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PERSPECTIVE

CLIMATE CHANGE

THE IMPACT ON THE COPPER MINING INDUSTRY

GEM

Paving the way for the future of mining

INDEX

ABOUT GEM

We are a specialized Industrial Engineering company that provides support to the mining industry in matters related to management and economics. Our expertise covers various fields as we develop the most advanced tools applied in the mining sector. With over 14 years of experience and the successful implementation of more than 400 projects worldwide, we stand out for our solid track record and commitment to excellence in the sector.

MISSION

We are a company providing products and services in industrial engineering that enable the path for the future of mining while maximizing the business value for our clients.

At GEM, we are committed to becoming a beacon for the global mining industry.

EDITORIAL

Necessary Transformation of Copper Mining in the Face of the Climate Change Challenge.

In the current scenario, marked by the growing urgency of climate change, the copper mining industry is at a critical crossroads that demands deep reflection and decisive actions. This report comprehensively addresses the intersection between copper mining and environmental challenges, exploring both the threats and opportunities in this context.

Copper mining, essential for various industries, has traditionally been associated with significant environmental impacts. The extraction and processing of this metal have been responsible for greenhouse gas emissions, deforestation, and disruptions to local ecosystems. At a time when the global community recognizes the imperative need to address climate change, the copper mining industry is under unprecedented pressure to evolve towards more sustainable practices.

This editorial seeks not only to highlight the environmental challenges facing the industry but also to propose a positive approach to transformation. Technology and innovation play a crucial role in this evolution. From the development of more efficient extraction methods to the implementation of more sustainable production processes, the copper mining industry has the opportunity to lead the way towards mining with a reduced negative impact on climate change.

Copper mining companies have the opportunity not only to reduce their environmental footprint but also to contribute to the development of local communities and promote fair and ethical practices.

ISAAC PAREDES
CHIEF OPERATING OFFICER GEM

In conclusion, the copper mining industry is at a crucial moment, where decisions made at this time will have a significant impact on the industry of tomorrow. This editorial advocates for a bold vision and a firm commitment to sustainability, not only as a response to current demands but as an investment in a future where copper mining and the environment can coexist harmoniously.

INTRODUCTION

According to the IPCC (2023), the concept of climate change is based on the understanding that human activities, primarily the emissions of greenhouse gases (GHGs), have indisputably caused global warming. This warming is evidenced by an increase of 1.1 [°C] in global surface temperature from the pre-industrial period (1850-1900) to the decade 2011-2020. The temperature rise is more pronounced over land (1.59 [°C]) than over the ocean (0.88 [°C]), and the first two decades of the 21st century experienced an increase of 0.99 [°C] compared to the reference period (IPCC, 2023).

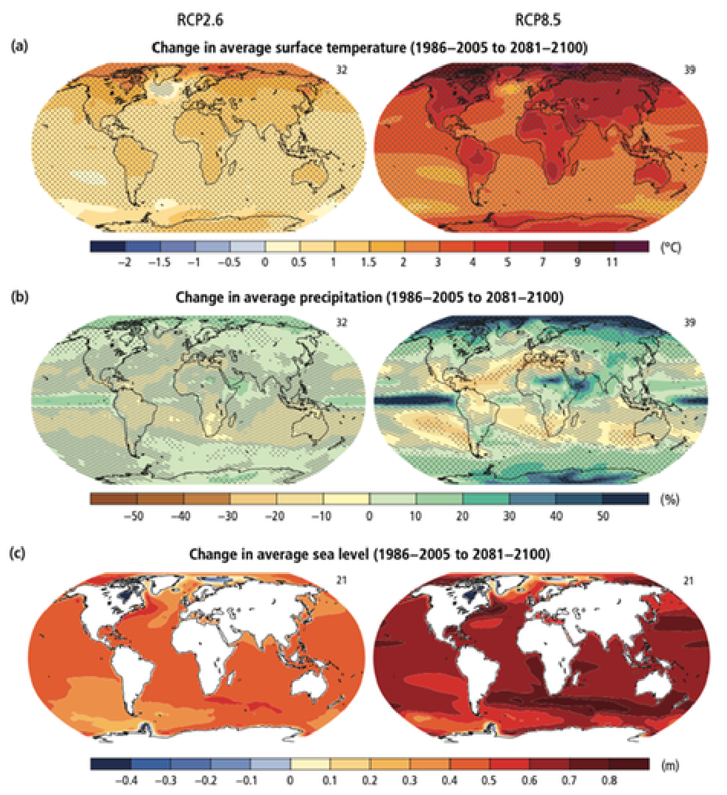
Lacking a singular model of climate change, various scenarios are used to capture the complexities and uncertainties associated with future climate change outcomes. In this regard, the Representative Concentration Pathways (RCPs) encompass diverse scenarios of global warming by modeling future concentrations of GHGs and associated pollutants resulting from human activities.

The RCPs provide numerical values for future amounts of greenhouse gas emissions (GEI) and the associated radiative forcing, which represents the extra energy absorbed by the Earth system due to increased pollution causing climate change. The scenarios range from RCP2.6 (lower emissions) to RCP8.5 (higher emissions).

ERCP8.5 is a scenario preferred and mandated by environmental authorities for a robust risk analysis, including in the mining industry. It anticipates more severe climate impacts, such as temperature increases (around 3.7 [°C]), sea level rise (around 0.63 [m]), extreme weather events, and other environmental changes that significantly affect mining operations and production. RCP8.5 provides insight into a future with minimal climate mitigation and helps understand the worst-case climate scenarios. It aids in assessing potential challenges and climate-related vulnerabilities.

Figure 1 represents the difference between RCP2.6, the best-case scenario for limiting anthropogenic climate change, and RCP8.5, the worst-case scenario with rapid emissions growth, especially during the first half of the century.

FIGURE 1. CONTRASTING CLIMATE FUTURES: RCP2.6 VS. RCP8.5



Source: IPCC (2014)

In the industrial landscape, the undeniable reality of climate change underscores the imperative of responsible and sustainable practices. Human-induced global warming, primarily driven by industrial activities, has led to significant disruptions in the atmosphere, oceans, and ecosystems. Rising sea levels and the intensification of extreme weather events pose challenges to industries worldwide.

Therefore, mining, as a significant anthropogenic activity, plays a role in climate change through its contributions to greenhouse gas emissions and environmental disruption. The extraction and processing of minerals are often associated with the combustion of fossil fuels and, consequently, the release of carbon dioxide, along with other pollutants, contributing to the global carbon footprint.

Mining companies must address their environmental footprint and adopt sustainable practices to mitigate their contribution to global warming. However, it is crucial to recognize that climate change also poses substantial risks to the mining industry, both directly and indirectly.

