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ENERGY TRANSITION AND MINING IN THE GLOBAL SOUTH

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Abstract

The worsening environmental, social and economic problems associated with the use of fossil fuels intensifies the urgency of transitioning to renewable energy sources, driving the adoption of technologies such as solar panels, wind turbines and electric vehicles. Although often promoted as sustainable solutions, these technologies have intrinsic characteristics – such as lower energy density, reduced useful life and limitations in recycling processes – that increase dependence on minerals, many of which are classified as "critical." This article seeks to contribute to the debate by analyzing the impacts of the significant increase in demand for these resources. Based on the International Renewable Energy Agency's definition of critical minerals – which includes cobalt, nickel, copper, lithium and rare earth metals – we carried out extensive data collection, systematization and analysis on a global scale, identifying the main producing countries and the socio-environmental contexts associated with their extraction. The results show the reproduction of a historical pattern: most of these minerals are extracted in countries of the Global South, especially in Africa, Asia and Latin America, where environmental, social and economic regulations tend to be more flexible, favoring large transnational corporations. It was also found that the extraction of these minerals is often associated with serious socio-environmental impacts, such as intense pollution, exposure of workers to toxic metals and the financing of militias linked to authoritarian regimes. These issues, which are still little debated in the dominant discourse on the subject, require greater attention from the scientific community and society in order to promote a truly fair energy transition on a global scale.

Keywords: Critical Minerals; Extraction; Impacts; Problematics.

Resumo / Resumen

TRANSIÇÃO ENERGÉTICA E MINERAÇÃO NO SUL GLOBAL

O agravamento das problemáticas ambientais, sociais e econômicas associadas ao uso de combustíveis fósseis intensifica a urgência da transição para fontes de energia renováveis, impulsionando a adoção de tecnologias como painéis solares, turbinas eólicas e veículos elétricos. Embora frequentemente promovidas como soluções sustentáveis, essas tecnologias apresentam características intrínsecas - como menor densidade energética, vida útil reduzida e limitações nos processos de reciclagem - que ampliam a dependência de minerais, muitos deles classificados como "críticos". Este artigo busca contribuir para o debate ao analisar os impactos do aumento expressivo da demanda por esses recursos. Com base na definição de minerais críticos da Agência Internacional para as Energias Renováveis - que inclui cobalto, níquel, cobre, lítio e metais de terras raras -, realizamos ampla coleta, sistematização e análise de dados em escala global, identificando os principais países produtores e os contextos socioambientais associados à sua extração. Os resultados evidenciam a reprodução de um padrão histórico: a maior parte desses minerais é extraída em países do Sul Global, especialmente na África, Ásia e América Latina, onde regulamentações ambientais, sociais e econômicas tendem a ser mais flexíveis, favorecendo grandes corporações transnacionais. Constatou-se, ainda, que a extração desses minerais frequentemente está associada a impactos socioambientais graves, como poluição intensa, exposição de trabalhadores a metais tóxicos e financiamento de milícias ligadas a regimes autoritários. Essas questões, ainda pouco debatidas no discurso dominante sobre a temática, exigem maior atenção da comunidade científica e da sociedade para a promoção de uma transição energética verdadeiramente justa em escala global.

Palavras-chave: Minerais críticos; Extração; Impactos; Problemáticas.

TRANSICIÓN ENERGÉTICA Y MINERÍA EN EL SUR GLOBAL

El agravamiento de las problemáticas ambientales, sociales y económicas asociadas al uso de combustibles fósiles intensifica la urgencia de una transición hacia fuentes de energía renovables, impulsando la adopción de tecnologías como paneles solares, turbinas eólicas y vehículos eléctricos. Aunque a menudo promovidas como soluciones sostenibles, estas tecnologías presentan características intrínsecas - como menor densidad energética, vida útil reducida y limitaciones en los procesos de reciclaje - que incrementan la dependencia de minerales, muchos de ellos clasificados como "críticos". Este artículo busca aportar al debate mediante el análisis de los impactos del notable aumento en la demanda de estos recursos. Con base en la definición de minerales críticos de la Agencia Internacional de Energías Renovables - que incluye cobalto, níquel, cobre, litio y tierras raras -, se llevó a cabo una amplia recopilación, sistematización y análisis de datos a escala global, identificando los principales países productores y los contextos socioambientales asociados a su extracción. Los resultados evidencian la reproducción de un patrón histórico: la mayor parte de estos minerales se extrae en países del Sur Global, especialmente en África, Asia y América Latina, donde las regulaciones ambientales, sociales y económicas tienden a ser más flexibles, lo que favorece a grandes corporaciones transnacionales. Asimismo, se constató que la extracción de estos minerales suele estar vinculada a impactos socioambientales graves, como contaminación intensa, exposición de trabajadores a metales tóxicos y financiamiento de milicias relacionadas con regímenes autoritarios. Estas cuestiones, aún poco abordadas en el discurso dominante sobre el tema, requieren una mayor atención por parte de la comunidad científica y de la sociedad, con miras a promover una transición energética verdaderamente justa a escala global.

