24-052

Impacts of ESG on the Copper Supply Chain—The New Critical Mineral

Casandra Gamez Gonzales
The University of Arizona, Tucson, AZ

Angelina Anani
The University of Arizona, Tucson, AZ

INTRODUCTION

Copper, the newest addition to the critical mineral list, is an essential metal whose electrical and heat conductive properties label it as a vital mineral for the creation of renewable energy sources and the reduction of Greenhouse Gases (GHGs). However, despite copper's leading role in the transition to sustainable energy and mining practices, the mining industry has faced various battles in the extraction of this valuable material. These challenges are based on mining's negative reputation and extensive impact on the environment, nearby communities, and human rights. To ensure the survival of mining in the future and achieve mineral demands, an emerging topic that has initiated the revolution of the traditional sector into a more environment-friendly and transparent industry, is Environmental, Social, and corporate Governance (ESG).

ESG has motivated companies to seek growth opportunities and standardize risk accountability and transparency based on its collective framework that creates, modifies, and implements local, national, and international standards. These standards focus on improving environmental, social, and governance issues faced by companies and their projects. ESG has served as a guideline that investors utilize to assess companies and promote sustainability, responsibility, and disclosure to create positive and balanced relationships with stakeholders and the environment. Nonetheless, concerns have been rising which state that ESG is negatively impacting the mining industry by targeting what fuels the industry and world: ore deposits and their resources. Therefore, this research focused on answering the following research questions: what are the impacts of ESG on the copper supply chain and how will stricter ESG standards affect future copper production?

METHODOLOGIES

We commenced this study by understanding ESG, its emergence, and its role across industries including mining. Then, a literature review was conducted to establish a baseline for the research by understanding what questions have already been answered and what gaps have been left. Third, we dissected the copper supply chain to showcase the stages needed from the identification of an ore deposit to the recycling of the goods produced from the copper mined.

The next stage connected the copper supply chain to ESG and determined ESG's impact on the copper supply chain stages. The connection was developed by collecting and analyzing current local, national, and international environmental, social, and governance standards and pairing them up with a copper supply chain stage. Once paired, the effect of the standard was determined by looking at risk mitigation, project improvements, number of injuries/fatalities, community acceptance, etc.

Industry compliance was determined by utilizing local copper mines as case studies and measuring compliance by examining yearly sustainability reports, ESG ratings, processes for achieving ESG goals, and whether those goals were met or not. Current practices of ESG risk analysis were investigated to understand their risk mitigation process and effectiveness. Furthermore, interviews were conducted with mining professionals who develop and apply ESG in their everyday tasks. The interviews presented a better understanding of how ESG is incorporated in mining settings, how feasible it is to enforce stricter standards, and how they believe ESG is affecting their abilities to complete their work. Lastly, based on all the information gathered, conclusions were drawn about the effect of stricter ESG standards on the future copper supply chain (its production, projects, permitting, and more).

LITERATURE REVIEW

After identifying and reviewing gaps in the methodologies used to examine the environmental impacts of the mineral and metal supply chains, Lee et al (2020) concluded that current methodologies are insufficient in encapsulating environmental, social, and corporate governance supply chain issues. The mining mineral and metal industry needs to adopt or develop a consistent and universally accepted ESG accounting framework. During policy development and legislative action, transparency is needed to ensure risks are properly being mitigated and given the appropriate amount of resources and time (Lee et al, 2020). Similarly, Giese et al (2019) presented a thematic research paper to accurately explain and represent the correlation between incorporating strong ESG frameworks and corporate financial performance. Giese et al (2019) concluded that companies with strong ESG profiles were more competitive and resourceful, produced a higher financial return, attracted more investors, demonstrated above-average performance in risk control, less frequently suffered from governance issues, and were more compliant with federal standards.

Moreover, Valenta et al (2019) studied 308 of the world's largest undeveloped copper orebodies in order to provide a supportive and potential profile of the world's future copper supply. It was found that the unlocking of large quantities of orebodies based on metal prices will require the development of a framework that will have the capacity to handle costly and hazardous ESG impacts/risks. In more depth, Kemp et al (2010) provided a better understanding of the connection between access to clean water and natural rights to help companies respect individuals and avoid social and environmental risks. Kemp et al (2010), conducted 19 company examinations that showcased a lack of integration of human rights in both technical water management strategies and water-related community contributions or investment strategies. The authors concluded that industry in general tends to oversee the integration of human rights in a social and community-sympathetic manner. Their conclusions were supported by the analysis of the 19 ICMM member company sustainability reports where most companies did not report any sort of human rights or reporting was biased and selective.

In conclusion, all of the papers reviewed varied in ESG and copper supply chain topics, but all determined the impact of ESG and its role in the modernization of traditional practices or perspectives. This modernization will benefit the copper supply chain and companies that successfully develop a concise and detailed regulatory framework by reducing project risks, preventing irreversible damages, and limiting time and money losses.

COPPER SUPPLY CHAIN

A supply chain is an interdependent network of individuals, organizations, resources, tasks, technology, and information interacting to deliver an end product or service on time and of quality to the customer. In more detail, the copper supply chain is a series of steps, as shown in Figure 1, used to represent all of the ideas, tasks, and stages needed to initiate a copper extraction project to the reclamation and monitoring of the mined land and the usage of copper products. The copper supply chain can be broken down into five main categories: Exploration and Prospecting, Mine-site Design and Planning, Construction, Production, and Closure and Reclamation (Hughes, 2021).

Exploration and Prospecting

The exploration and prospecting category is the initial stage of the copper supply chain which involves geologists, geochemists, public health experts, lawyers, consultants, and other contributors who evaluate potential copper deposits, land characteristics, resource availability, and legislation. These scientists and legal advisers must map, sample, measure, and analyze surrounding soil, rock, water, air, ecology, magnetic field radiation, electrical conductivity, ore, ore grade, socio-economic effects, mineral rights, and more (Hughes, 2021).