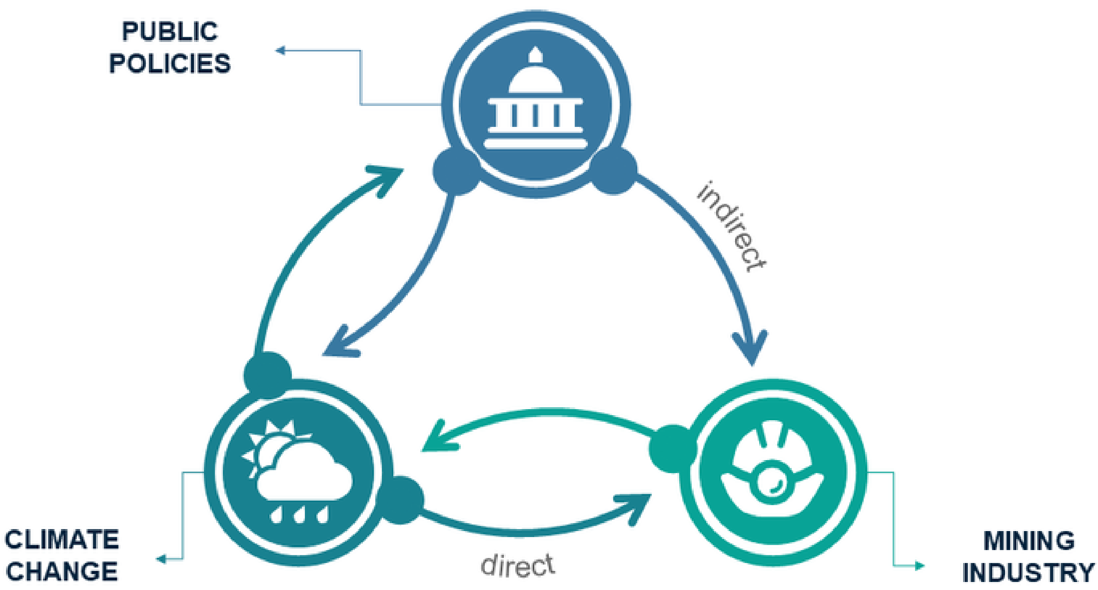
The indirect impact is manifested through the implications of public policies, such as carbon pricing mechanisms, mining royalties and fees, regulations and standards on emissions, land use and conservation policies, water use regulations, and insurance costs, among others (see **Figure 2**).

The objective of this report is to assess the vulnerability of the mining industry to the increasing hazards associated with climate change.

It aims to examine the potential risks and challenges posed by changing climatic conditions, emphasizing the need to take proactive measures to adapt to the evolving climate landscape.

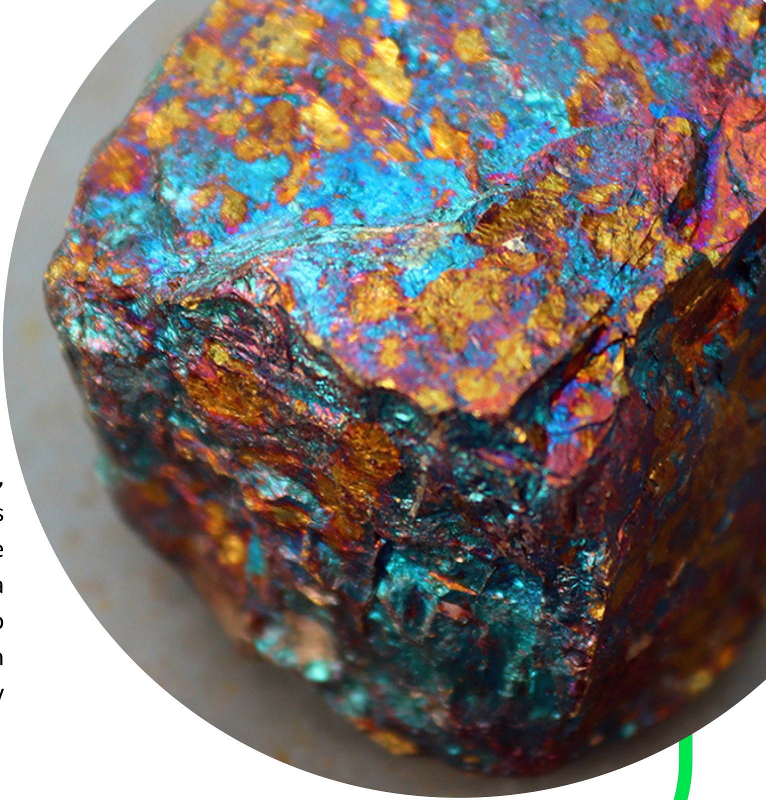
Neglecting the impact of climate change on mining is suggested to lead to heightened vulnerabilities and significant operational and financial challenges.

FIGURE 2. RELATIONSHIP BETWEEN CLIMATE CHANGE AND MINING INDUSTRY



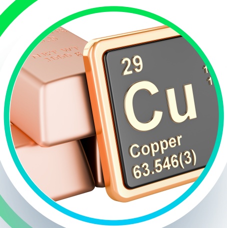
Source: Own elaboration

CONTEXT



Copper, a cornerstone

Copper, a cornerstone among globally extracted metals, plays a pivotal role in various industries (see **Figure 3**). Its versatility in electronics, construction, and renewable energies underscores its indispensable nature. As a leader in conductivity and durability, copper continues to drive innovation and sustainable progress, making it an essential component of our interconnected and rapidly evolving world.



Copper is extracted worldwide.

Copper is extracted worldwide. Chile, as a historical leader, hosts significant mines such as Chuquicamata and El Teniente, operated by Codelco, the world's largest producer, or the massive Escondida mine, operated by BHP Billiton (Mining.com, May 25, 2023; Statista, November 23, 2023). Peru, with mines like Cerro Verde or the copper-zinc Antamina mine (BHP Billiton), the Democratic Republic of the Congo (Glencore), and mining giants like China (Zijin Mining Group), also contribute significantly. Other notable producers include the United States and Indonesia (Freeport-McMoRan), Russia (Norilsk Nickel), Australia (Glencore), Zambia (First Quantum Minerals), Mexico (Grupo México), and Kazakhstan (Kazakhmys, Kazminerals).

Large-scale global production.

Copper production methods vary: in Chile, open-pit mining is common, while in other places, underground mining, such as at El Teniente, and heap leaching in certain operations are prevalent.

Given the enormous global production, the copper mining industry leaves a considerable environmental and social footprint. The scale of operations, from extraction to processing, has far-reaching implications: soil disturbance and water use, energy intensity, waste generation, habitat alteration, and community and social aspects.

