production has been falling since 2013 (World Mineral Production Statistics, 2016) as many countries opt for cleaner fuel sources in an attempt to meet their Paris Agreement targets (Climate Action - European Commission, 2018). In 2016, 7.38bn tonnes of coal was mined worldwide, (BGS WMP, 2016) down from 7.93bn in 2015. In early 2018 the UK Government announced it would close all thermal coal fired power plants not equipped with carbon capture technology resulting in capacity reducing by 4.5GW by 2025 (Power Engineering Int, 2018). In the US, the sector is experiencing a similar downwards trend with capacity of thermal coal plants expected to reduce by more than 13,600MW during 2018 (Reuters, 2017).

Until recently US coal miners were permitted to hold their own assets as collateral for land reclamation during the closure of a mine. However, between 2015 and 2016 more than 50% of the country's biggest coal miners filed for bankruptcy. Billions of dollars set aside for clean-up costs disappeared with the company's assets (Olalde, 2018). President Obama enacted legislation to stop the coal industry self-bonding and 75% of bonds were converted mostly into insurance-backed guarantees thereby safeguarding land rehabilitation. However, in October 2017 President Trump rolled back this legislation (Olalde, 2018).

In 2017 President Trump signed an executive order to cancel a President Obama-era moratorium on US coal mining leases and abolish the requirement to undertake an environmental impact assessment (EIA) for the area surrounding a mine site (Lo, 2018). Concomitantly an Australian supply shortage of metallurgical coal, used in the production of steel, resulted in an increase in the price of this type of coal encouraging new market entrants to fill the supply gap (Lo, 2018). Short-term market entrants, coupled with relaxed regulatory requirements, has the potential to increase the risk of a large-scale catastrophe. As seen in Figure 4, coal mining is hazardous and must be carefully managed.

Without an EIA, it is difficult for underwriters to accurately quantify the level of risk a specific site may pose to the environment and workers. Harmful pollutants may be overlooked, and the size and proximity of nearby aquifers may not be well understood, increasing the probability of pollution events. These events could harm the surrounding population and environment, which would not be able to be restored to its original state as there would be no benchmark to measure reclamation against. Allowing a company to carry out work without an EIA and without a guarantee of land reclamation may encourage reckless, unsafe and unsustainable mining practices. As increasing numbers of insurance companies decline to write coal (e.g. AXA, 2018), it will be increasingly difficult to obtain insurance for coal mines. While the price of coal is high, coal projects will still go ahead with or without insurance. It is important for the health and safety of workers, the local community and the surrounding environment that these projects are governed responsibly by Equator Principal Banks or the World Bank, for example, if not insured.

On 1 April, Lloyd's introduced a responsible investment policy that excludes coal from assets held in segregated portfolios, which account for approximately 75% of its central fund investments. Other industry leaders such as Aviva, Allianz and AXA have adopted similar investment policies.

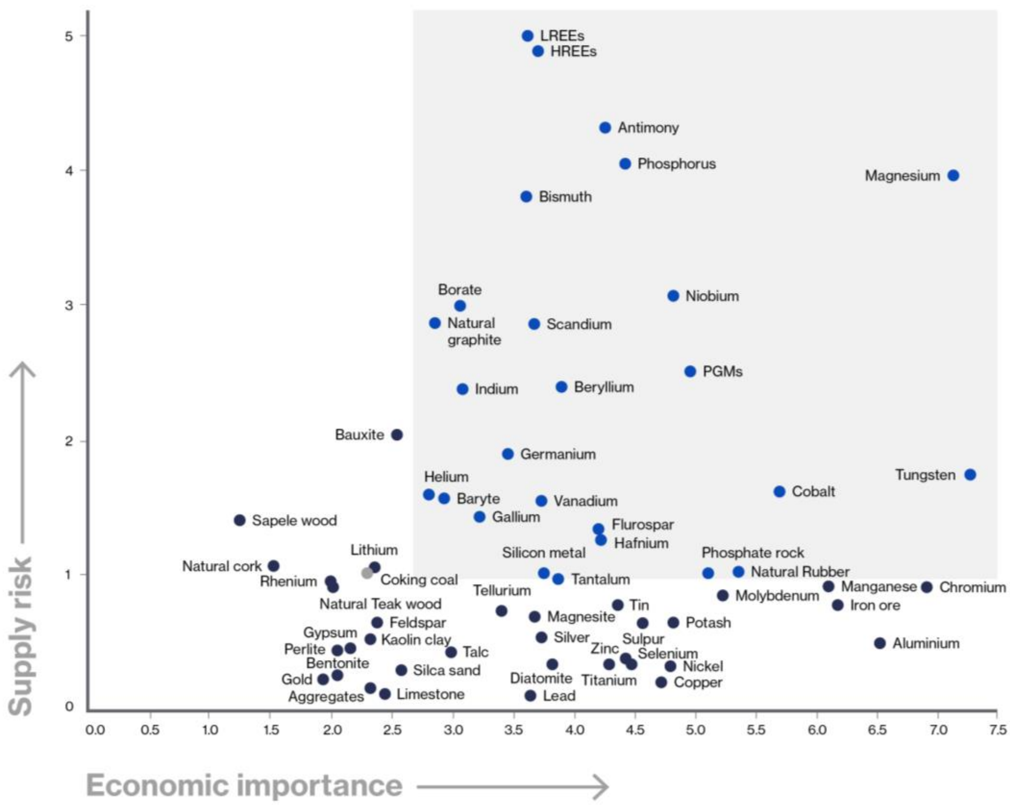
Demand for novel metals and minerals

Many technological developments, beyond those that deliver low-carbon forms of energy, require novel mixes of commodities. Many regions are addressing the materials supply security through strategies that ensure their region can maintain supply in accordance with their resource needs.

European Union

In 2017, the EU produced a revised list of 27 critical raw materials (see Figure 11). The materials on this list are economically important and required to be reliably available across Europe (Europa, 2017) as they are crucial to existing and newly developed technology. The EU hopes this list will help to strengthen the competitiveness of European industry, increase awareness of supply risks and related opportunities, negotiate trade agreements, challenge trade distortion measures, stimulate production of critical raw materials by increasing new mining and recycling activities, and foster efficient use and recycling in line with the EU's circular economy action plan.

Figure 11: List of 27 critical raw materials as defined by the EU



Source: Europa, critical raw materials, 2017

***HREE** – Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, Lutetium and Yttrium
***LREE** – Lanthanum, Cerium, Praseodymium, Neodymium and Samarium.
***PGE's** – Platinum, Palladium, Ruthenium, Rhodium, and Iridium. Osmium was not included in study.