This category deals with the following stages: research, ore research and exploration, feasibility study phase 1, preparation of geological documentation, preparation of deposit exploration, exploration of deposit, and feasibility study phase 2. Each of these stages is used to fulfill the purpose of this category which is to ensure the company can

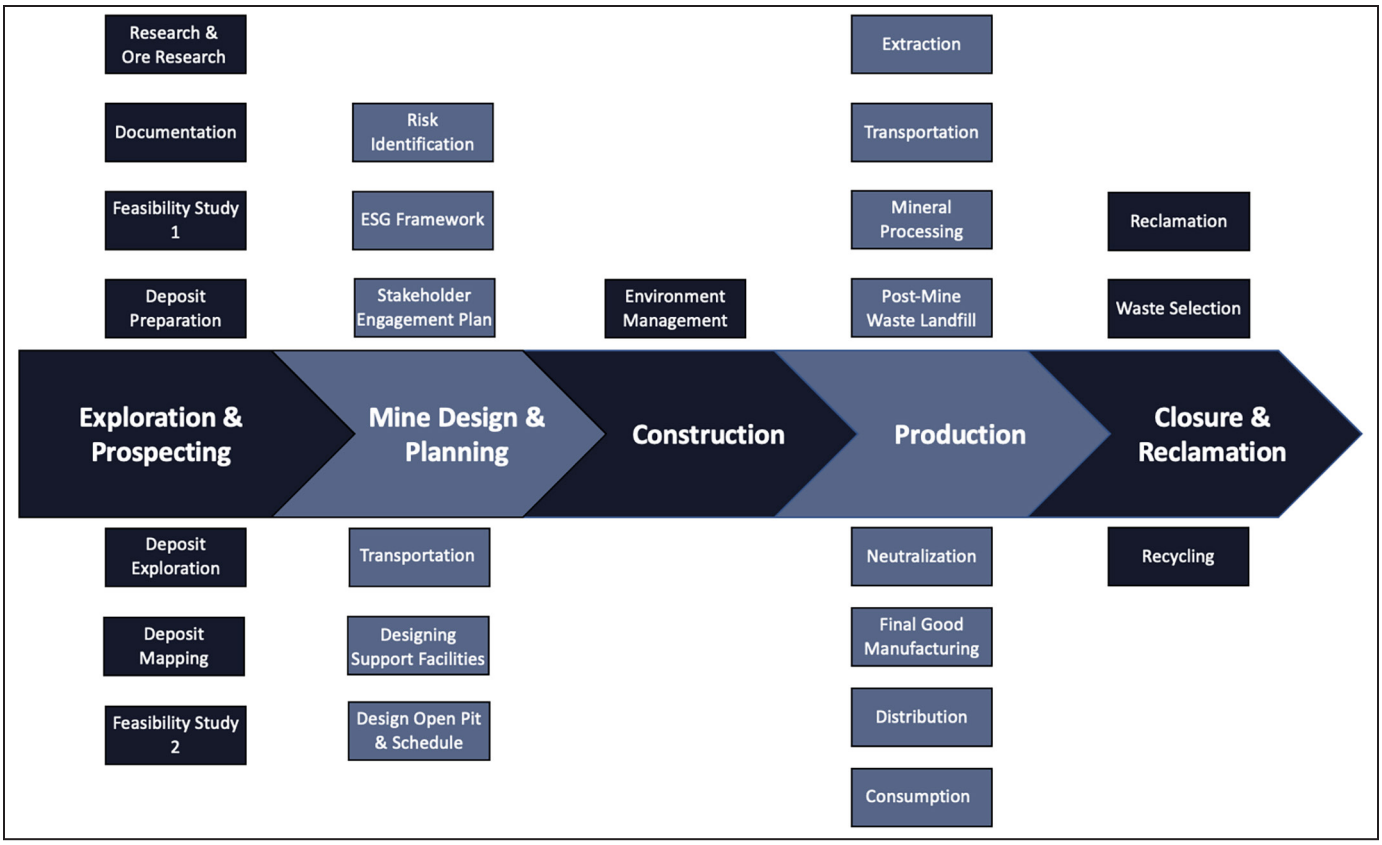

Figure 1. The stages of the copper supply chain needed for the production of pure copper inspired by Marta Wincewicz-Bosy, Malgorzata Dymyt, and Katarzyna Wasowska 2021

secure a deposit with a feasible and profitable future as well as ensure community relations and support.

Mine-Site Design and Planning

The mine-site design and planning category continues the copper supply chain by involving geologists, mining engineers, project engineers, planning engineers, project managers, planners/schedulers, accountants, consultants, and other contributors who can create, review, and identify the best plan from various options structured to design the most effective and feasible copper project. These professionals collaborate to draw up multiple copper project proposals which allows for the comparison and estimation of different financial implications. This category deals with the following stages: mine-site design and planning, construction of an ESG framework, development of risk identification, and the implementation of a stakeholder engagement plan.

The mine-site design and planning stage deals with the mapping of the mine and facilities needed to support the mine operation. This stage deals with the defining of project objectives such as expected mine lifecycle, an estimate of income throughout mine life, products being made, quality of products, environmental goals, safety policies and regulations, pit design, water and energy needs, facilities and site access, risk assessment program, and material purchasing documentation or software (Hughes, 2021).

Construction

The fourth major category of the copper supply chain is the construction of the resources, services, and preliminary mine excavations. Engineers, miners, and contractors collaborate in this stage to determine the best placement and methods to use to build the infrastructure and transportation resources needed to help support the mine and its production. This step is important as major cost and production rates rely on the effectiveness of construction since well-designed and managed roads can lead to reductions in cycle times, fuel consumption, and tire cost (Thompson et al., 2018).

It is vital to establish monitoring and measurement arrangements from the beginning of the construction stage to ensure no harmful damages are being inflicted on the used land or species nearby. This will allow for an easier reclamation process and the prevention of permanent harmful

environmental effects especially as copper mines become deeper and are located in politically and ecologically sensitive areas (Valenta et al., 2019).

Extraction and Processing

The extraction and processing stage is concerned with the exploitation of Earth's minerals through a sustainable and safe mining operation which is reliant on collaboration with various disciplines. Once those minerals are extracted, the second major concern is the purifying of the minerals into high-grade copper, used to produce consumable goods or copper wires, by utilizing their known physical and chemical properties. Therefore, this stage requires the expertise of engineers, geologists, chemists, metallurgists, electricians, mechanics, planners and drafters, public health and social workers, attorneys, accountants, surveyors, etc. Diverse disciplines are needed to ensure the development and maintenance of adequate working conditions for employees, fostering healthy relationships, proper monitoring and usage of energy sources, technologies, and equipment, and more.