ALL THE METALS WE MINED IN 2022

The world produced almost 2.8 billion tonnes of metal in 2022

METALS VS ORES

Ores
Are naturally occurring rocks that contain metals or metal compounds

Metals
Are the valuable parts of ores that can be extracted and sold

INDUSTRIAL METALS
185.111.835 tonnes

2.600.000.000 ORE Tonnes **IRON**

69 M Aluminum

41 M Chromium

22 M Copper

20 M Manganese

13 M Zinc

9,5 M Titanium

4,5 M Lead

3,3 M Nickel

1,4 M Zircon

1 M Magnesium

340 K Strontium

49 K Uranium

20 K Bismuth

2,2 K Mercury

280 Berylium

Tecnhnology and precious metals
1.500.008 tonnes

310K Tin

300K Rare earth oxides

250K Molybdenum

190K Cobalt

130K Lithium

100 K Vanadium

84K Tungsten

79K Niobium

26K Silver

24K Cadmium

3,1K Gold

2K Tantalum

900 Indium

550 Gallium

400 Platinum group metals

58 Rhenium

Largest End-use

- Steelmaking
- Construction
- Chemicals
- Energy/batteries
- Alloying agents
- Magnets
- Electronics
- Others

Usable ore: 2.600.000.000 tonnes
Iron content: 1.600.000.000 tonnes

Source: Own elaboration based on USGS Mineral Commodity Summaries (2023)

CLIMATE CHANGE AND COPPER MINING

As mentioned earlier, the mining industry also faces significant impacts from climate change. Changes in weather patterns, extreme events, and ecosystem disruptions pose substantial risks to mining operations. These risks include productivity interruptions, safety issues, and challenges in supply chains. The industry must address these vulnerabilities and implement adaptation strategies to navigate effectively through the changing climate landscape.

Multiple research studies observe the impact of climate change-induced phenomena across different stages of mining, from exploration to transportation, to varying extents. A comprehensive review has allowed us to identify the primary phenomena directly affecting the industry, including copper mining.

Table 1 has been divided into four subcategories based on the source of origin of climatic phenomena: (a) high temperatures, (b) low temperatures, (c) hydrometeorological events, and (d) other hazards. In addition to a brief summarized overview, each table contains a detailed description of the impacts caused by each listed climatic hazard, distributed across the affected areas: (i) operational disruptions, (ii) damage to infrastructure, (iii) health and safety issues, and (iv) other areas.

TABLE 1a. PHENOMENA INDUCED BY CLIMATE CHANGE AFFECTING COPPER MINING PRODUCTION AND COSTS. HIGH TEMPERATURES

IMPACT AREA	WILDFIRES	HEATWAVES	DROUGHTS	CHANGES IN GEO RANGES OF FLORA
OPERATIONAL DISRUPTIONS	Evacuation orders and road closures Process water contamination with ash, sediment, and chemicals	Power outages Reduction of process water availability	Shortage water supply required for ore processing, dust suppression, equipment cooling	Soil stability violation in mining areas Limited areas available for mining exploration and extraction
INFRAESTRUCTURE DAMAGE	Roads, power lines, communication networks destruction	Malfunctions and breakdowns of equipment	Additional investments in alternative water sources or advanced water recycling technologies	N/A
HEALTH AND SAFETY CONCERNS	Harmful pollutants from wildfire smokes Poor air quality	Reduced productivity and concentration levels Cardiovascular issues or respiratory diseases Dehydration and fatigue Expansion of the habitat of disease-carrying mosquitoes, responsible for malaria, dengue, zika virus, yellow fever	Respiratory illnesses and diseases Dust-related illnesses such as silicosis	Workers might need to adapt to new locations, get proper training to recognize and protect the species Some of the newly identified plant species might be toxic
OTHER AREAS	Soil erosion and water pollution causing stricter environmental regulations	Dry conditions during heatwaves increase the risk of wildfires	Stricter environmental regulations related to water usage and conservation	Stricter guidelines and regulations to protect newly identified plant species requiring adjustment in mining practises

Source: Agrawala et al. (2010); Chavala (2016); Ford et al. (2010); Gasbarro & Pinkse (2016); Ghadge et al. (2019); Goldstein et al. (2019); Mason et al. (2013); Rüttinger et al. (2020); Simpson et al. (2021)

T**able 1a** presents climate change-induced phenomena caused by extremely high temperatures, usually accompanied by low precipitation levels: wildfires, heatwaves, droughts, and changes in the geographical distribution of flora.

Rising temperatures pose operational challenges in copper mining. Increased heat can strain equipment and machinery, leading to potential breakdowns. Additionally, additional resources may be required for cooling systems, affecting overall operational efficiency.

Climate change exacerbates water scarcity issues, crucial for copper mining processes. Rising temperatures contribute to reducing water availability, impacting ore processing, dust suppression, and equipment cooling. This can lead to decreased production levels and increased competition for water resources.

High temperatures contribute to the vulnerability of critical infrastructure in copper mining areas. Roads, power lines, and other components may experience accelerated wear and require more maintenance and repairs.

TABLE 1b. PHENOMENA INDUCED BY CLIMATE CHANGE AFFECTING COPPER MINING PRODUCTION AND COSTS. LOW TEMPERATURES

IMPACT AREA	EXTREME SNOW	HAILSTORM	EXTREME COLD	GLACIAL MELTING
OPERATIONAL DISRUPTIONS	Road obstruction Power outages	Destruction of mining facilities, buildings, and storage units Undesirable repairs and inspections	Costly repairs and operational downtime caused by frozen fuel lines and engine failures Issues with ore processing, dust control caused by water freeze Production delays	Reducec glacier volume altering water availability, leading to water shortages during dry seasons
INFRAESTRUCTURE DAMAGE	Equipment destruction Mine roofs, sheds of storage facility collapse	Substantial damage to mining equipment, vehicles and infraestructure and facilities Delayed replacement of the damage parts	Machinery, vehicles, and hydraulic systems freezing or malfunctioning Pipelines, conveyors, and storage facilities damage Metal structures becoming brittle and prone to breakage	Higher sediment loads in nearby rivers impacting water quality and increasing the wear and tear on mining and processing equipment Roads, bridges, and storage facilities erosion
HEALTH AND SAFETY CONCERNS	Risk of accidents and injuries due to slippery surfaces and	Direct injuries or creation of hazardous working conditions due to surfaces slippery and increasing the risk of trips and falls	Cold-related illenesses incl. hypothermia and frostbite Prolonged exposure leading to numbness, reduced dexterity, and, in severe cases, tissue damage Reduced working hours and productivity slowed down by cold conditions, bulky and warm PPE	Sudden floods and flash floods posing inmediate risks to those working in low-lying areas
OTHER AREAS	Delayed delivery of essential materials and spare parts	N/A	Additional investments required in cold-weather specific equipment, infraestructure and training	Changes in glacial melt patterns can necessitate adjustments to environmental regulations

Source:* *Agrawala et al. (2010); Ford et al. (2010); Gashbarn & Pinkse (2016); Ghadge et al. (2019); Klein et al. (2022); Loechel et al. (2013); Mavrommatis &Damigos (2020)

Heatwaves can overload electrical grids and lead to outages. Given the high energy consumption of the industry, disruptions in power supply can impact production schedules and increase operational costs.