Box 3: China - the world’s largest producer and consumer of rare earth elements

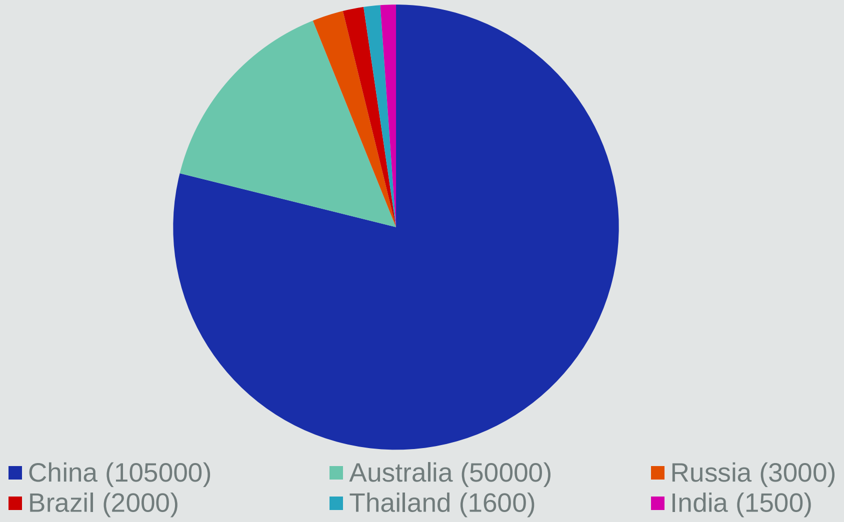
China is the major producer of more than 20 of the world’s most important commodities including coal, gold, molybdenum, titanium, tungsten and rare earth elements (REEs). While China is transitioning from industrial to a service-based economy, mining will continue to play an important role in its ongoing development (Investing News, 2017).

China recently introduced regulation that has forced factories to decommission coal fire power generation and move to cleaner forms of energy such as gas. While the majority of the energy in China is still produced by coal-fired power stations (China consumes approximately 50% of the world’s thermal coal supply) much of which is produced by its own coal mines, of the 113 gigawatts (GW) of new power plant generation that came on line in 2014, 2GW was wind power, and 9GW solar PV (Lawrence Berkeley National Laboratory, 2016). REEs will be integral to the increase of the use of renewable energy in China.

The REE market is dominated by China, with the country controlling almost 80% of global production in 2017 (see Figure 12). A crackdown on the illegal mining of REEs was introduced in 2017, with the Department of Raw Materials taking a “zero-tolerance” approach to practice. This was in part due to the difficulty of minimising the environmental and occupational health impacts of processing REEs. REEs share common properties, which means a range of sulphates, ammonia and hydrochloric acid are required to separate them. The ore can also be radioactive due to the common presence of elements such as thorium.

The methods through which REEs are mined need to be carefully controlled to make sure the potential damage to areas surrounding the mines does not outweigh the international environmental benefits of using them in wind turbines and solar PVs.

Figure 12: Million tonnes of REE produced by the top six producing nations in 2017



Potential impacts for insurers include:

- New mining and recycling activities taking place in regions such as the EU may result in European countries prospecting for new minerals and metals which are not historically produced in the region such as REE, lithium and cobalt to reduce their import dependency.
- Mining and processing REEs requires deep technical knowledge and often carries significant environmental risks. Accurate quantification of the risks associated with these mines is therefore difficult.
- Innovation across the raw materials supply chain may result in new technologies being used. Underwriters may therefore see a significant increase in “prototypical” technologies being used by companies seeking insurance.
- Disruption to the supply of raw materials to regions such as the EU may result in increased third party or subcontractor liability claims.

Services enabling research and development

Minerals and metals are distributed heterogeneously across the globe and are dependent on where geological processes have naturally concentrated the elements economies need. The majority of near-surface, easily accessible, high-grade deposits have been exhausted, forcing mining companies to explore for deposits in frontier regions. These “new” regions are termed frontiers due to their relatively difficult accessibility, technological, environmental, economic, social and governance contexts. Three new frontiers explored here are listed below.

Ultra Deep Mining

Ultra-deep mining (UDM) is categorised as a mine that is more than 2.5km deep. At present, the deepest mine in the world is the Mponeng gold mine in South Africa, which is more than 4km deep.

Deep sea mining

Deep sea mining (DSM) is the extraction of resources from the seafloor. Many minerals and metals occur in economic quantities on the seafloor in the form of seafloor massive sulphide deposits (SMS), polymetallic nodules and cobalt-rich ferromanganese crusts, amongst others.

Asteroid mining

In recent years asteroid mining has gained a lot of media attention with several companies investing considerable resources in research to turn the concept of mining asteroids into a reality. Currently space exploration is considering the mining of near-earth asteroids (NEAs).

Box 4: Ultra-deep mining

UDM is costly and complex. When compared to traditional underground mining, UDM projects must overcome the structural engineering complexities of operating at great depths where the risk of sudden rock bursts and falls are likely and can severely endanger miners. UDM can activate dormant faults which can cause tremors. For example, the TauTona gold mine in South Africa experiences as many as 24 tremors per day (Wanneburg, 2018). Air temperatures exceed 50℃ at these depths and rock face temperatures can reach 60℃. Ventilation is a major cost for UDMs, as more energy is required to cool the mine the deeper it extends. Additional measures are used to ensure the health and safety of miners, such as cooling vests. (Vella, 2014).

Despite these challenges, the mine must remain profitable whatever the current commodity price happens to be.

Table 3: The top 10 deepest mines in the world

No.	Name	Location	Commodity	Depth	Operator
10	Creighton Mine	Sudbury, Ontario, Canada	Nickel	2.5km	Vale
9	Great Noligwa	Vaal River, South Africa	Gold	2.6km	AngloGold Ashanti
8	Kidd Creek	Ontario, Canada	Copper and zinc	2.9km	Xstrata
7	South Deep	Mpumalanga, South Africa	Gold	2.99km	Gold Fields
6	Moab Khotsong	Vaal River, South Africa	Gold	3.0km	AngloGold Ashanti
5	Kusasalethu	Gautenng, South Africa	Gold	3.27km	Harmony
4	Driefontein	Gauteny, South Africa	Gold	3.4km	Gold Fields
3	Savuka	West Wits region, South Africa	Gold	3.7km	AngloGold Ashanti
2	TauTona	West Wits region, South Africa	Gold	3.9km	AngloGold Ashanti
1	Mponeng	Johannesbury, South Africa	Gold	> 4km	AngloGold Ashanti

Source: Metallurgist, 2018

Fatalities in UDMs most often result from “fall of ground” incidents, which involve tunnel roofs or walls falling and crushing miners. These incidents may be attributable to seismic activity, structural issues or misinterpreted geology.

A number of research and industry collaboration projects are focusing on how to better manage the risks faced by UDM. The Canadian Centre for Excellence in Mining Innovation (CEMI) has launched an industry-funded initiative, the Ultra Deep Mining Network (UDMN), which aims to develop technological solutions to make ultra-deep mining commercially viable and human operated rather than robotic (CEMI, 2018). The European Commission launched a deep mine project, i2mine, which is focused on developing the concept of an invisible, zero impact and zero entry deep mine. Contrary to the UDMN project, i2mine intends to design a zero entry mine that is fully automated (Europa, 2018). However, both projects will be heavily reliant on digitalisation. While the CEMI project is focused on developing solutions for humans, this may be due to the fact that it wants to make this type of mining a reality on a relatively shorter timescale than the i2mine project. Prototypical technology is being developed by the UDMN and i2mine to assist this type of mining. Developments include: a fully connected wearable technology suit with built in cooling systems and GPS tracking, and a 4D geo-technical hazard assessment and reporting tool that can detect rock bursts.