Closure and Reclamation

The last stage of the copper supply chain is the closure and reclamation which targets the shutdown, restoration, and monitoring (post-mine production) of the land used to mine the material such that mines initiate their reclamation plans at the beginning of the mine life to ensure their capability of supporting their surroundings. Throughout the mine's operational years, reclamation is supported by ensuring that practices and equipment are not damaging the environment by causing prevalent issues such as water scarcity, resource contamination, animal endangerment, and climate change (k2fly, 2019).

Towards the end of the mine life, companies start their mine closure plans by ramping down production and commencing the clean-up process. When the mine is shut down and the clean-up is complete, the company in charge will commence its reclamation plan of either refilling the pit in the case of open-pit operations and restoring it to its original condition or building a facility or space that is of benefit for nearby communities. After the reclamation action plan is finished, the company has the responsibility to monitor the area for potential hazards and environmental impacts such as acidic drainage, unstable ground, and so on (k2fly, 2019).

IDENTIFIED RISKS IN THE COPPER SUPPLY CHAIN

Risks and operational hazards are unavoidable in copper projects due to the interaction and collision of various groups of people, their interests and concerns, cultures and traditions, imbalance consumption and access of resources, and different safety behaviors. It is important to identify project and operational hazards before they occur or find solutions to mitigate risks present.

Exploration and Prospecting

In the exploration and prospecting stage, economic and regulatory risks are more prominent as this stage deals with the location and evaluation of a potential copper deposit. Risks that companies can face during this stage include:

- Environmental: Invasive practices can lead to environmental impacts, habitat disturbances, resource contamination, and disruption of ecosystems.
- Financial: Lack of funds or investments can lead to the adoption of cheap and inaccurate practices or technology that can predict false metallurgical data.
- Political and Social: Changes in federal policies, community opinions, and land ownership can lead to project delays or cancellations.
- Regulatory/Permitting: Delays or denial of permits can hinder exploration plans and therefore increase costs.

Mine-site Design and Planning

The mine-site design and planning stage is considered the most critical phase of the supply chain since vital decisions can impact the mine's resilience, operational strategies, costs, layout, and future developments. If appropriate and sustainable decisions are not made, several risks can surface such as:

- Closure and Reclamation: Lack of proper planning to limit environmental hazards from the beginning of the lifecycle can lead to irreversible damage and the formation of health and safety risks. Additionally, failure to integrate closure and reclamation considerations into the design can challenge compliance with federal regulations, company closure plans/promises, and community expectations.
- Environmental: The absence of environmental monitoring systems can increase environmental risks such as greenhouse gas emissions, water and soil contamination,

endangerment of species, etc. Lack of compliance with environmental requirements can lead to fees, penalties, community opposition, lawsuits, and even mine closure.
- Infrastructure: Unsuitable placement of resources and facilities can increase cost, wear rate of equipment and its components, travel time, malfunctions, insufficient supply of energy, and more. These scenarios can lead to frequent fixture of roads, increasing demand for water trucks or dust suppression, adoption of alternatives to connect stages, larger emissions of greenhouse gasses, higher noise levels, increase in community complaints, and surge in traffic.
- Mineral Identification: Inaccurate classification of metallurgical characteristics can lead to lower financial recovery rates, an increase in operational and processing costs, and a waste of resources for a deposit that may not be economically viable.
- Regulatory/Permitting: Not obtaining the necessary permits and licenses can set back the project timeline, increase the cost of materials, result in fines or legal issues, lack of access to federal services to prevent damages (e.g., water and gas pipe detections), and mine closure.
- Resource Estimation: Improper monitoring, distribution, saving, and/or investing of mine resources and finances can lead to financial losses or the development of challenges that limit operation and production.
- Social: The absence of a community engagement plan or establishment of methods to respect individuals' human rights can lead to social disagreements, resistance, and delays.

Construction

In the construction stage, permitting and safety risks are more prominent as this phase deals with the building of facilities, management of heavy equipment, and the liability over worker's well-being. This means construction requires the hiring of consultants and engineering professionals to approve designs and practices in order to comply with design codes. Furthermore, risks that companies can face during this stage include:

- Economical: Lack of long-term financial planning can lead to an increase in expenses if project delays, inflation, material purchasing, or other challenges surface.
- Geotechnical: Improper ground stability and material stress assessments, calculations, and monitoring can lead to the collapse of buildings, workers' injuries and fatalities, pipeline and utility failures, erosion and cracking of foundations, and bearing capacity failures.
- Health: Missing safety procedures and health standards can result in the exposure of workers to hazardous materials, dust, noise levels, chemicals, and metal fumes that can cause the development of adverse health effects.
- Machinery and Human Interaction: Inadequate training, unfulfillment of pre-shift equipment inspections, and human error can cause injuries and fatalities of workers, downtime, pushback of project delivery date, and equipment breakdowns.
- Permitting/Regulatory Compliance: Not acquiring necessary permits in order to comply with local, state, and federal regulations and building principles can put lives in danger. Construction plans must be reviewed and approved by contractors to ensure that proposed construction plans meet safety and environmental standards without a biased approach.
- Safety: Construction sites and activities involve various dangerous tasks and safety hazards such as falls from heights, injuries from machinery or tools, electrical hazards, falls or slips, dropping of heavy material, and more. Additionally, the lack of safety culture or communication, qualified training, and enforcement of safety procedures can lead to trauma, injuries, and even death of workers.
- Workforce: The unavailability of skilled workers and involved supervisors can increase the risk of bad behaviors, shortcuts, and project setbacks due to errors and corrections.

Extraction and Processing

The extraction and processing stage is considered the most dangerous period of the supply chain since safety behaviors and operational decisions influence environmental and social impacts or conditions. In this stage, educational, regulatory, and leadership approaches are required to ensure a safe working environment. It is necessary for companies to identify and plan for the following risks:

- Closure and Reclamation: Lack of environmental compliance and utilizing harmful practices can create permanent damages that may prevent the fulfillment of reclamation goals and plans approved by the government and local communities. This can ruin the company's reputation, and its relationship with the community, and lead to long-term environmental and social issues.
- Economical: Not properly planning for future expenses, copper price fluctuations, and/or investments could lead to financial struggles, mine closure, debt, and job losses.
- Environmental: Utilizing non-preferred methods of extraction and processing can lead to water, air, and soil pollution, large quantities of energy consumption, soil erosion, disruption of biodiversity, significant changes in landmarks, and more.