Palabras-clave: Minerales Críticos; Extracción; Impactos; Problemáticas.

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INTRODUCTION

In order to build infrastructures, supply industries, supply transportation systems, light homes and keep medical equipment running, among countless other applications, countries have been producing and consuming more and more energy, albeit in a significantly unequal way (EnerData, 2024). On a global scale, a significant proportion of this energy still comes from fossil fuels, such as oil (29.5%), coal (27.2%) and natural gas (23.6%), which together account for around 80% of all the energy consumed on the planet (IEA, 2023).

However, despite playing a central role in meeting growing energy demand, the severe environmental impacts associated with the use of these fuels, coupled with the possibility of future depletion of these resources, have driven a transition to renewable energy sources (Chen et al., 2019). This movement has intensified especially with the recent economic viability of sources such as solar and wind energy, which have already become competitive in several regions of the world (Statista, 2023a).

Between 2013 and 2022, approximately 3.4 trillion dollars were invested in renewable energy infrastructure, with solar (47.8%) and wind energy (38.7%) accounting for around 86.5% of all investment (IRENA; CPI, 2023). As a result, in just over a decade, global solar power generation capacity has expanded by 1,817.6%, from 74 Gigawatts (GW) in 2011 to 1,419 GW in 2023 (IRENA, 2024a). Wind power generation followed a similar trajectory, increasing by 362.3% over the same period, from 220 GW to 1,017 GW (IRENA, 2024b).

However, despite being essential to the current energy transition model, these renewable technologies have intrinsic characteristics that significantly increase their dependence on minerals, such as lower energy density (Van Zalk; Behrens, 2018) and reduced lifespan compared to traditional sources (Statista, 2023b). In a previous study entitled "Global Geography of the Energy Transition and Mineral Extraction" (Stacciarini; Gonçalves, 2025), we pointed out, based on data from the International Energy Agency (IEA), that an onshore wind turbine can demand up to nine times more mineral resources than a natural gas plant of equivalent capacity (IEA, 2021). In offshore wind projects, this demand can reach fifteen times more mineral resources, while electric vehicles require up to six times more minerals than conventional cars (IEA, 2021), especially because of the large batteries and electrical systems. In addition, the recycling of these technologies still faces significant limitations (Chowdhury et al., 2020; Jensen et al., 2020; Massoud et al., 2023), further increasing the demand for raw materials (Stacciarini; Gonçalves, 2025).

A scientific model developed by Watari et al. (2019) estimates that the energy transition could result in an increase in the flow of minerals of between 200-900% in the electricity sector and 350-700% in the transport sector in the period from 2015 to 2050, depending on the scenarios for meeting the International Energy Agency's targets.

Historically, a large part of mineral exploration has taken place in countries of the Global South (Hilson; Haselip, 2004; Freslon; Cooney, 2018; Riofrancos, 2022; Alonso, 2024) – a term that, in recent decades, has replaced expressions such as "underdeveloped countries" or "third world" (Buarque, 2023). These countries, characterized by low income levels, limited development and precarious living conditions, often relax their environmental and social regulations in exchange for minimal benefits, such as royalties and direct investments (Gonçalves; Milanez, 2019). Corporations, in turn, take advantage of this scenario to maximize their profits, without significant efforts to change the local reality (Davis; Tilton, 2005; Coumans, 2019; Svampa, 2019). In addition, a large part of the technological infrastructure and the main companies involved in the entire production chain come from rich countries, which benefit from the higher profits generated by mineral processing, the manufacture of cutting-edge technologies and their commercialization (Freslon; Cooney, 2018; Coumans, 2019). Meanwhile, workers and communities in extraction areas face the most severe consequences of these activities (Freslon; Cooney, 2018; Alonso, 2024).