Box 4: Ultra-deep mining (continued)

Mining at these depths is difficult and dangerous, so it is essential that insurers allocate resources and research to fully understand the inherent risks associated with this type of mining. UDM is already prevalent in South Africa and Canada, and will continue to become more popular as deposit grades decline and mining companies revisit old mines to extract higher grade deposits from deeper in the earth. Prototypical technology will frequently be deployed at these sites to better deal with falls of ground and ventilation problems, adding another layer of complexity for insurers. Technical underwriters will be required to understand the complexities of UDM to ensure it can be profitably underwritten.

Box 5: Deep sea mining

Seafloor Massive Sulphide (SMS) deposits are formed at hydrothermal vent sites where mineral fluids impregnated with dissolved metals precipitate out of solution upon mixing with cold seawater. This ongoing activity causes rich deposits of iron, copper, zinc, lead, gold and silver to build up. Polymetallic nodules are rock concretions formed of concentric layers of iron and manganese surrounding a core, and ferromanganese crusts are found in areas of significant volcanic activity and form from the precipitation of metals dissolved in seawater.

A number of pioneering companies have begun to investigate how to take advantage of the wealth of resources on the seafloor. Nautilus Minerals Inc. has made the most progress in this space to date, focusing on the harvesting of copper and gold under the waters of New Britain, Papua New Guinea. A subsidiary of Nautilus Minerals, Tonga Offshore Mining Ltd has undertaken similar exploration programs in Tongan waters where it has been granted a 75,000km² licence for the Clarion Clipperton Fracture Zone in the Central Pacific to explore for polymetallic nodules. UK Seabed Resources, a wholly owned subsidiary of Lockheed Martin, was granted a 58,000km² exploration licence for the same area. A total of 27 exploration licences have been granted for 15-year terms by the International Seabed Authority (ISA) to date (ISA, 2018).

The most prominent risk associated with DSM is environmental damage. These environments were only discovered in the 1970s, and as a result little is known about them making environmental liability unquantifiable. DSM has the potential to cause deleterious effects to benthic ephemeral ecosystems that surround vent sites and support upwards of 500 different species. Mining in these areas may result in leakage of toxic sulphides which alter the water column (Hoagland, 2010). Sediment plumes created by tailings are often impregnated with fine particulate and can affect water turbidity on the seafloor and clog benthic organisms' feeding apparatus. Closer to the surface, these plumes affect light penetration and alter the water's chemical composition threatening the production of phytoplankton (Potters, 2013). The ISA is responsible for overseeing regulations governing the granting of DSM licences and ensuring the marine environment is protected from harmful effects created by mining activity (ISA, 2018).

Opportunities exist for insurers to enter the market at this early stage by working with licensing authorities and DSM companies to ensure regulations and mining plans incorporate sufficient risk engineering and baseline monitoring surveys.

Box 6: Asteroid mining

The majority of space exploration is focused on the mining of near-earth asteroids (NEAs). These asteroids contain high levels of water, organic carbon, sulphur, nitrogen and phosphorus as well as ferrous base metals, iron, cobalt, manganese, nickel, aluminium and precious metals, gold, silver, platinum, palladium, osmium and iridium. The concentration of precious metals such as platinum in certain asteroids is estimated to be at a grade of 6.8g/t* (Hoashi, 1990) compared to a grade of 2.9g/t (Pubs.usgs, n.d.) in the earth's richest known platinum resource. [* Please note that exploration companies have published estimated grades of 100g/t].

Despite these high grades of precious metals, it is thought unlikely that asteroid mining is economically viable. Using asteroids as staging posts for deeper space exploration is therefore considered more realistic. The low gravity associated with each NEA reduces the energy required for spacecrafts to take off from the surface (Deep Space Industries, 2018). Space exploration companies plan to split water using solar power into oxygen and hydrogen to produce fuel; while mining other materials on the asteroid will provide the materials required to construct parts for other equipment and space station bases.

Several companies are actively engaged in this sector, developing pioneering technology to assist with the extraction of resources including Planetary Resources, Deep Space Industries, and The Asteroid Mining Corporation. Planetary resources aim to deploy multiple spacecrafts to a number of asteroids by 2020 (Planetary Resources, 2018).

The legal basis of space mining is still uncertain. The Outer Space Treaty which governs the activities of states in the exploration and use of outer space, was created in 1967 and provides a basic framework for international space law. The treaty states "space is not subject to national appropriation by claim or sovereignty" (Unoosa, 1967) but does not condone or forbid mining on asteroids. In 2015, President Obama signed the Space Resource Exploration and Utilisation Act which gives any US company property rights over natural resources from space (U.S. Commercial Space Launch Competitiveness Act, 1002-403). In August 2017, Luxembourg became the first European country to draw up legislation relating to space exploration which defines the conditions companies must fulfil to obtain a licence for launching a space mission. Operations have ownership of these metals only once they have been successfully mined. Luxembourg signed a five-year co-operation agreement with Japan as part of Luxembourg's SpaceResources.lu initiative which was launched to promote the mining of celestial bodies for minerals, and will cover the exchange of information and expertise on the matter and further enhance collaboration. Luxembourg has recently signed similar agreements with Portugal and the United Arab Emirates.

Similar to other new mining frontiers, the mining of NEA provides insurers with an array of opportunities. The highly advanced technological equipment required for space exploration will likely be insured in normal insurance markets should underwriters have an appetite for this type of business. It is thought that this type of mining is still 10-20 years away from becoming a reality within which time the actual process and equipment required will have developed significantly.

Technological advancements

Digitalisation of mines

Digitisation, automation, machine learning and artificial intelligence are becoming increasingly common within the mining sector. Seen as providing an operation or service provider with a competitive advantage, investment in technology is fundamental to the survival of companies in this industry. The skillsets required by novel technologies differ to those traditionally employed within the mining industry.

The digitalisation of mining incorporates several "new technologies" *(See Figure 13*).

Digitisation

Digitisation is the transferring of data from physical form to electronic form. Examples of digitisation in the mining industry may include electronic employee identification cards, staff security clearances and health records, and electronic mining and water licences.

Many benefits exist for insurers. For example, the digitising of workers' information, identity and security management systems, the tracking of an employee's location, access rights, training, safety certification, permissions and compliance allow claims to be more rapidly settled as circumstances surrounding loss events are quickly and effectively documented and control processes are in place. Having all permits, checklists and controls, such as mining and environmental authorisations, located in one easy-to-access platform enables a company to effectively manage their licences ensuring they are still in good standing and reducing the risk of temporary mine closure due to lacking the correct permits.