- Equipment and Human Interaction: Not properly training, supervising, or instructing employees on safe procedures to follow when operating mining equipment or machinery can lead to life-threatening injuries or death. Additionally, employees must be examined and tested for fit-for-duty status as well as completing a pre-shift equipment inspection.
- Geotechnical: Invasive and fragmenting practices to weaken rock can lead to ground instability, slope failures, rockfall, fly rock, airborne dust, wildlife disruption, and water contamination.
- Health: During normal operations, if companies are not actively seeking ways to engineer, substitute, or eliminate hazards workers can be exposed to, employees are subjected to develop respiratory issues, chronic illnesses, loss of hearing, and metal poisoning.
- Regulatory Compliance: Financial and legal consequences and challenges may arise if non-compliance occurs. The mine, its facilities, and components needed to produce copper must meet MSHA requirements and operational standards.
- Safety: Lack of understanding, communication, and supervision can cause injuries and fatalities if rockfall, equipment malfunctions, human collision with machinery, and falls and slips occur.
- Supply Chain: Involvement with geopolitical issues or changes can impact trade, the economic viability of a deposit, and the sustainability of mining operations.

Closure and Reclamation

The closure and reclamation stage focuses on the restoration of the mined site and its resources into a clean, monitored, and community-usable area and therefore a critical phase of the copper supply chain. In this stage, environmental, social, and governance issues are common if the affected land is not properly maintained during the previous stage. The following risks can be experienced:

- Ecological Recovery: Based on how previous environmental risks were managed, restoring ecosystems can be challenging based on soil disturbance or changes, deprivation of native vegetation, settling of non-native species, heavy metal and chemical contamination of water and soil, and erosion.
- Financial: Insufficient financial budgeting or savings for this stage can lead to inadequate closure and reclamation results that do not meet promised or proposed plans. With limited funds, companies may resolve to cheap or easier closure plans that can lead to an inaccurate analysis of the deposits or tailings' current state and therefore increase the chance of toxic waste spills and community resource contamination.
- Liabilities: Not developing solutions at or above the required level for mitigation can lead to long-term responsibility over both the reclaimed land and surrounding communities. This can impact the company's finances as money is being spent on fixing prominent environmental issues and errors in implemented reclamation solutions.
- Long-term Stability: Improper planning of the long-term stability of reclaimed areas can lead to erosion, demolishment, or structural failures over time. Companies will need to consider the following areas when closing and reclaiming the mine: tailings storage facility, open/underground mine, waste rock dumps, heap leach pads, processing facilities, roads, pregnant leach solution ponds, and water management systems.
- Post-Closure Monitoring: Lack of effective post-closure monitoring programs can hinder the assessment and development of successful long-term reclamation management systems. Non-effective monitoring programs can result in inaccurate data and undetected issues that can increase in severity over time.
- Regulatory Compliance: Non-compliance with local, state, and federal regulations and commitments can lead to legal and financial penalties as well as the unsuccessful completion of the closure and reclamation stage.
- Social: Community engagement is essential in all stages of the supply chain. However, once the mine is closed, the community will have access to the area. Companies must consult with nearby communities and formulate a consensus on what community expectations should be met for the reclaimed land.

The listed risks are prominent risks faced during copper mining projects however they may vary in severity and consequence from site to site depending on:

- Geological conditions
- Extraction techniques
- Company culture
- Employee training
- Risk assessment
- Mitigation strategies
- Waste and tailings management
- Health and safety monitoring
- Community engagement
- Operational costs
- Implemented policies to meet local, national, and international regulations.

ESG

ESG is a framework consisting of environmental, social, and governance issues, approaches, standards, and/or solutions utilized to assess the compliance and sustainable and ethical performance of businesses. In the mining industry, ESG has been adopted with the hope of being able to create a positive relationship and balance between the planet, its people, species, resources, and mining. ESG's vision is to be able to preserve mining, its projects, and renewable energy sources in the future while altering or replacing complex and harmful practices with more innovative, safe, and sustainable ones. Nowadays, mining companies must look through the following issues to successfully plan and determine their project impact on the following categories:

Environmental

ESG's environmental section deals with mining issues targeting the preservation of nature and its inhabitants which allows stakeholders and the government to understand and visualize what their risk analysis and management systems will provide. This holds companies responsible for permanent or harmful environmental issues that occur throughout the project's lifetime from the exploration stage to the monitoring of the reclamation stage. ESG holds companies accountable for preventing and mitigating any environmental issues their production may have directly or indirectly caused by looking through the following categories and setting action plans:

- Mine Waste
- Air, Water, and Land Contamination
- Noise
- Climate Change
- Mine Closure
- Greenhouses Gasses
- Rock or land instability
- Floods
- Sinkholes
- Deforestation,
- Biodiversity loss or endangerment, etc. (Walker, 2022).

Social

ESG's social section is concerned with supporting and avoiding compromises to humans and their interdependencies (such as systems or other humans that people rely on in their everyday lives). This urges mining companies to establish healthy relationships with governments, local communities, and other involved parties to ensure individual rights and resources are not being exploited throughout the mining process. It is vital for companies to include all types of stakeholders in their decision-making processes and meetings in order to hear a variety of opinions and decide on an effective solution or compromise.
Furthermore, ESG ensures companies are not bypassing the natural rights and well-being of individuals as well as their concerns by establishing a framework that explores the following categories:

- Human Rights
- Land Use
- Displacement of Communities
- Gender Equality and Equity
- Labor Practices
- Health & Safety
- Security
- Violence
- Poverty
- Health Hazards
- Cultural and Spiritual Threats, etc. (Walker, 2022).