In view of this set of problems, the aim of this article is to map the main countries producing critical minerals, which are essential for meeting the growing demands of the energy transition. It then seeks to assess whether these major producers are in fact concentrated in the Global South. Finally, the study aims to investigate, present and debate the social, economic and environmental impacts of increased extraction of these minerals.

METHODOLOGY

To investigate, map and interpret the relationship between "Energy Transition and Mining in the Global South," we used the following methodological procedures. First, we defined the list of minerals critical to the energy transition. Although this definition may vary, we chose to adopt the classification of the International Renewable Energy Agency (IRENA, 2021), an intergovernmental body with around 170 member countries, whose studies and publications on renewable energy are used by companies and governments in various regions of the world.

After defining the critical minerals – cobalt, nickel, copper, lithium and rare earth metals –, we carried out a comprehensive search on various global platforms and databases, with the aim of identifying, based on reliable and up-to-date information, the main producing countries of these minerals. The data on nickel (Statista, 2024a), copper (Statista, 2024b) and rare earths (Statista, 2024c) was extracted from reports by the German company Statista, which specializes in providing statistical information. References to the largest cobalt producers were obtained from reports by the United States Geological Survey (USGS, 2024). The data on lithium was taken from a report produced in partnership between the US stock exchange Nasdaq and the news and investment information platform Investing News Network (INN), which focuses on sectors such as mining and energy (Pistilli, 2024).

After tabulating the data, we carried out extensive bibliographic and documentary research – including books, academic articles, journalistic reports, field research reports and interviews – which enabled us to identify how the extraction of these critical minerals has taken place in the main producing countries, as well as the multiple environmental, economic and political consequences resulting from this process.

THE RELATIONSHIP BETWEEN THE ENERGY TRANSITION AND THE RISE OF MINING IN THE GLOBAL SOUTH

The growing demand for raw materials, driven by the energy transition, has triggered a race for various minerals, leading to the classification of some of them as "critical." Although this definition varies, the International Renewable Energy Agency (IRENA, 2021) defines critical minerals as those essential for the technologies associated with the energy transition, which have one or more of the following characteristics: they are produced in a limited number of countries, face major extraction challenges or have declining quality.

Although the list of critical minerals varies depending on the analyses and periods, IRENA (2021) highlights cobalt, nickel, copper, lithium and the rare earth metals, with an emphasis on neodymium and dysprosium. Based on comprehensive research (see methodology), which included extensive data collection and tabulation, we have drawn up a table that highlights the significant contribution of the countries of the Global South to the current production of these critical minerals.

According to researcher Daniel Sousa Buarque, the term "Global South" has been used in recent decades as a substitute for expressions such as "underdeveloped countries" or "third world" (Buarque, 2023). These nations, predominantly located in Africa, Latin America and Asia, share similar political, geopolitical and economic characteristics. Most have been colonized in recent centuries, have lower income levels, greater economic inequality and face more complex development and quality of life challenges compared to the countries of the "Global North," which are mostly concentrated in North America and Europe.

Historically, the exploitation of minerals in countries of the Global South has been advantageous for multinational companies, which find in these countries an abundance of resources and less stringent labor and environmental regulations, thereby reducing their production costs and increasing their profits (Hilson; Haselip, 2004; Davis; Tilton, 2005; Freslon; Cooney, 2018; Coumans, 2019; Gonçalves; Milanez, 2019; Svampa, 2019; Alonso, 2024).