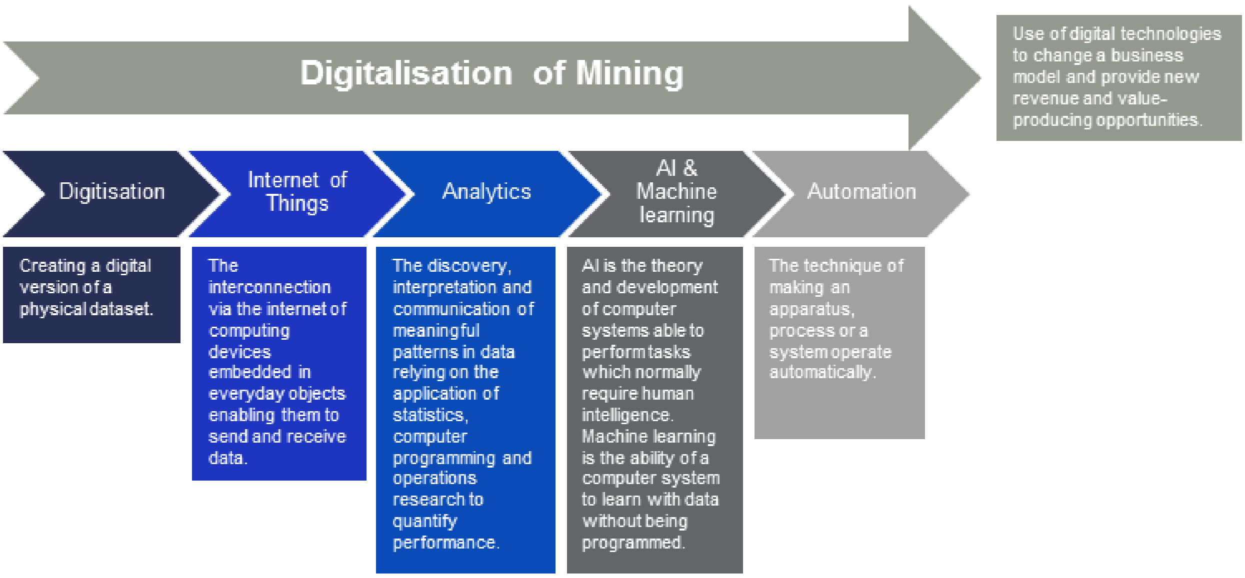
With the increase in digital data, mining companies will require robust cyber insurance policies. An opportunity exists for insurers to develop new products and expand the cover they currently offer to the mining industry. A cyber insurance product should ideally include not only physical damage to property as a result of a hack but also the loss of intellectual property, extortion, data breeches and loss of bandwidth.

Internet of things

The internet of things (IoT) refers to everything electronic on a mine site that has the ability to transmit data. Sensors that have this ability on a mine site include everything from gas detectors and truck weighing scales, to employee entry barriers to the site and the tyre pressure gauges on a haul truck. A network of leading indicators that can be developed via the IoT to create an operation with a tighter zone of tolerance between the desired service level and the level of service considered adequate. This is not only lower cost, but also allows for more dynamic management. For example, a haul truck can be scheduled for maintenance as soon as the tolerance thresholds are triggered on the robustness of a tyre, rather than risking the tyre degrading further and potentially exploding.

The benefit of the IoT can be leveraged further by creating a consolidated database. As with many industries, the mining industry is plagued by siloed IT systems, making data less accessible and difficult to understand. Database consolidation has huge benefits for both mining companies and insurers as the status of the mine can be more accurately tracked.

Figure 13: Different aspects of mining digitalisation



Source: Lloyd's, Satarla,

Analytics

There is little value in collecting data unless analysis is undertaken to understand it. Connections between datasets need to be made, and refined with time and experience. While certain metrics such as tonnes mined per day, and grade of ore are clearly understood in mining, the potential to develop more meaningful metrics through the analysis of digitised data is considerable, such as analysing driver's behaviour to support appropriate insurance packages.

Numerous reports have been written on the difficulties and lessons learned from attempting to introduce leading indicators into the mining sector (e.g. ICMM, 2011). Theoretically metrics such as these should make mines safer and more efficient; however they require good quality data in order for the analysis to be carried out.

Artificial intelligence and machine learning

Artificial intelligence (AI) is being increasingly researched for the mining industry to explore its potential use to view and classify images of rock samples and core logs, with the end goal of improving the understanding of the geology of an ore body.

Machine learning also allows predictive signs of weakening machine health to be identified, thereby triggering maintenance orders even earlier, providing maximum time for fleet maintenance planning and the optimised use of assets and increased productivity (IBM Corporation, 2009).

Automation

Automated trucks were first trialled by Rio Tinto in 2008 as part of its "Mine of the Future" programme. Autonomous haulage system trucks (AHS) lend themselves to large, open and flat lying mining operations and are therefore perfect for areas such as the Pilbara in Western Australia where vast quantities of iron ore is mined. AHS trucks have collision detection sensors built in ensuring their safe operation. The trucks are remotely controlled from an operations centre via a supervisory computer. When not undergoing maintenance, the trucks non-stop delivering, delivers greater productivity than human drivers. Approximately 20% of Rio Tinto's existing fleet of 400 haul trucks is AHS enabled. It plans to continue retrofitting their Komatsu fleet, with the aim of reaching 30% automation by 2019 and a fully automated mine at Brockman 4 in the same year (McKinnon, 2017).

In the past decade zero injuries have been attributed to AHS trucks, a testament to the safety of these operations. Roy Hill, Fortescue Metals, BHP Billiton and Suncore Energy have also employed driverless trucks in mines around the world, signalling that these trucks will be prominent in the industry and important to the future of mining. In addition to AHS trucks, Rio Tinto successfully trialled an automated drilling system for use in the Pilbara. Rio Tinto also intends to create the world's first fully autonomous heavy haul, long distance railway system, the first autonomous railway journey was completed in July, 2018. (Rio Tinto, 2018).

In general, property insurance policies cover damage to property as a result of AHS software malfunction or abuse but do not provide cover for the software itself. There may be a market for insurance products to provide cover for complex pieces of software in the future; therefore insurers should endeavour to keep abreast of technological advances and the increasing use of AHS trucks should an opportunity arise to write such business. Autonomous drilling and autonomous trains will be the next frontier in this type of mining, and insurers' resources should be dedicated towards better understanding this technology to ensure insurance solutions are ready to be provided to the wider market. Rio Tinto expects to roll out its first fleet of autonomous trains by the end of 2018.

Swarm robotics is also anticipated to be an important form of automation in the future. Small robots mimic the behaviour observed in social insects such as ants or locusts in a behaviour known as "swarm intelligence". Facilitating constant communication between the group builds a system of feedback and understanding of the environment it is in. These swarms can be used to mine faces precisely while real-time algorithms take into account energy constraints, prices and other issues ensuring precision and economic extraction with minimal waste (Creamer, 2017). The safety of workers is improved with this type of technology, eliminating the need for humans to enter dangerous operating environments.

Remote monitoring

The increase in commercially available high-resolution satellite imagery allows mines to be monitored remotely on a regular basis. This allows mine experts not necessarily based at that operation to remotely monitor anything from the status of waste piles, pit slopes, truck fleet activity, to the extent of artisanal activity in the mine area, or vegetation changes (see Figure 14, below). This increases the efficiency and effectiveness of global teams of technical experts, enabling them to better manage 'their' risks and controls from a central position.

These datasets also present an opportunity for insurers. Archive imagery can provide evidence as to the causal factors leading up to a loss event. The potential to remotely assess the extended context of an asset that is being insured, prior to risk engineers visiting the site, may identify areas of interest for those risk engineers, as well as provide a more complete picture of the risk profile of theoperation.

Blockchain and transparency

Technology does not just make mining more efficient; it can also improve relationships with governments and end customers. For example, a number of different blockchain ledgers are in the process of being built and tested by the gem sector. The purpose of using blockchain is to provide a robust record of provenance and steps taken to beneficiate that gem as it makes its way to market. This is valuable to governments not least because they can monitor the value of gems being extracted within their jurisdiction and tax them accordingly.