Governance

ESG's governance section deals with the legal and ethical standards or rules that companies create, implement, and enforce in order to maintain compliance as well as the distribution of responsibilities amongst involved parties. This means ESG drives company transparency and holds companies accountable for any promises or written agreements they have established. This is important for the cultivation of positive relationships among mining companies, governments, and residents. Therefore, companies must be able to answer and set solutions for the following concerns:

- Legal compliances
- Anti-bribery and Corruption
- Exploitation
- Compensations/ benefits
- Pay Equity and Equality
- Practices for new hires and onboarding employees
- Response to new laws
- Transparency and Information Disclosure
- Auditing
- Taxing, etc. (Walker, 2022).

Furthermore, ESG is a system used by mining companies to ensure the longevity of their companies as well as to secure investments. Mining companies have begun implementing ESG in hopes of evaluating how ESG risks will affect their ability to improve income, secure permits, connect with communities, and protect employees from

harm and future illnesses/impairments. Lastly, ESG is used by investors and companies to perform an analysis process (structured review of all steps and procedures that need to be conducted to finish or accomplish an activity) to identify material risks and growth opportunities.

ESG STANDARDS AND THE COPPER SUPPLY CHAIN

To meet regulatory requirements and community expectations, companies must identify all risks associated with their mining projects and ways to prevent hazards or mitigate present challenges. The following figure lists important local, national, and international standards companies should consider when formulating their ESG framework.

Exploration and Prospecting

As previously mentioned, the exploration and prospecting stage deals with economic and regulatory risks that can impact the approval or unlocking of copper projects if left unaddressed. When addressing ore deposit examination risks, companies must acknowledge:

Environmental

- Arizona Mining Permitting Guide
- National Historic Preservation Act of 1966
- Endangered Species Act
- Federal Land Policy and Management Act of 1976
- National Environmental Policy Act of 1969
- Title IV of the Surface Mining Control and Reclamation Act

Social

- Freedom of Speech
- Freedom from Discrimination
- Right to Freedom and Equality
- Minority Rights
- Religious and Cultural Rights
- Indigenous People's Right
- Universal Declaration of Human Rights
- Right to Life
- Prohibition of Retrogression
- Right to Privacy

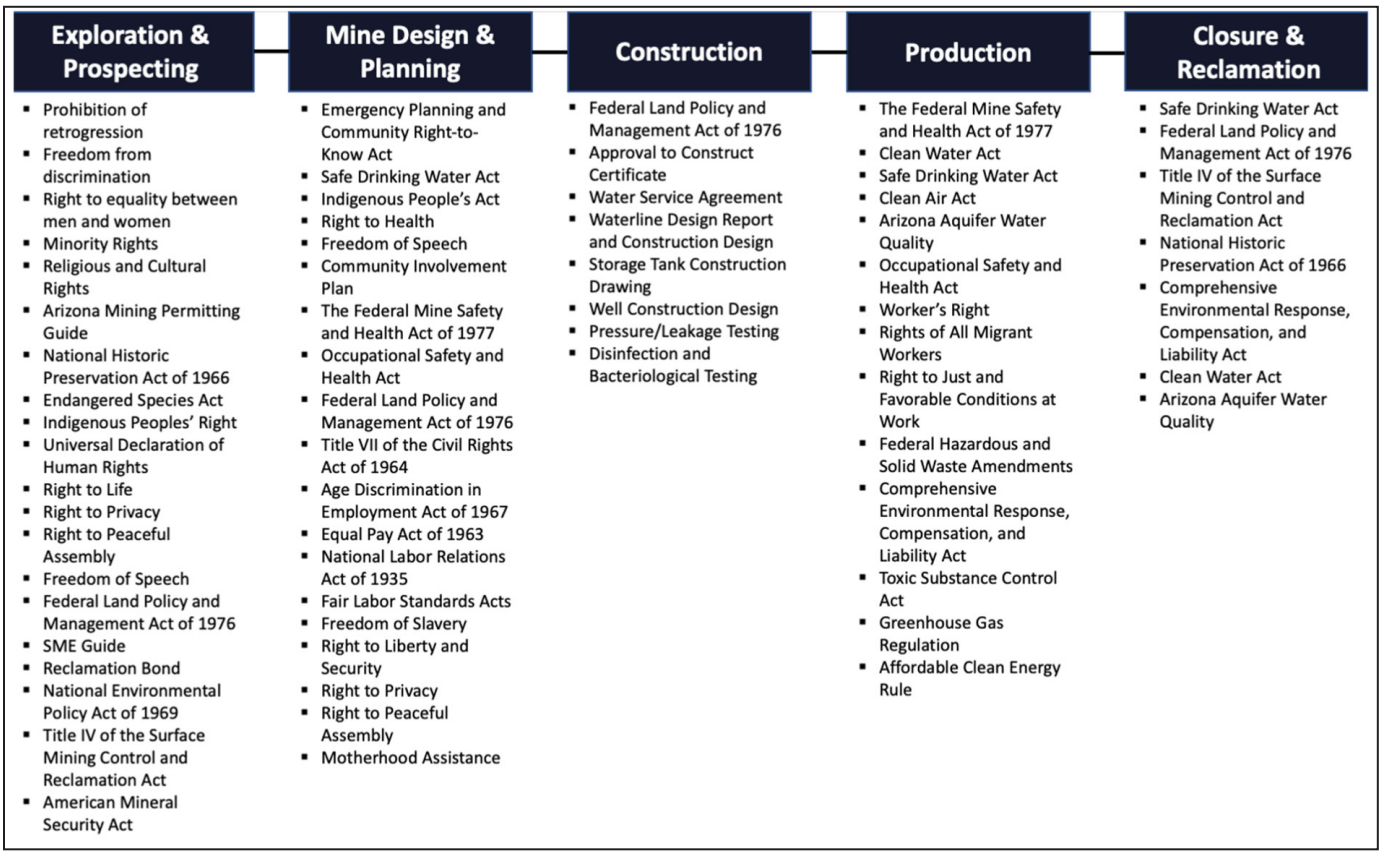

Figure 2. Lists local, national, and international ESG standards that must be considered by the identified copper supply chain stage in order to improve and resolve potential or current risks

- Right to Peaceful Assembly
- Miner's Rights and Responsibilities

Governance

- Arizona Mining Permitting Guide
- Arizona Blue Stake Laws
- American Mineral Security Act
- Mining Law of 1872