Finally, high temperatures pose a health risk to mining workers, affecting their productivity and well-being. Thermal stress, dehydration, fatigue, and mosquito-borne illnesses increase the risk of accidents.

Table 1b contains information on the effects caused by low temperatures on the copper mining industry: extreme snowfall, hail, extreme cold, and glacier melting. Operational disruptions that may arise from cold temperatures and snow and hail precipitation are primarily associated with restricted access to the mining site for personnel, equipment, and supplies, as well as power outages.

Furthermore, snow and ice can impact the operational lifespan efficiency of mining equipment. All of this can halt operations for a tangible period until spare parts arrive and all necessary repairs are completed.

In such conditions, in addition to the obvious risk of hypothermia and, in general, hazardous working conditions, mining workers are exposed to more specific disruptions. The need to wear bulky and warm personal protective equipment (PPE) results in reduced working hours and productivity, slowing down the work process.

TABLE 1c. PHENOMENA INDUCED BY CLIMATE CHANGE AFFECTING COPPER MINING PRODUCTION AND COSTS. HYDROMETEOROLOGICAL EVENTS

IMPACT AREA	FLOODING	SEA LEVEL RISE	SEA WELLS	OCEAN ACIDIFICATION
OPERATIONAL DISRUPTIONS	Submersion of the machinery, equipment, and access roads Mine site contamination with silt, debris and chemicals	Risk of flooding and erosion in coastal and low-lying regions Intrusion of saltwater into freshwater sources, affecting process water quality Logistic delays	Difficulties with loading or unloading materials, operating marine vessels, or conducting offshore mining activities Disruption of the maritime transportation of copper products Increase in demurrage cost	N/A
INFRAESTRUCTURE DAMAGE	Mines, processing plants, storage facilities, and transportation system destruction	Critical infraestructure destruction: processing plants, storage facilities, transportation routes	Coastline infraestructure destruction (jetties, piers,) Erosion and structural damage	Accelerated corrosion of metal structures and equipment used in marine environments
HEALTH AND SAFETY CONCERNS	Risk of being trapped underground Compromised stability of mine structures Exposure to waterbone diseas and hypothermia	Exposure to waterbone illnesses, skin infections, and respiratory problems Risk of flooding and other water-related incidents at the workplace	High risk of accidents, injuries and seasickness Physical strain and mental exhaustion	N/A
OTHER AREAS	Environmental contamination caused by mining operations releasing pollutants into floodwaters	Stricter regulations and environmental standards for mining operations located in vulnerable coastal areas	Additional investments in advanced weather monitoring systems to plan operations accordingly	Stricter environmental regulations forcing mining companies to minmize environmental impact, potentially increasing compliance costs

Source: Agrawala et al. (2010); Chavalala (2016); Ford et al. (2010); Gasbarro & Pinkse (2016); Ghadge et al. (2019); Janson et al. (2020); Loechel et al. (2013); Mason et al. (2013); Sharma & Franks (2013)

Table 1c contains the effects of hydrometeorological phenomena such as floods, sea level rise, storm surges, and ocean acidification. These climatic phenomena have serious consequences for the copper industry, causing operational disruptions, affecting infrastructure stability, halting production, as well as temporary logistic delays and increased maintenance costs.

In wet conditions with the risk of seawater infiltration, mining machinery and equipment are susceptible to detrimental effects, which is particularly relevant for operations conducted in coastal and low-lying areas.

The corrosive nature of seawater accelerates the deterioration of metallic components in mining equipment, reducing their operational efficiency and lifespan. Electrical control systems are susceptible to corrosion, leading to malfunctions. Water management systems, including pumps and pipes, experience increased wear and require more frequent maintenance.

Unstable and unpredictable working conditions, coupled with a growing risk of waterborne diseases, can lead to physical strain and mental exhaustion.

TABLE 1d. PHENOMENA INDUCED BY CLIMATE CHANGE AFFECTING COPPER MINING PRODUCTION AND COSTS. OTHER CLIMATE RISKS

IMPACT AREA	FOG / MIST	RAINFALL-INDUCED LANDSLIDES	TROPICAL CYCLONES	PERMAFROST THAWING
OPERATIONAL DISRUPTIONS	Limited visibility challenging to safely operation of heavy machinery and navigation within the mine site Transportation routes disruption limiting access to the mine site	Block of access roads, equipment damage, and mining operations disruptions Block of transportation routes	Power outages, flooding and damaged infrastructure Inundation of mine sites, complicating access to machinery to access and its operation Disruption of transportation routes	Ground instability causing subsidence and sinkholes Mining infraestructure (roads, foundations, and pipelines) disruption
INFRAESTRUCTURE DAMAGE	Moisture penetrating electrical systems and machinery, leading to equipment malfuntions and breakdowns	Crucial mining infrastructure (conveyor belts, storage facilities and processing plants) damage	Damage and destruction of the buildings, roads, bridges, and equipment	Building on unstable ground requiring expensive engineering solutions to ensure the stability of structures
HEALTH AND SAFETY CONCERNS	Respiratory issues The risk of slips and falls due to wet and slippery surfaces	Inmediate risk of injuries and fatalities for those working in or near the affected area Workers involved in rescue and cleanup efforts are exposed to hazardous materials and unstable ground conditions	The danger of falling debris, structural collapses, and flooding Stagnant water can become breeding grounds for waterbone illnesses, skin infections, and respiratory problems	Hazardous working conditions due to sudden ground collapses, sinkholes, and landslides Increased moisture creating breeding grounds for insects, increasing the risk of vector-borne diseases
OTHER AREAS	N/A	Soil erosion, sedimentation of water bodies affecting water quality and aquatic ecosystems and leading to stricter regulations and increased scrutiny	Soil erosion, landslides and water pollution caused by runoff from mining sites Environmental damage leading to regulatory scrutiny and fines impacting industrys reputation and financial standing	Alteration of the natural drainage patterns, leading to increased water infiltration and mine site flooding

Source: Agrawala et al. (2010); Chavalala (2016); Ford et al. (2010); Gasbarro & Pinkse (2016); Ghadge et al. (2019); Janson et al. (2020); Loechel et al. (2013); Mason et al. (2013); Sharma & Franks (2013)

Table 1d compiles all the remaining climate risks examined: fog/mist, rainfall-induced landslides, tropical cyclones, and permafrost thawing.