Position	Cobalt (2023)		Nickel (2022)		Copper (2022)	
	Country	%	Country	%	Country	%
1st	DR Congo	73.9 %	Indonesia	48.6 %	Chile	24 %
2nd	Indonesia	7.4 %	Philippines	10.0 %	Peru	10 %
3rd	Russia	3.8 %	Russia	6.7 %	DR Congo	10 %
4th	Australia	2.0 %	New Caledonia	5.8 %	China	9 %
5th	Madagascar	1.7 %	Australia	4.9 %	USA	6 %
6th	Philippines	1.7 %	Canada	4.3 %	Russia	5 %
7th	Cuba	1.4 %	China	3.3 %	Indonesia	4 %
8th	New Caledonia	1.3 %	Brazil	2.5 %	Australia	4 %
9th	P. New Guinea	1.3 %			Zambia	4 %
10th					Mexico	3 %
Other (Sum)		5.5 %	Other (Sum)	13.9 %	Other (Sum)	21 %

Position	Lithium (2023)		Rare Earths (2023)	
	Country	%	Country	%
1st	Australia	46.6 %	China	68.3 %
2nd	Chile	23.8 %	USA	12.3 %
3rd	China	17.9 %	Myanmar	10.6 %
4th	Argentina	5.2 %	Australia	5.1 %
5th	Brazil	2.7 %	Thailand	2.0 %
6th	Zimbabwe	1.8 %	India	0.8 %
Other (Sum)		2.0 %	Other (Sum)	0.9 %

Countries of the global South

Table 1 - Countries of the Global South, highlighted, lead the way in the extraction of minerals critical to the energy transition. Source: Pistilli, 2024; Statista, 2024a; 2024b; 2024c; USGS, 2024. Collection, tabulation and organization by the authors.

Faced with the imperative of development, many companies entice governments in the Global South into giving up their territories and resources to neo-extractivist mega-enterprises, accepting the social and environmental impacts of these activities in exchange for small economic returns, such as royalties (Gonçalves; Milanez, 2019).

Davis and Tilton (2005) have shown that although mineral deposits represent significant natural capital for a country, their exploitation alone is not a sufficient condition for sustainable economic development. Due to various intrinsic characteristics of the sector and the global economic organization – such as the import of a large part of the inputs necessary for the activity, the predominance of multinational companies and the low added value realized domestically due to the possibility of mineral processing abroad –, host countries in the global south often obtain few financial benefits (from taxes and royalties) while bearing the entire burden generated by the activity.

By appropriating portions of territories and transforming them into corporate entities (Silveira, 2007; Harvey, 2016), these companies reinforce their position of dependence in terms of the international division of labor (Santos, 1996), establishing themselves as veritable "warehouses" (Svampa, 2019) of natural resources necessary for global production logics and the aspirations of hegemonic nations.

Furthermore, mining is, in itself, a high-impact activity. Characterized by the expropriation of land, control and occupation of large territories, appropriation of nature and common goods (such as land and water), this process – which involves extracting ore from the ground and subsoil, transporting it to processing plants, crushing, separating and refining – uses large amounts of energy and water, as well as generating considerable volumes of waste (Freslon; Cooney, 2018). It is no coincidence that tens of billions of tons of waste derived from the mining process are generated every year (EPA, 2024), contributing to this being one of the most impactful human activities today (Blight, 2011).

In the Global South, where labor and environmental regulations are less strict, governments are more dependent on resources, the economy is less diversified and civil society is less organized, the situation tends to be even worse, as will be exemplified in the following topic. Furthermore, the precarious working conditions and environmental damage caused by mining in the Global South often affect mainly those with less political influence, such as members of racial and ethnic minorities, people living in poverty or individuals living in geographically isolated areas (Davis; Tilton, 2005; Riofrancos, 2022). As a result, the workers involved in this process rarely benefit from the products that their workforce will create, such as electric cars and other technologies linked to the energy transition.

Many mining multinationals justify their practices by claiming that host countries in the Global South have weak governance, shifting responsibility for social, economic and environmental impacts onto the political and legal weaknesses of these nations. However, it is common for these companies, through their lobbying associations, to act to obstruct initiatives that seek to establish more robust accountability mechanisms (Coumans, 2019).

Although most of the big mining companies originated in the Global North, some elites and governments in the South have also organized themselves and currently control mining companies that are among the most capitalized and influential in the world. An emblematic example is Vale S.A., a Brazilian multinational – the country from which we are writing this article. However, in a highly globalized sector subordinated to the interests of large investment groups – mostly based in Northern countries – it is common for companies originating in the South to adopt the same exploitation logics used by Northern corporations (Garcia, 2017; Asuncion et al., 2022).