Mine-Site Design And Planning

Considered the most critical stage of the copper supply chain, mine-site design and planning deals with the decision-making of operational practices and the layout of the mine which can lead to safety, financial, and environmental hazards. Therefore, it is vital for companies to consider these standard policies:

Environmental

- Safe Drinking Water Act
- Arizona Groundwater Code
- Clean Air Act
- Federal Land Policy and Management Act of 1976
- National Historic Preservation Act of 1966
- Environmental Impact Assessment
- Global Industry Standard on Tailings Management
- Best Available Demonstrated Control Technology (BADCT)

Social

- Emergency Planning and Community Right-to-Know Act
- Community Involvement Plan
- Indigenous People's Act
- Right to Health
- Right to Liberty and Security
- Right to Peaceful Assembly
- Freedom of Speech
- Freedom of Slavery
- National Labor Relations Act of 1935
- Occupational Safety and Health Act
- Federal Mine Safety and Health Act of 1977
- Mine-Specific Emergency Response Plans
- Equal Pay Act of 1963
- Motherhood Assistance

Governance

- Fair Labor Standards Act
- Reclamation Bond
- Arizona Blue Stake Laws
- Comprehensive Environmental Response, Compensation, and Liability Act
- Best Available Demonstrated Control Technology (BADCT)

Construction

The construction stage involves the physical implementation of the mine design and infrastructure layout and therefore requires the compliance of design specifications and safety requirements to ensure workers' safety. These requirements were identified as:

Environmental

- Federal Land Policy and Management Act of 1976
- Water Service Agreement
- Waterline Design Report and Construction Design
- Storage Tank Construction Drawing
- Well Construction Design (if applicable)
- Energy Supplying Standards
- Ground Stability Assessment
- Building Codes
- Arizona Blue Stake Laws
- Toxic Substances Control Act

Social

- Pressure/Leakage Testing
- Disinfection and Bacteriological Testing
- The Asbestos Hazard Emergency Response Act (AHERA)
- Zero Tolerance Policies
- Emergency Response Plans
- Certified Employee Training
- Ventilation Requirements
- Occupational Safety and Health Act
- Miner's Rights and Responsibilities

Governance

- Approval to Construct Certificate
- Transparent Incident Reporting
- Site-Specific Risk Assessment
- Federal child labor law

Extraction and Processing

The exploitation and purification of ore and minerals develops a variety of risks for workers, the environment, stakeholders, the company, and the government in terms of how they are fulfilling their responsibilities. The following listed standards and policies are important to acknowledge and utilize to mitigate risks:

Environmental

- Clean Water Act
- Safe Drinking Water Act
- Clean Air Act
- Arizona Aquifer Water Quality
- Federal Hazardous and Solid Waste Amendments
- Comprehensive Environmental Response, Compensation, and Liability Act
- Toxic Substance Control Act
- Greenhouse Gas Regulation
- Affordable Clean Energy Rule
- Global Industry Standard on Tailings Management
- Ore Mining and Dressing Effluent Guidelines
- Mineral Mining and Processing Effluent Guidelines

Social

- Occupational Safety and Health Act
- Miner's Rights and Responsibilities
- Rights of All Migrant Workers
- Right to Just and Favorable Conditions at Work
- Emergency Planning and Community Right-to-Know Act
- Community Involvement Plan

Governance

- Corporate Sustainability Reporting
- Corporate Social Responsibility
- Foreign Corrupt Practices Act
- Federal Child Labor Law
- MSHA Incident/Fatality Reporting
- State Royalties and Taxes

Closure and Reclamation

The last stage of the copper supply chain deals with all operation repercussions and cleanup of environmental impacts. To comply with federal regulations, community expectations, and company set reclamation goals, companies need to utilize and implement the following regulations:

Environmental

- Safe Drinking Water Act
- Clean Water Act
- Arizona Aquifer Water Quality
- Design and Evaluation of Tailings Dams-1994 the Environmental Protection Agency
- Stability Requirements for Heap Leach Pads- Bureau of Mining Regulation and Reclamation
- Federal Land Policy and Management Act of 1976
- Title IV of the Surface Mining Control and Reclamation Act
- Comprehensive Environmental Response, Compensation, and Liability Act
- Resource Conservation and Recovery Act
- *Social*
- Emergency Planning and Community Right-to-Know Act
- Community Involvement Plan
- Universal Declaration of Human Rights
- *Governance*
- Reclamation Bond or SuperFund
- Corrective Action Program

Some of the identified ESG standards and regulations overlapped in categories and stages based on criteria used to develop the objective, requirements, and consequences of the standard. The overlapping standards were generalized and targeted a diverse set of copper supply chain risks. Moreover, it is vital for companies to understand, identify, and comply with local, national, and international standards in order to ensure financial resilience, maintain healthy relationships with stakeholders, and reduce environmental impacts. Only then will companies be able to optimize the efficiency and safety of their mining projects.

COMPLIANCE OF THE MINING INDUSTRY

The mining industry's compliance with ESG can be measured through a variety of factors. These factors are essential in the rating of mining companies' financial and risk mitigation performance as they highlight strengths and weaknesses in the company's safety culture, ESG framework, enforcement system of ESG policies, and more. The current methods of measuring compliance include:

- Sustainability Reports
- ESG Ratings
- Fulfillment of ESG Goals
- Implemented Corporate Strategies
- Financial and Risk Control Performance
- Employee Retention
- Reported Work-Related Injuries and Fatalities

Furthermore, a few case studies were conducted utilizing active Arizona copper mines. The majority of companies evaluated have standardized ESG commitments and practices. However, a trend was observed, "wealthier" and "older" companies were more flexible in the addition of ESG to corporate approaches and regulations. These companies' resources and financial conditions gave them

an advantage in altering practices and implementing new regulations to achieve compliance.

Yet, companies with new or developing copper projects were more resilient in the execution of ESG in their mining operations and exploration. These companies were able to establish a concrete foundation from the initial stage which prevented the altering of rooted operational behaviors or practices. Companies with new copper projects were more effective in communicating with communities and securing a positive relationship through the early formation of a community engagement plan. They were able to recognize and implement community expectations into their mine design and planning to create a sustainable and community-friendly operation.