Similar to the previously observed cases, the occurrence of these phenomena results in limited visibility at the mine site, disruptions in transportation routes, blockage of access ways, leading to the suspension of mining and production activities, and delays in the delivery of materials, equipment, and spare parts. The stability of essential systems may be compromised, leading to structural damage and operational and infrastructural disruptions.

In each of the scenarios outlined in **Table 1**, miners at the epicenter of these events are exposed to serious physical threats. Furthermore, in extreme conditions, they are also compelled to shoulder additional workload and responsibility, undergoing special training, coping with the consequences of climate disasters, and participating in rescue operations.

This imposes additional physical exhaustion and mental stress on them. Finally, all observed climate change phenomena may lead to the introduction of stricter environmental regulations. Governments and regulatory bodies can enforce measures on water usage, emissions, and sustainable mining practices.

Additionally, concerns about climate change and the global shift toward sustainability can influence the dynamics of the copper market. Stakeholders are increasingly mindful of environmental and social responsibility, impacting the industry's reputation and market access.

Disruptions to operations and infrastructure damages are presumed to entail a higher proportion of financial risks, while the realm of health and safety can be associated with both financial and human losses.

Therefore, from operational disruptions and cost escalation to market volatility and regulatory pressures, navigating the complexities of climate change is essential for the long-term sustainability and economic resilience of the industry.

ENVIRONMENTAL COMPLIANCE IN COPPER MINING

As noted earlier, the evolution of climate regulations and policies significantly impacts the copper mining industry. Compliance with new regulations and emerging standards is undertaken by companies not only as a new global requirement but also as a critical component for strategic and marketing purposes.

In addition to establishing a risk management system that addresses issues related to climate change and biodiversity preservation, copper mining companies strive to gain competitive advantages by becoming more attractive for investment.

By incorporating global environmental priorities, dictated by various performance management associations, both general and mining-related, companies primarily focus on decarbonization, health and safety, and climate change issues. For more information on the key climate-related commitments in the copper mining industry, refer to the "GEM Perspective" report (June 2023).

Furthermore, multiple studies assert that "although the mining sector perceives climate change as a threat to its activities, it has not invested the necessary resources to adapt to future climate" (Mavrommatis & Damigos, 2020). It is also emphasized that "ignoring climate change and extreme weather events can have serious, costly, and far-reaching consequences," for which many companies do not seem to be prepared (Klein et al., 2022).

In this regard, **Figures 4 and 5** present the observation of climate change-induced phenomena that have significantly impacted copper-mining countries and companies in the last two decades. Evidently, in Figure 4, the highest number of cases was recorded in Australian and Canadian mines, mainly affected by heavy rains and associated hazards such as floods and landslides, as well as wildfires, respectively.

However, despite mining companies working diligently to establish suitable medium and long-term goals to meet the new reality, the lack of a unified strategy and a clear understanding of environmental and sustainable mining components risks slowing down the transition from planning to actual actions

FIGURE 4. GLOBAL IMPACT: CLIMATE CHANGE-INDUCED EVENTS IN THE COPPER MINING INDUSTRY SINCE 2010

Source: Own elaboration

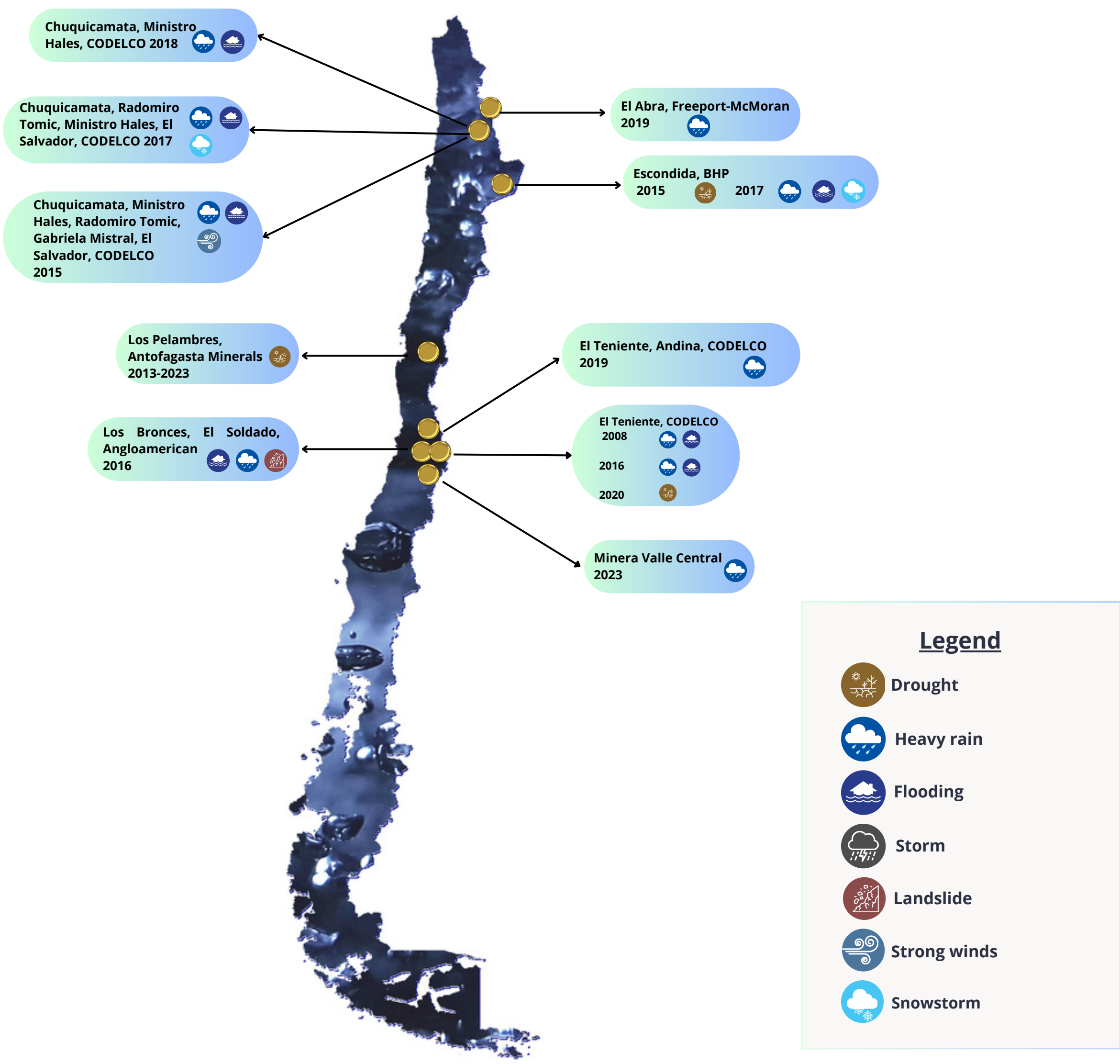
Meanwhile, Chile, as seen in Figure 5, being the world's largest copper producer and heavily reliant on open-pit mining, also faces notable vulnerabilities in the context of climate change. Its unique environmental characteristics, climatic diversity, and geographic conditions throughout the country contribute to the industry's susceptibility to droughts, rainfall, floods, landslides, strong winds, snowstorms, and earthquakes. For example, in recent years, specifically in 2016, 2017, 2019, and 2023, the country experienced rainfall-induced landslides characterized by weather fronts, intense rains, a phenomenal amount of precipitation, and a freezing level isotherm that remained at the 2,900-3,300 meters above sea level range.