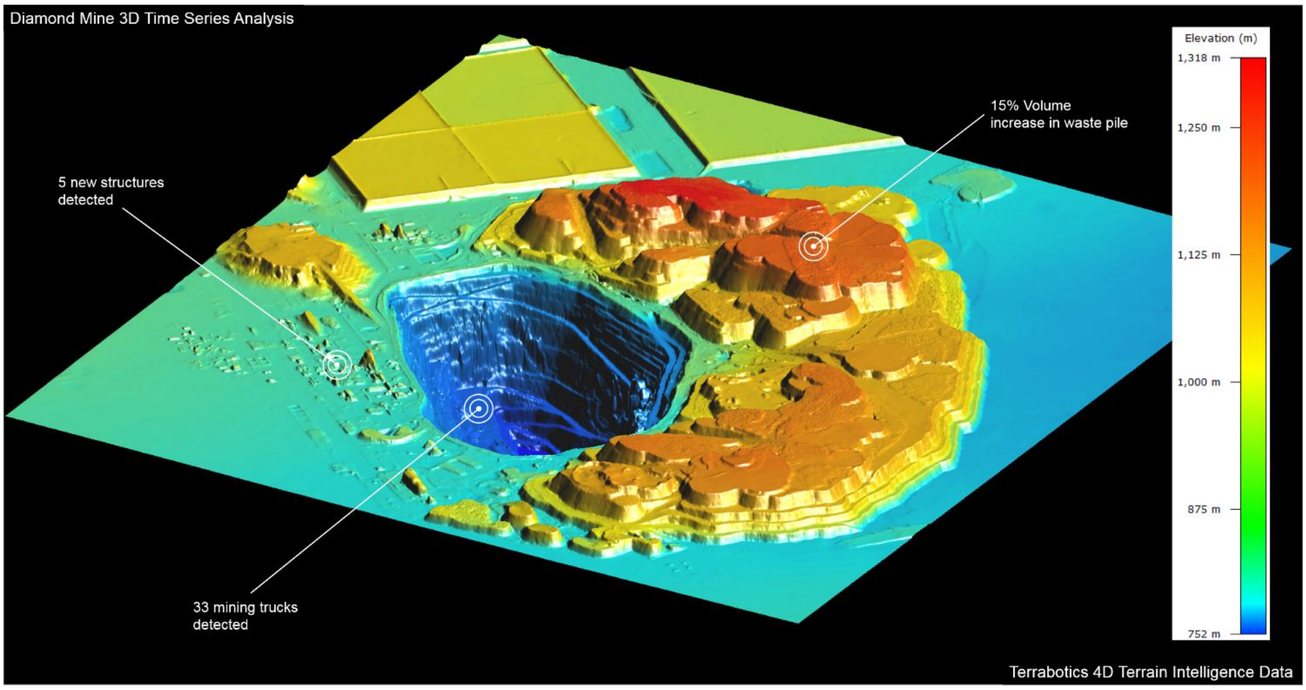
It is estimated that a ruby with a record of its provenance and beneficiation logged via blockchain can command a 15-20% mark up on other gems (Clarici, 2018). This is driven by the demand of jewellers and end customers for ethically sourced products. The Kimberley Process introduced by De Beers in 2003 (Kimberley Process, 2003) led the way in tackling “Blood Diamonds” (Diamond Facts, 2018) and set a benchmark for ethically sourced diamonds. The use of blockchain provides a more robust record for each gem, especially important for the livelihoods of thousands of small-scale miners who produce 80% of the world’s gems.

Blockchain could also improve transparency in mining in other ways. For example, the European Parliament Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (Regulation (EC) No 1907/2006, 2006) requires all companies importing more than one tonne of 143,000 chemical substances into the EU to register the import. The purpose of this regulation is to address the potential impacts of these chemical substances on human health and the environment. Many of the products produced by mining are on this list, therefore requiring a large paper trail of information for European imports. If a single electronic ledger was used it would reduce mistakes and the costs incurred when ships are prevented from unloading products due to incorrect paperwork.

A number of different initiatives have also been launched in recent years to increase the transparency of raw materials such as the Extractive Industries Transparency Initiative (EITI), (EITI, 2018) in Europe and the Extractive Sector Transparency Measures Act (ESTMA) (NRCAN, 2014) in Canada. These initiatives rely on companies reporting accurate data. These sorts of data are rapidly escalating in importance for financiers, going beyond the requirements outlined in the International Finance Corporation (IFC)’s Equator Principles (Equator Principles, 2018). Should a more integrated record of the provenance of a tonne of copper or cobalt (see the cobalt section in DRC and Box 8) be possible to maintain, many of the questions surrounding transparency and ethical investment would be addressed.

Transparent and complete records are useful not only for governments and financiers, but also for insurers as they provide easy-to-access-and-analyse insight into the full details of an operation. This allows insurers to undertake more robust, quantitative risk assessments of those insured.

Figure 14: Remote mine monitoring using satellite data to derive volumetric analytics



Source: Terrabotics, 2018

Societal drivers

Resource nationalism and relationships with governments

Resource nationalism is characterised by the tendency for states to take or seek to take direct and increasing control of economic activity (Ward, 2009). This may include but is not limited to nationalism and expropriation of foreign companies, export restrictions, cartel pricing and high taxation (HMRC, 2014).

While resource nationalism is both an opportunity and threat to different stakeholders globally, many African nations have redesigned their legislation in the past few years to give them more control over their own natural resources and realise greater local benefits as a result of mining operations. Previously, many of these nations had offered very favourable terms to foreign investors to attract investment into their country. A number of case studies in African nations are outlined below.

Box 7: Tanzania

In 2017 the Tanzanian President, John Magufuli, made several changes to the mining regulatory environment after ordering an audit of Acacia Mining, the country's largest gold-mining operator. The audit committee alleged that Acacia failed to declare significant quantities of gold and copper concentrate and reported that the company owed US$40bn in unpaid taxes and US$150bn in penalties (Acacia Mining, 2018). Acacia Mining claimed these allegations to be unfounded, and a report by IHS Markit also found these figures to be unreliable (IHS Markit, 2017). Based on the audit committee's findings, Magufuli also introduced regulations which can force the renegotiation of contracts and see a transfer of between 16% to 50% of the company into Government ownership. Arbitration talks between Acacia and the Tanzanian Government reached conclusion as Acacia agreed to transfer 16% ownership in three gold mines and pay US$300 million as a show of good faith (Zandi Shabalala, 2017).

In March 2017, an export ban was also imposed on copper and gold concentrates in an attempt to raise the value of exports by ensuring smelting operations were located in Tanzania. However, miners in the region argue that Tanzania does not produce enough ore to warrant the construction of a smelting plant (Ng'wanakilala, 2017).

In January 2018, the mining ministry passed new regulations to make it compulsory for foreign-owned mining groups to offer shares to the Government and local companies. These rules will also restrict the way in which foreign-owned banks and insurance companies conduct business with mining companies in Tanzania; mining companies and allied entities will be required to transact business through Tanzanian banks, and insurance and re-insurance brokers. Companies who fail to comply with the new regulations face a fine of at least US$5 million (Ng'wanakilala, 2018). The result of the regulations makes it very difficult for insurers to write new business in Tanzania..