Despite all efforts used to create and implement an ESG framework, companies are facing pressure from stakeholders and the government to eliminate and engineer safer mining practices. According to industry professionals, a concise and specific ESG framework is needed in the mining industry to create structure and organization because companies are uncertain of what they need to do at a baseline level. Companies are relying on consultants, organizations, and their own knowledge to determine whether their monitoring and risk-solving are being done properly. It is difficult to navigate and follow rules that provide a lot of gray areas and require the guidance of others since interpretation can lead to variations on what companies believe they need to do and their actions.

Overall, the interviewees believe that stricter ESG is necessary to help companies understand what is expected of them and to know all the responsibilities they have while not seeming too concerned about the effect on copper production. Although ESG will create an expensive short-term cost, it will provide a long-term disciplined solution to mining minerals while considering prevalent and future environmental, social, and governance issues.

CURRENT ESG RISK ANALYSIS AND MANAGEMENT

In order to ensure the effectiveness of an ESG framework, a diverse set of factors must be developed and function interdependently. Two important factors to consider in order to ensure ESG compliance are competent and well-rounded risk analysis and management systems. The risk management program serves as a five-step process that allows companies to prepare and plan for identified project risks and take preventative actions in order to mitigate them. The risk management system is made up of the following stages:

Identification

Detecting, describing, and recognizing potential project risks, in each of the copper supply chain stages, which can negatively affect the company's ability to operate efficiently, safely, and economically. The risks identified can be associated with the following damages:

- Inadequate working conditions
- Worker's exposure to contaminants, chemicals, and fatal tasks
- Irreversible water, soil, and land impacts
- Over-emissions of GHG
- Money, time, and resource loss
- Low copper recovery
- Low income
- Negative reputation
- Mine or ground failure
- Exploitation of human rights
- Not meeting production targets, etc.

Assessment

Estimating and determining the potential hazards or consequences associated with the occurrence of the identified risk. In this stage, risk analysis models are used to evaluate the likelihood of a risk occurring and the negative ramifications that will follow. A risk analysis model requires the assigning of the probability of occurrence [range: 1 (rare) to 5 (definitely)] and consequence [range: 1 (insignificant) to 5 (severe)] such that the two scores will intersect in the center and estimate the urgency and grade of the risk [range: 1 (very low to 25 (extreme)]. The assigning of scores is based on the risk's exposure and effect on workers, the company and its components, stakeholders, nearby communities, etc.

Mitigation

Planning and developing detailed processes or solutions to reduce or prevent the project risk from worsening or occurring. With the help of the information collected in the previous two steps, multiple plans are formulated with the help of a diverse team to determine the best possible mitigation solution. This "best plan" is then put into action.

Monitoring

Observing, reviewing, and altering risk mitigation solutions to ensure the maximum minimization of the risk and its consequences. This step deals with the collection of real-time data and results from the implemented solution to determine its effectiveness and is often completed with the help of software, sampling, surveying, etc.

Reporting

Involves communicating and presenting effective mitigation measures used to reduce risks in sustainability reports, stakeholder or community meetings, mine-site line-out meetings, Mine Safety and Health Administration (MSHA), etc.

Overall, the competency of the risk management program is determined by its effectiveness to prevent, mitigate, and resolve site-specific challenges. Investment in the creation of an adequate risk management system may be expensive; however, it is vital for the development of long-term solutions. This would be most beneficial for copper projects that have an extensive mine lifetime. Yet, it is advisable for companies to develop effective and resilient risk management systems for any project even if it costs a bit more than short-term solutions as short-term solutions require frequent fixtures.

STRICTER ESG STANDARDS AND MEETING FUTURE COPPER DEMANDS

With the development of renewable energy sources and operational transitions to meet net zero goals, copper is becoming a highly demanded commodity. According to the World Bank, copper's demand is estimated to increase by 200% by 2050 due to copper's involvement in the functioning of wind, solar, hydro, geothermal, energy storage, nuclear, coal, gas, and carbon capture technologies (Hund et al., 2020). This means more deposits will need to be unlocked to meet demands which will increase negative environmental and social effects due to the need for invasive practices to reach deeper, low-grade copper deposits in politically and ecologically sensitive areas (Valenta et al., 2019).

To ensure the survival of mining in the future, stricter ESG standards will be developed to prevent and mitigate expected project risks but, in the process, it will limit mine operations by extending permitting waiting time, increasing qualifications for new projects, and so on. Despite this expected limitation, the interviewed mining professionals stated stricter ESG policies will be beneficial as they will alarm the industry of the change that is occurring and make companies responsible for corresponding to affected individuals and developed environmental damages. Companies that are unable or unwilling to adopt ESG will not persist in the future as ESG is an investment specification. If companies are required to increase the quality of their mining planning and risk management to prevent project risks, investments will be necessary as projects will become more economically inviable.

RELEVANCE

It is important to analyze and understand the impacts of ESG on the copper supply chain in order to create a framework that allows companies to reach their production goals in a responsible, efficient, and sustainable way. Although ESG is not a mandatory governmental law, it is a framework that enforces widely used regulations and rights that can be violated during mineral extraction. ESG is important because it targets and works towards solving urgent and hazardous risks in mining projects by looking at environmental, social, and governmental policies and approaches. ESG is a tool that helps impacted individuals, stakeholders, and companies to communicate, negotiate, and resolve project risks and concerns. These frameworks hold the power to provide a more structured and safer way to mine as well as a transition for companies to improve their working conditions and community relations.

CONCLUSION

As previously mentioned, copper is the driving force to a functioning modern society since electricity, appliances, and vehicles being used on a regular basis are reliant on copper's electrical conductivity. This places copper in high demand as it promises a future with sustainable, carbon-zero power sources that will help solve current environmental concerns such as climate change and contamination of resources. This means as accessible and economical mines are drained of their copper ores, the industry will have to turn to more invasive practices to reach more challenging ore deposits leading to more negative environmental impacts. This is due to the energy requirements needed to reach the copper ores, water usage despite potential water scarcity, and a massive generation of waste (Valenta et al., 2019).