As a consequence, at various times, significant copper mining operations were affected, including El Teniente, Chuquicamata, Radomiro Tomic, Ministro Hales, El Salvador, Andina (Codelco), Los Bronces, El Soldado (Anglo American), Minera Escondida (BHP Billiton), El Abra (Freeport-McMoRan), and Minera Valle Central, among others.

As can be observed, even the largest and most advanced companies are not immune to the forces of nature. Among the severe consequences recorded are the suspension or closure of operations, disruption of transportation routes, closure of access roads to the mining site, power and water supply outages, and risks to health and safety.

This led to significant economic losses reflected in the reduction of annual production. For example, in 2016, Codelco announced the suspension of operations at its long-standing El Teniente underground mine, anticipating a reduction of approximately 5,000 tons in fine copper production.

FIGURE 5. CHILE: CLIMATE CHANGE-INDUCED EVENTS IN THE COPPER MINING INDUSTRY SINCE 2010



Source: Own elaboration

CASE STUDIES

In order to better understand the impact of climate change-induced events it would be interesting to take a closer look at a few of them within the copper mining operations conducted in Chile

CASE 1: RAINFAL-INDUCED LANDSLIDE RISK EVALUATION AT THE COPPER MINE A

01

BACKGROUND: Case 1 examines the risk of the alluvial phenomenon at the Copper Mine A sector to ensure its future operations. It has been observed that the occurrence of the alluvial events has been a substantial challenge for the Mine A, both in the past and in the future.
In accordance with the most pessimistic scenario (RCP8.5), it has been estimated that the minimum temperature at the observation area could increase by more than 3 [°C] by the end of the century (please see Figure 6).
Further climate change at the forecasted pace would lead to more intense rainfall and higher temperatures (increasing the zero isotherm). Each increase in temperature in the area will lead to events with greater intensity, translated into greater instantaneous and accumulated precipitation for each event. It is expected that the probability of landslides would increase between 20% to 35% per year in 2023 to between 35% to 46% per year in 2038 and exceed 50% in 2075. Apparently, in this case the operational and economic damage would grow as well, challenging the mining area even greater.

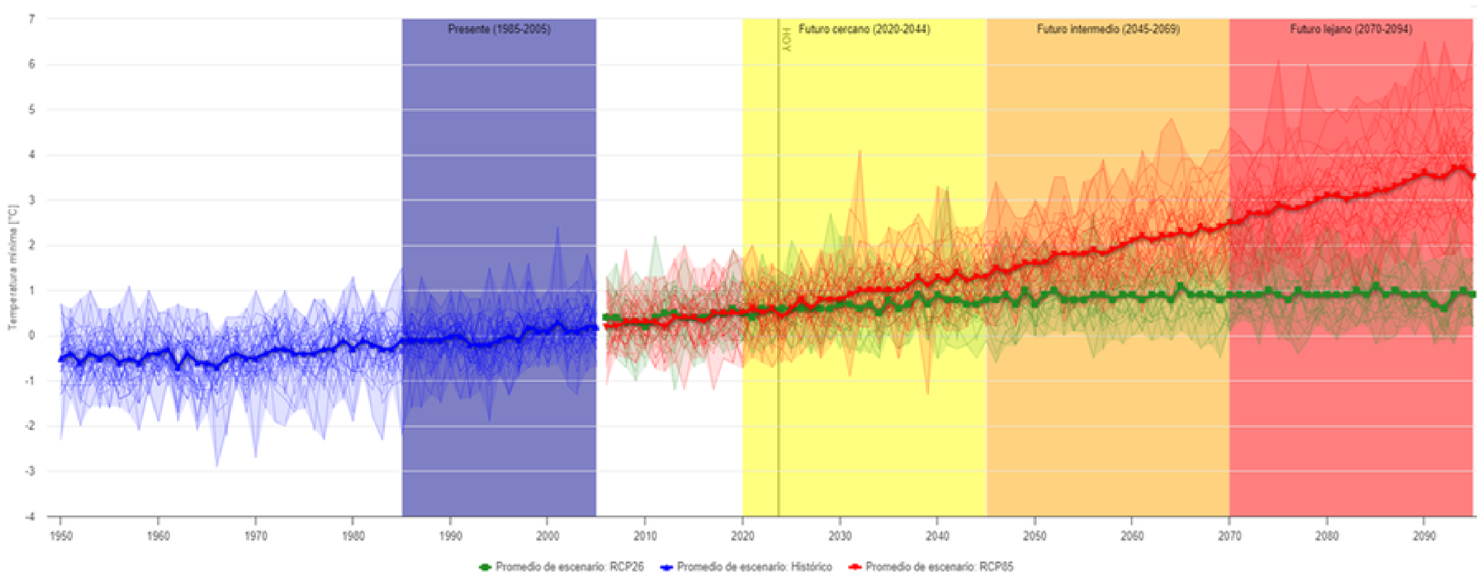
02

RESULTS: The Copper Mine A case took place in 2023 and was characterized by deadly floods destroying critical infrastructure at the mine area, including access roads, pulp channels, and maintenance objects, among others. It has been estimated that the cost of repairing the critical infrastructure was equivalent to 17 [cUS$/lb]. In general, the loss associated with the rainfall-induced landslide event was evaluated as 3 [%] of annual copper production.
According to previously discussed climate change models, the likelihood of such events occurring is anticipated to rise. Specifically, in the central-southern Chile zone housing Mine A, projections indicate an increase in temperature, linked to a rising snow isotherm and heightened precipitation intensity. Consequently, the rising probability of these events correlates with an augmented risk of reduced Net Present Value (NPV) for Copper Mine A, attributable to both lost operational days and increased repair costs.