Box 8: The Democratic Republic of the Congo

The updated mining code for the Democratic Republic of the Congo was signed into legislation by President Joseph Kabila on 9 March, 2018 (Rodd, 2018). The revised code attempts to recapture a greater share of mining companies' revenues compared to that of the 2002 code which was aimed at attracting investment to the region following the end of the civil war (Shafaie, 2018). The revised code incorporates several new regulations such as:

- Increased royalty rates from 2-3.5% for non-ferrous base metals and from 2.5-3.5% for precious metals
- A 10% royalty rate for minerals and metals deemed "strategic" to the state by discretionary government decree. It is likely that this will include copper and cobalt although this is yet to be confirmed at the time of writing
- A super-tax of 50% which will apply to income realised when commodity prices rise 25% above levels included in a project's bankable feasibility study
- Non-dilutable state equity stake in companies will increase from 5-10%; this will further increase by 5% upon renewal of mining licences every 25 years
- A 10% share capital stake for Congolese private citizens when creating a mining company, plus a requirement to pay 0.3% of company turnover towards local development needs (Norton Rose Fulbright, 2018).

The updated code is applicable to existing licence holders immediately. The impacts of increased regulations will affect profit margins of international companies invested in the region and may make it significantly more difficult to raise finance for projects. Executives of the largest DRC international operators met with President Kabila to discuss the changes made to the mining code and their concerns regarding the potential knock-on effects of deterring foreign investment. The Congolese Government promised to consider each company's concerns on a case-by-case basis (Clowes, 2018).

Box 9: South Africa

In regions such as the north west of South Africa, mining accounts for approximately 30% of regional GDP and employs 16% of the workforce (Stats SA, 2017). Historically it is an incredibly influential industry, shaping the country geographically and culturally.

South Africa's new President Ramaphosa announced in February 2018 that the incoming Mineral Resources Minister Gwede Mantashe's first task would be to focus on the new version of the Mining Charter. The previous version was revised in 2017 under former President Zuma, and created outcry among the mining industry due to insufficient consultation with miners and the creation of an increasingly onerous operating environment.

The change of government in South Africa has restored a great deal of confidence in investors and operators. The Chamber of Mines described Minister Mantashe as a man of integrity and dignity, and stated that his appointment is a clear demonstration of the President's commitment to ethical leadership (Thaw, 2018).

The mining charter and accompanying mineral and petroleum resources development amendement bill is currently being reviewed with further clarification of changes expected to be confirmed in November 2018 (Department for Mineral Resources, 2018). Mantashe has met with interested parties such as the chamber of mines and mining trade unions to discuss the proposed changes (Manyathela, 2018). While limited changes are expected to be made to the charter, Mantashe's balanced approach of addressing growth and transformation for the industry while enabling it to be globally competitive is a positive sign for industry stakeholders.

Licence to operate

Mining companies (be they international or artisanal and small-scale mining (ASM) require the permission (formally or informally) of the local community to mine. The social licence to operate (SLTO) is the acceptance and permission granted by a local community to an organisation for it to mine the assets within the community's area of influence. Based on goodwill rather than a physical contract, it needs to be built and maintained continuously. As perceptions and opinions within a community change, so too may the robustness of the SLTO.

The SLTO differs from formal licences to mine in that it is granted by the community rather than by governments or local authorities. Tension can build between a community and government as they may have differing opinions regarding whether mining should take place or not, and how wealth from mining should be distributed.

Of all the stakeholders in a mine, the local community is typically that which sees the largest impact on their way of life. These impacts range from pressure on resources such as water, to the provision of jobs, education and improved infrastructure (see Table 4). Should a company lose their SLTO, all production may be stopped indefinitely.

Table 4: Positive and negative impacts that may be experienced by a community local to a mining operation

	Potential negative impacts	**Potential positive impacts**
Water	It is common for a large volume of water to be required for mining activity. The local community should have first rights to that water, primarily for drinking and washing, and then for existing activities such as agriculture. Tension may therefore develop between the community and miners as communities may perceive miners as "stealing" their water.	Mining can introduce new technology to an area that may already suffer from drought, therefore ensuring the community does not suffer due to lack of water.
Jobs	A large influx of people to the community may occur due to the need for specific skillsets and manpower needed on the mine. This may alter the dynamics of the local community as different cultures mix.	For every mine worker several supporting jobs are created in the local community. One study by the World Bank found that for every direct job created by the Yanacocha mine in Peru, 14 supporting jobs were created in the local community (Mining Facts, 2018). These boost the local community economically.
Education	An increased level of education may lead to young adults leaving the community to seek higher education and more complex jobs elsewhere.	Children and young adults will typically be provided with the opportunity to take part in a better quality of education, widening their employment opportunities as a result. Local members of the community may be trained in jobs working in the mine, which often provides a higher paid source of income.
Infrastructure	The mine will require good quality roads and transportation links; a robust source of power; continuous supply of water; and connectivity with the broader world. The construction and use of this infrastructure may disrupt the local community. Also, when the mine closes, the local community will need to have developed a plan through which they can maintain the infrastructure.	The community will benefit from having access to much of the new infrastructure which would otherwise not have been built, including internet, energy and transportation links.

Environment	The past has seen a large number of case studies in which a mine has polluted the area surrounding a community, be it through allowing toxic materials to be leaked from trucks as they pass through a town (Hecht, 2005); contaminated dust from nearby smelters (Carrington, 2018); or pollution of water courses and groundwater (Bontron, 2018).	Mines have experts who not only monitor the status of the local environment, but also have the skills necessary to ensure that biodiversity is protected. Where there is the potential for the environment to be disrupted, regulations and international standards provide the impetus for key risk areas to be appropriately managed.
Wealth	The community has survived prior to the arrival of the mining company. Some business owners will need to change in order to make the most use of new business opportunities that arise from the mine.	Depending on the jurisdiction, the local community will increase its financial standing through taxes, jobs, construction of critical infrastructure and other developments for the long term.

Source: Lloyd's, Satarla, 2018

The SLTO starts to be developed before the first exploration geologist enters a community. Numerous best practice guides, such as Anglo American's SEAT program (Socio-Economic Assessment Toolbox) and the IRMA standard (Initiative for Responsible Mining Assurance) have been published to help mining organisations successfully build a SLTO; however, it is now rare to be the first mining company to engage with a community, and often legacy agreements and expectations have been pre-set before a robust SLTO between a community and incoming mining company can be constructed.

The ability of a mining company to maintain its SLTO can have a large impact on insurance companies. Civil unrest has been known to halt operations and can cause damage as a result of violence associated with protests, delaying or stopping production for a number of years. Mining companies are often forced to make a claim on their insurance policies to recoup some of the losses associated with production stoppage.

The requirement by the IFC for funded mines to obtain "free, prior and informed consent (FPIC)" from indigenous host communities is widely becoming the expectation by which SLTO processes are benchmarked. The FPIC concept requires miners to expressly obtain community support for their proposed project in advance of project implementation in an effort to mitigate opposition later in the project's life. This concept seeks to improve on the legally required public consultation processes by specifically advocating for the rights of indigenous persons.

Insurers have an opportunity to introduce a mechanism whereby they can independently measure a mining company's performance regarding its SLTO. Introducing an index to benchmark and measure a company's sustainability performance would help to safeguard insurance companies from avoidable claim pay-outs, which can arise anywhere from two months to two years from the initial events. An index also allows insurance companies to ensure they are aligning themselves with responsible operators, and demonstrates their commitment to protecting the environment and the people within it to the wider world.