Therefore, an accountable system is needed to help guide companies in current and future copper projects to ensure the health and safety of the world. ESG has a negative impact on the unlocking and budgeting of copper projects by restricting and extending permitting waiting periods which lead to downtime and requiring expensive alternatives and solutions to reaching net-zero goals. Despite this, ESG majorly impacts the industry and copper supply chain by improving issues and making sure unsolved hazards are being fixed and monitored such as abandoned mine waste sites. ESG frameworks target each stage of the copper supply chain by listing requirements needed to prevent and mitigate risks in order to optimize the efficiency and renewability of the tasks needed to complete the stage.

According to industry experts, ESG builds a stronger and narrower path towards changing the way mining

is being conducted and straying from traditional harmful practices. ESG allows companies to understand regulations that are being created based on public perspectives and testimonies on challenges that mining projects pose to their well-being and the fulfillment of their universal rights. For example: since Arizona is the home to multiple Native tribes, it is vital for Arizonian mining companies to communicate and engage with these tribes before starting any invasive work to respect their cultural rights, establish resources that could benefit the tribes, and prevent tension. Overall, ESG will help guide the mining industry in its journey toward creating feasible and responsible copper projects to meet future copper demands.

REFERENCES

[1] Lee, J., Bazilian, M., Sovacool, B., & Greene, S. (2020). *Responsible or reckless? A critical review of the environmental and climate assessments of mineral supply chains.* Environmental Research Letters. iopscience.iop.org/article/10.1088/1748-9326/ab9f8c

[2] Giese, G., Lee, L. E.,...& Nishikawa, L.. (2019, July). F*oundations of ESG Investing: How ESG Affects Equity Valuation, Risk, and Performance.* The Journal of Portfolio Management. doi.org/10.3905/jpm.2019.45.5.069

[3] Valenta, R.K., Kemp, D., Owen, J.R., Corder, G.D., & Lebre, E. (2019). *Re-thinking complex orebodies: Consequences for the future world supply of copper.* Elsevier. doi.org/10.1016/j.jclepro.2019.02.146

[4] Kemp, D., Bond, C. J.,...& Cote, C.. (2010). *Mining, water and human rights: making the connection*. The Journal of Portfolio Management. www.sciencedirect.com/science/article/abs/pii/S0959652610002209?via%3Dihub

[5] Hughes, W. (2021, June 17). *The stages of mining: 5 lifecycle processes explained.* Opens. www.opens.co/articles/the-stages-of-mining

[6] Wincewicz-Bosy, M., Dymyt, M., & Wasowska, K. (2021). *The Supply Chain of the Mining Industry: The Case of Copper Mining.* ResearchGate. www.researchgate.net/publication/349385618_The_Supply_Chain_of_the_Mining_Industry_The_Case_of_Copper_Mining

[7] Thompson, R., Peroni, R., & Visser, A. (2018). *Mining Haul Roads.* Taylor & Francis Group. www.taylorfrancis.com/books/mono/10.1201/9780429491474/mining-haul-roads-roger-thompson-rodrigo-peroni-alex-visser

[8] *The 5 Stages of the Mining Life Cycle.* (2019). k2fly. k2fly.com/blog/mining-resources/the-5-stages-of-the-mining-life-cycle/#:~:text=There%20are%20five%20stages%20of,production%2C%20and%20closure%20and%20reclamation

[9] Walker, D. (2022). ESG Insights: What does ESG mean for the Mining industry? SLR. www.slrconsulting.com/insights/esg-insights-what-does-esg-mean-for-the-mining-industry/

[10] Hund, K., La Porta, D… & Drexhage, J. (2020). Minerals for Climate Action: The Mineral Intensity of Clean Energy Transition. World Bank Publications. pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf

24-053

Improved Drilling Controls Through Forecasting

Karl Ingmarsson
Boart Longyear, West Valley City UT

ABSTRACT

Larger mines spend millions of dollars annually on rock drilling tools, but often purchase based on historic consumption. The results vary from excess inventory to acute tools shortages. These lead to emergency sourcing, sometimes mixing products that don't perform optimally. Boart Longyear analyzed the usage pattern of 96 thousand drill bits at thirteen different underground mining contracts, showing very high variability. The monthly standard deviation on a product level was 42%, with the highest for development and low volume bits. A new rule of thumb is suggested to carry only one month of safety stock for high volume bits, but increase to three months for low volume bits. This balance will reduce the risk of outages with less inventory. The accuracy can be improved by considering the specific conditions at each mine and reclassifying individual bits for a different safety stock level. Root cause analysis and collaborative forecasting between mines and suppliers can lead to further optimization of availability and inventory levels.

PROBLEM STATEMENT

Measure-While-Drilling is used to predict downstream impacts, but mine operators do not reverse the flow of geomechanical knowledge and production plans to forecast rock tools usage. Conventional wisdom has it that historic consumption is a good enough predictor of future rock tools needs. The average monthly consumption from the past is used to forecast what is needed in the following months. A common practice is to purchase one month's expected usage while having another two months' worth of safety stock. Theoretically, the inventory level will fluctuate for between two and three months of usage. While this sounds sufficient, we know empirically that mines often under forecast. No mine is shut down because of a lack of rock tools, but shortages impact both sourcing teams and operations. Emergency sourcing takes away from other priorities and typically increase costs, while product substitutions or mixing of brands can lead to poor drilling performance.

Boart Longyear decided to challenge the old rule of thumb by analyzing reliable, actual consumption data from mining contracts. To limit the scope, we focused on drill bits since bit consumption has the highest degree of variability. The analysis is exclusively based on tophammer drill bits used in underground metals mining. Leveraging sound statistics, the objective was to identify better ways to forecast, to manage inventory, and eventually drive longer, more consistent bit life. Conceptually the logic is a proxy for all rock tools and types of drilling applications.

BASIC METHODOLOGY

The starting point was to base the statistical analyses on as much compatible bit data as possible.

- Thirteen underground mines in Peru, all metallic and using tophammer drilling for both development and production drilling.
- All sites under Boart Longyear tooling contracts.
- Mix of small to large operations, with tools contracts ranging from less than US$250k to more than US$2M per year.
- Identical reporting processes with monthly inventory tracked by Boart Longyear.
- Planned constant production or amount of drill meters.

The analysis followed the following steps:

1. Narrow the list to the regularly used bit designs. This eliminated test, specialty, or rarely used bits. It reduced the "high runners" to between two and seven bit part numbers (SKUs) per mine.