03

RECOMMENDATIONS: Consequently, it has been advised to implement proactive measures to mitigate future risks at the Copper Mine A. Constructing appropriate barriers would be a cost-effective solution compared to the potential expenses associated with continued risk exposure. Installing engineered barriers, such as retaining walls or slope stabilization structures, can effectively reduce the likelihood and impact of landslides. This investment in preventive infrastructure not only safeguards the mine's operational continuity but also minimizes the financial implications related to potential production disruptions and the considerable costs of post-event recovery and repairs, both in short run and in the long run.

FIGURE 6. MINIMUM TEMPERATURE PROJECTION: RCP2.6 VS. RCP8.5



Source: Agrawala et al. (2010); Chavalala (2016); Ford et al. (2010); Gasbarro & Pinkse (2016); Ghadge et al. (2019); Janson et al. (2020); Loechel et al. (2013); Mason et al. (2013); Sharma & Franks (2013)

CASE 1: EVALUATION OF ECONOMIC, RISK AND OPTION IMPACT OF SEA SWELS ON THE PORT FACILITIES AT THE COPPER MINE B

01

BACKGROUND: A comprehensive analysis was undertaken to assess the potential risks posed by climate change-induced sea swells and their impact on the port facilities, with a specific focus on the shiploader at Copper Mine B. This evaluation considered the plausible scenario of shiploader failure resulting from a critical event.

As part of the analysis, it is proposed that, in the event of a significant incident causing the shiploader to be incapacitated, the remainder of the port operations would seamlessly continue in accordance with the business case. This strategic planning aims to ensure the resilience of the port facilities in the face of climate-related challenges, fostering operational continuity and preparedness for potential disruptions.

02

RESULTS: In evaluating both options for the development of the established scenario as depicted on Figure 7, it is evident that the risk most significantly impacting the business case is the potential failure of the shiploader. This risk is associated with a decline in copper concentrate sales, a situation that could be exacerbated if the project is not considered. However, this risk can be mitigated by efficiently shipping materials to the port.

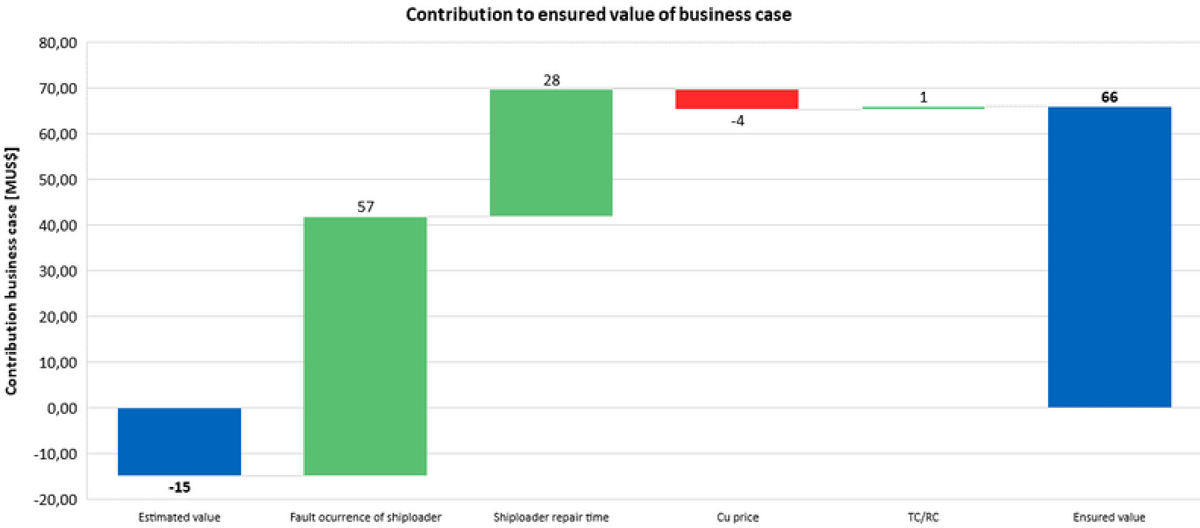
Upon careful analysis, it is concluded that the likelihood of shiploader failure is very low, estimated at no more than 1.1 [%] per year. Consequently, this failure can be classified as a rare event or, colloquially, a "black swan" occurrence. This insight informs decision-makers about the infrequency of such events, allowing for informed and strategic planning in the development and implementation of the selected scenario.

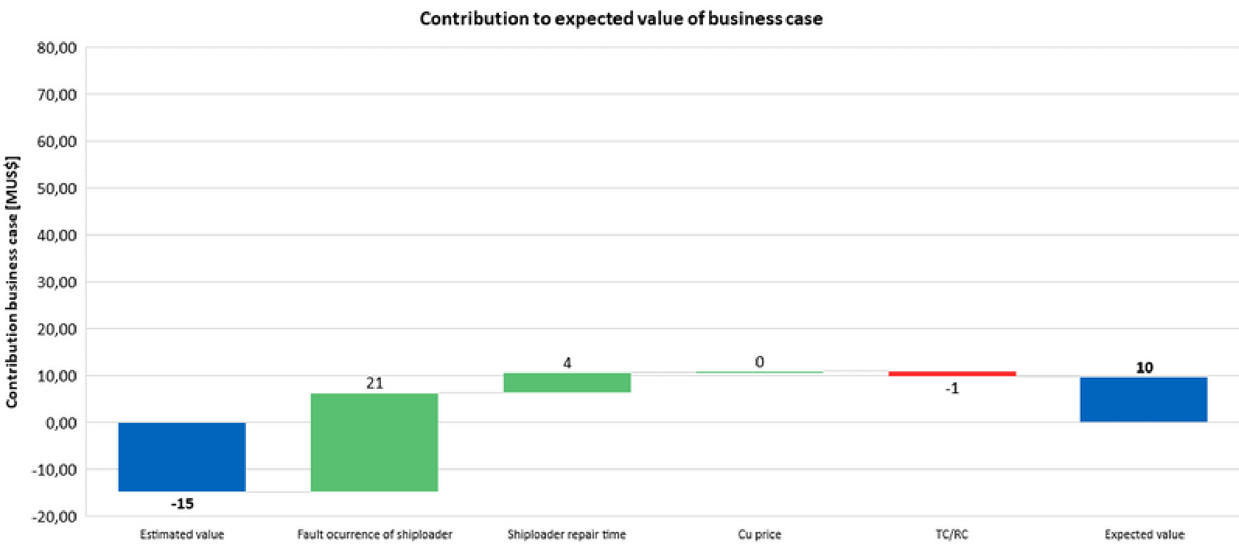
03

RRECOMMENDATIONS: In order to enhance the resilience and safety of operations, it was strongly recommended to undertake a comprehensive evaluation of the shiploader's structural integrity. This involves employing dynamic structural analyses to assess its failure rate, particularly under extreme weather conditions such as earthquakes and tsunamis. This thorough examination will pinpoint vulnerable areas within the infrastructure and facilitate the assessment of potential damages. Subsequently, it enables a strategic evaluation of reinforcements or auxiliary structures to mitigate the risk of failure.