Artisanal mining

SLTOs do not just exist between large international mining companies and local communities; they also exist between a community and artisanal and small-scale miners (ASM), many of whom are members of that community. An artisanal or small-scale miner is essentially a subsistence miner; they are not employed by a mining company but mine independently using their own tools and resources. ASM refers to informal mining activities carried out using low technology or with minimal machinery *(see Figure 15)*. It is estimated that 100 million people rely on this sector for their livelihood (Mining Facts, 2012). An artisanal miner will mine on a seasonal basis or part-time to subsidise their regular income from other employment such as agriculture (Assets Publishing, n.d.).

Artisanal mining is legal in some countries such as Burkina Faso; however, it is often referred to as ”illegal mining” by the mining sector. This is due to artisanal miners often encroaching on the licence areas permitted by the larger mining companies. Some 80% of global sapphire production and 20% of global diamond mining production comes from ASM (The World Bank, 2013), much of which is legal mining.

The difficult conditions in which artisanal miners work, coupled with their often-illegal encroachment on the mining licence areas of larger companies, can lead to conflict and violent clashes (Slack, 2009). This can negatively impact insurers as mining equipment may be damaged, or conflict could lead to intermittent mine closure and production stoppages, all of which may result in claims being lodged to insurance companies. This highlights the importance of understanding and measuring how a company operates with regard to the local community.

Figure 15: An ASM operation in Burkina Faso

Source: Uvuna Sustainability, 2018

Environmental drivers

Long term impact of mines – closure

When ore can no longer be extracted from a mine economically, the mine and associated facilities should be closed in a responsible manner. This includes the closing of waste facilities such as waste rock dumps, overburden, wet or semi-dry tailings, slags and in many instances contaminated mine water. The formal decommissioning of a mine reduces the potential for latent risks and long-term impacts on the local community and environment. Associated risks may include:

- Leaching of contaminated mine water into the local environment such as acid mine drainage from coal mines (Shahid, n.d), or metals and waste reagents concentrated during hydrometallurgical processing (Europa, 2009). This has the potential to create a pollution plume, which may stretch for many kilometres.
- Unstable waste dumps and facilities may (re)settle or fail, which can result in a large-scale disaster (e.g. Aberfan disaster, 1966).
- Potential for spontaneous combustion in sulphide-rich assets such as coal mines after closure.
- Inferior covers placed on top of waste facilities during closure may allow chemical and water ingress into the facilities, altering the chemistry of the waste and reducing facility stability. This increases the likelihood of continued generation of ground and surface water contamination, or even mine dump failure if excessive volumes of water are able to ingress and impact stability.

The suite of legislation pertaining to waste streams often includes best practice guidelines that mines are expected to implement (Europa, 2009). Proactive management of closure-related risks includes the appropriate selection of localities for waste disposal, and ground preparation ahead of active disposal, thereby ensuring maximum stability of facilities can be ensured. Rehabilitation trials should also be undertaken during the operational phase of the mine, increasing the likelihood of successful stabilisation.

The full closure of a mine is relatively rare however, as seen in the numerous examples of mines that have been abandoned or "mothballed". Where a mining company has gone out of business or not put aside enough provision to finance full closure, the liability often falls to the government in that region (e.g. Coal Authority, 2018).

Insurers may be impacted by environmental liability claims many years after a mine has closed. Depending on the severity of the pollution caused, this could represent a large and unexpected cost to the insurer. It is therefore an insurers' prerogative to ensure that mining projects are appropriately closed and waste streams addressed.

Insurers have an opportunity to assist and advise their clients on best practices with regard to the operational design of rehabilitation facilities during the early stages of a mining project. Land reclamation bonds in the mining insurance market have many benefits for insurers; money is set aside for land rehabilitation ensuring mines can be safely closed, lowering an insurer's exposure to risk. The existing asset incentivises owners to rehabilitate land concurrently with mining activities. This has proven to be more effective than rehabilitation at the end of mining projects and insurers can earn a profit from interest gained while bonds are invested in the financial market.

Recycling and the move to the circular economy

A circular economy is one in which resources are kept in use for as long as possible *(see Figure 16)*. Where possible, waste is designed out and products are optimised for a cycle of disassembly and reuse (Ellen Macarthur Foundation, n.d). Mining has a large role to play in the circular economy. No matter how effective our recycling, we will always require new materials as technologies change and improve.

Policies based on circular economy principles have been launched around the world. For example, in the EU the End-of-Life Vehicles Directive (2000), the Waste Electrical and Electronic Equipment Directive (2000) and the directive on eco-design requirements for energy-using products (2005) have been transcribed into legislation in EU states (Europa, 2017). The Mining Association of Canada (MAC) designed a "towards sustainable mining initiative" which incorporates circular economy principals and is aimed at improving mine operations and mine closures. The initiative recommends that slag is to be used in aggregate and concrete in road construction; overburden used for landscape contouring and revegetation during mine closure; mining equipment such as tyres and heavy machinery to be recycled; and key mining inputs such as water and chemicals to be reused (Mining, 2004).

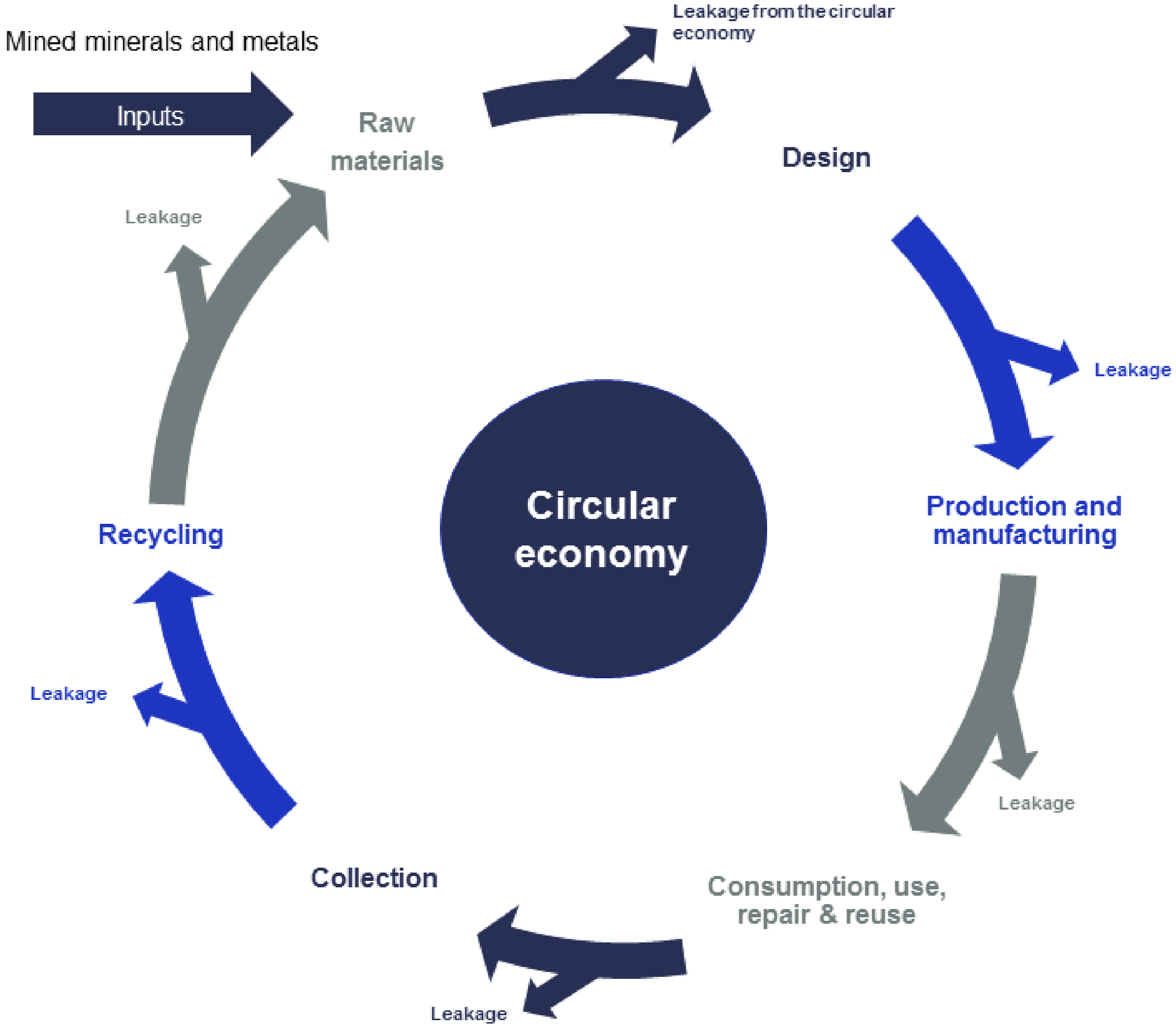
Circular economy principals can be further applied to other activities in the mining sector. Circularity is enhanced at the smelting and refining stage of ore by increasing the recovery of mining by-products. Copper processing can recover cobalt, molybdenum, gold, silver, selenium and platinum group metals (PGMs), (Brady, 2016). Steel is the most recycled material in the world with 630 million tonnes recycled annually (Broadbent, 2018).