Additionally, it is advised to uphold and, if feasible, enhance the existing high safety standards. This pertains not only to the materials used in the components but also to the regulations governing their utilization. This proactive approach is crucial for minimizing the probability of potential risks, particularly with regard to the risk of belt fires.

FIGURE 7. EVALUATION OF THE RISK CONTRIBUTION TO THE BCP VALUE





Source: own elaboration

FUTURE PERSPECTIVES, CHALLENGES, AND OPPORTUNITIES

The future of the copper mining industry is at a crucial juncture, facing challenges and opportunities influenced by climate change. Experts predict a shift in climate patterns, marked by rising temperatures and intensified weather phenomena. This is not merely theoretical; history demonstrates that destructive weather events have impacted both open-pit and underground mining. Major hazards include torrential rains, droughts, and heatwaves, affecting mining facilities differently.

For instance, vulnerability factor assessments, considering topography, mine size, proximity to healthcare centers, water access, and coordination with nearby companies, revealed that large-scale copper processing plants face high climate risks from droughts and often lack adequate adaptation measures (Del Rio et al., 2023). Henderson & Maksimainen (August 27, 2020) reported that water stress is already high in 30-50% of copper, gold, iron ore, and zinc production areas, further disrupting operations.

Recognizing the industry's vulnerability to climate change, there's an urgent need to find new ways of operating. To ensure the industry can continue and thrive, smart plans are required that not only reduce risks from climate-related phenomena but also capitalize on new opportunities for sustainable growth.

The demand for mineral commodities, such as copper, is expected to shift rightward due to various factors like technological advancements, increasing use in renewable energy technologies, and emerging applications. However, the long-term supply of these minerals is subjected to the impacts of climate change-induced events, creating a complex scenario.

Climate hazards, such as extreme weather patterns, rising temperatures, and hydrometeorological phenomena, pose significant risks to mining operations, such as operational disruptions, damage to critical infrastructure, and increased maintenance costs. These challenges can limit the supply of copper, affecting the quantity available in the market. Climate change constraints on supply could drive up prices due to increased demand and limited availability, potentially reducing the quantity demanded.

Therefore, while the demand for mineral commodities is anticipated to rise in the long run, climate change-induced events may exert upward pressure on prices due to constrained supply. This can result in a complex dynamic where the market experiences higher prices and potentially lower quantity demanded as consumers adjust to the changing economic landscape shaped by both demand-side and supply-side factors.

ECONOMIC PERSPECTIVE

In the context of the long-term dynamics of the copper mining industry, the interplay between the growing demand for mineral raw materials and supply challenges induced by climate change phenomena can have profound effects on market dynamics. The demand for mineral raw materials, such as copper, is expected to shift to the right due to various factors such as technological advancements, increasing use in renewable energy technologies, and emerging applications.

However, the long-term supply of these minerals is subject to the effects of climate change-induced phenomena, creating a complex scenario. Climate risks, such as extreme weather patterns, rising temperatures, and hydrometeorological events, pose significant risks to mining operations, including operational disruptions, damage to critical infrastructure, and increased maintenance costs.

These challenges can constrain the supply of copper, impacting the quantity available in the market. Climate change constraints on supply could drive prices up due to increased demand and limited availability, potentially reducing the quantity demanded.

Therefore, while the demand for mineral raw materials is expected to increase in the long term, climate change-induced events may exert upward pressure on prices due to supply constraints.

This can lead to a complex dynamic where the market experiences rising prices and a potential decrease in the quantity demanded as consumers adapt to the changing economic landscape shaped by factors from both the demand and supply sides.

This can give rise to a complex dynamic in which the market experiences rising prices and a potential decrease in the quantity demanded as consumers adapt to the changing economic landscape shaped by factors from both the demand and supply sides.

In the context of climate change and the ongoing increase in environmental risks impacting mining operations, GEM Mining Consulting's team of professionals, with their extensive expertise and backed by numerous successful projects, is ready to quantify the various variables affected by climate change through the use of the following tools:

ECONOMICS

Integrating climate risk assessments into market studies and analyses helps mining companies better understand and address the climate impacts on their supply chains, costs, and market dynamics, facilitating more informed decision-making in the face of climate challenges.

STRATEGY

Conduct strategic analyses of mining projects to estimate potential Net Present Value (NPV) and provide support for decisions, taking into account the impact of climate change. Additionally, develop manuals and guidelines that incorporate the latest trends and methodologies in the market.

EVALUATION

Evaluate and mitigate the impacts of climate change on mining operations, addressing climate risks, adaptive planning, scenario analysis, and providing support for strategic decisions in climate resilience.

OPTIMIZATION

Develop a strategy to reduce costs and address uncertainties of climate change by determining optimal maintenance strategies, optimizing integrated mine-to-plant processes, and providing optimal estimation of reserves and sources.

CONCLUSION

The growing threat of climate change represents a crucial moment for the copper mining industry, requiring a balance between addressing challenges and seizing opportunities. The sector grapples with increasing risks associated with climate-induced phenomena, ranging from extreme temperatures to hydrometeorological events. Proactive risk mitigation and adaptation strategies are essential to ensure the sustainability and resilience of mining operations.

Compliance with evolving environmental standards is crucial for the industry's long-term viability. Adherence to emerging regulations not only meets global requirements but also enhances the industry's attractiveness for investment. However, the lack of a unified strategy and a clear understanding of environmental and sustainable mining components pose a risk to the sector's transition from planning to practical measures.

Looking to the future, the industry is undergoing a transformative phase marked by technological innovations and adaptation strategies. Desalination plants, the adoption of renewable energy, and advancements in mining equipment symbolize the sector's commitment to responsible practices. The integration of autonomous and electric vehicles, real-time monitoring using advanced sensors, and improved management of mining waste reflect a forward-looking approach.

While challenges such as water scarcity, operational disruptions, and regulatory pressures persist, the industry's response to climate change is oriented toward sustainable growth. The future demands a proactive and flexible approach to navigate uncertainties, reduce environmental impact, and position the copper mining industry for success.

As history has shown, the industry's ability to adapt to the changing dynamics of climate change will be crucial in shaping its trajectory in the coming years. Furthermore, the idea of climate change adaptation strategy is important not only for companies to ensure production and costs for the future but also for mining-dependent countries relying on their copper supply, as it will also impact tax revenues.

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