The circular economy model places a great deal of emphasis on the concept of recycling metals from the “urban mine”. Stocks of resources are locked up in buildings, cars, planes, telecommunication infrastructure and personal devices such as telephones, laptops and TVs. While recycling of industrial metals such as copper wire is relatively straightforward, as it is used in its elemental form, technology metals such as REEs and gold are used in small concentrations in combinations not found in nature. This complicates their end of life re-use and sometimes results in their extraction being uneconomical (Bloodworth, 2014). Manufacturing processes must be optimised to consider end-of-life recoverability of metals in a circular model. The European Institute of Innovation and Technology Raw Materials (EIT) assists with enhancing recoverability by driving research and innovation in the European raw materials sector, combining knowledge from businesses, educational providers and research groups (Hanghøj, 2017).

Societal demand for metal requirements cannot be met by recycling alone. Primary mining of resources and secondary recovery must be considered within the same system to effectively balance supply and demand (Bloodworth, 2014). The mining industry can teach the recycling sector a great deal about optimising processes for maximum metal recovery. Mining companies of the future could become suppliers of material as opposed to primary miners, not dissimilar to the evolution of industrial quarriers to aggregate suppliers.

Insurers can benefit from a circular economy through the elimination of waste facilities such as tailings dams, eliminating the risk they impose on a mine site. Machinery will also be purchased, or increasingly leased, for the long-term. This will require refined insurance products to meet the needs of clients. As recycling increases, and mining potentially moves downstream into this growing market space with the metallurgical skills inherent to mining, opportunities emerge for insures to enter new markets with the miners and write new business by insuring mineral and metal recycling facilities.

Figure 16: Diagram of a circular economy



Source: Lloyd’s, Satarla, 2018

Opportunities for insurers

Emerging Risks Report 2018

Technology

Opportunities for insurers

As outlined above, many opportunities for insurers exist in the rapidly evolving mining industry. Actions they could take to realise these opportunities include:

1. Get involved earlier

Insurers currently tend to get involved in mining projects after the design for the operation has been signed off and finance is being finalised. This is too late in the project to change aspects of the design that are going to be inherently high risk for the future operation of the mine. Where possible, insurers and miners should start to build their relationship earlier.

2. Take an enterprise risk management approach

Not all risks posed by a mine can be insured; this may be due to a company's financial constraints or because the risk is uninsurable e.g. commodity reserves which have yet to be extracted. By assessing both insurable and uninsurable risks as a network, more refined and appropriate insurance products can be offered.

3. Learn from and build relationships with miners

It is important for both insurers and miners to learn from one another and achieve a deeper understanding of the objectives both parties wish to achieve through purchasing insurance. Enhanced communication helps rule out assumptions made by both parties as to how one another operates. Insurers should facilitate communication even when a miner is not currently their client.

4. Include a sustainability index in the terms of cover

It was supported by everyone interviewed for this report that the better the attitude towards sustainability adopted by a mining company and operation, the lower the residual risk faced by that mine. A wealth of sustainability indices exist, primarily based on sustainability reporting provided by mining companies (e.g. Dow Jones indices; FTSE4Good, GRI reporting). These are used by financiers and NGOs to rank and assess mining organisations. Should insurers begin to regularly use such indices and sustainability datasets to assess the level of risk posed by a mine, it is likely these indices will be refined and improved further. Alternatively insurers could create and audit their own index.

5. Make use of increasingly transparent value chains

Social expectation coupled with technology advancements such as blockchain is allowing the supply chain for materials to become increasingly transparent. There is potential for enhanced insurance of products as they pass along the full value chain.

6. Use remote, timely and transparent monitoring of mine sites

Technology such as the internet of things and improved satellite image capabilities increasingly allows for the ongoing, live monitoring of high-risk assets. It also allows for more rapid understanding of the retrospective causal factors leading to a loss event, and therefore faster claims pay-outs.

7. Take advantage of the increased requirement for cyber insurance

The increased digitalisation of mines will result in an increased risk of cybercrime, and therefore requirement for insurance in this area.

8. Use financial instruments to drive better mine closure practices

Many mines will be put into care and maintenance instead of being closed properly due to the cost involved. The introduction of land reclamation bonds to the mining insurance market ensures that mines are safely closed and alleviates the potential for long-term environmental and social risks. Setting aside adequate budgetary provision for land reclamation encourages mining companies to follow best practice guidelines and comply with increasingly strict legislation for waste disposal. Early involvement by the insurance company in mine design would further ensure these best practices are adopted and effectively implemented throughout the lifecycle.

9. Get a better understanding of new technology and "prototypes"

In order for the mining sector to deliver on the demand it faces for novel and frontier zone minerals, new technology is going to have to be deployed. Currently a 50% premium exists on this sort of technology, often making insurance economically unviable. As a result, miners either absorb the risk in-house or default to tried-and-tested methodologies, many of which introduce larger risks downstream. Insurers should engage more closely with miners so that all parties can understand the nature of new and emerging technology and the true risk associated with it.

10. Increase knowledge of new mining geographies

Insurers will have to expand their knowledge and coverage of territories if the mining of tomorrow is to be insured. Mines focusing on novel materials will be high-risk projects as they will be forced to use prototype technology and accelerated timeframes to achieve full ramp-up and operation.

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