This dynamic can be seen in recent cases of negligence in Brazil, such as the dam collapses of Samarco/Vale S.A./BHP Billiton, in Mariana (MG), and Vale S.A., in Brumadinho (MG), which resulted in the deaths of hundreds of people (PoEMAS, 2015; Milanez; Felippe, 2021). Also illustrative are the various problems associated with Vale's expansion projects on the African continent, marked by controversies involving expropriations, violations of labor rights, environmental pollution, impacts on the health of communities near the mines, among others (Kato; Garcia, 2023; Cezne; Garcia, 2024).

Thus, in addition to the neglect historically imposed on the territories of the South by many of these corporations, the social, economic and environmental damage – significantly more intense in the South compared to the North – is deeply linked to the structural and historical dependence of the South on the interests and logic of accumulation of the North (Coumans, 2019).

In this context, it is essential to understand how the expansion in demand for critical minerals in the context of the energy transition poses new environmental, economic and social challenges and impacts for mining countries located in the Global South.

IMPACTS OF THE EXTRACTION OF MINERALS CRITICAL TO THE ENERGY TRANSITION IN THE GLOBAL SOUTH

Based on the definition of critical minerals for the energy transition established by the International Renewable Energy Agency and the analysis of the data presented in Table 1, this topic examines, on a case-by-case basis, how the extraction of these minerals has generated social, economic, political and environmental impacts in the countries of the Global South.

COBALT

Cobalt plays a crucial role in the energy transition, being essential for the batteries used in various technologies. In 2023, electric vehicle batteries already accounted for 40% of global demand for cobalt (Statista, 2024d), followed by portable batteries. The demand for this metal has been increasing every year, with projections that it will double by 2030 (CB, 2023).

Currently, approximately 74% of the world's cobalt production (Table 1) comes from the Democratic Republic of Congo (DRC), a Central African country that was a colony of Belgium until the 1960s. However, cobalt extraction in the country often takes place without the use of adequate safety

equipment, which results in high contamination of workers by toxic metals, increasing the risk of respiratory and heart diseases and cancer (Sovacool et al, 2020).

In addition to the formal circuit operated by multinationals, artisanal mining employs tens of thousands of Congolese as a means of subsistence. An extensive investigation by Maconachie (2024) revealed alarming situations, such as people carrying sacks of cobalt on bicycles, women handling raw ore with their bare hands, deaths caused by landslides, and child labor. The ore extracted is then sold by middlemen and ends up in large corporations, forming part of the global supply chain. Neglected by the government and the international community, this model of operation is effective in increasing the profits of the companies, which, protected by agents, traders and brokers, avoid being directly associated with the numerous irregularities (Maconachie, 2024).

In addition to the direct degradation of workers, an investigative report conducted by the organizations Rights and Accountability in Development (Raid) and African Resources Watch (Afrewatch) revealed that rivers, lakes, streams, groundwater and wetlands near cobalt and copper mines in the Democratic Republic of Congo are severely contaminated by mining activities (Raid; Afrewatch, 2024). As a result, fishing and agriculture have been drastically affected, women have suffered from gynecological and reproductive problems, and skin diseases have become more common.

NICKEL

Due to its physical and chemical properties, nickel has become an essential component in the manufacture of batteries, which are widely used in electric vehicles and renewable energy storage systems. Studies indicate that demand for this metal is expected to increase exponentially in the coming decades (IEA, 2021).

Currently, Indonesia, a Southeast Asian nation that was a Dutch colony for nearly three centuries and only gained its independence after World War II, in 1945, is the world's largest producer of the metal. Nickel production in the country increased sixfold between 2010 and 2023 (Statista, 2024e), and today accounts for around half of global production (Table 1).

Contradictorily, a large part of the energy used in the exploration and processing of nickel in Indonesia – which will later be used in renewable energy technologies – comes from new and old coal-fired power plants (Jong, 2023), a highly polluting source that is harmful to human health (Gasparotto; Martinello, 2021). Between 2020 and 2021, coal consumption in the country increased around sixfold, making Indonesia the world's third largest producer and eighth largest consumer of this fuel (IEA, 2024), as well as ranking as the seventh largest emitter of carbon dioxide (CO2) globally (ClimateWatch, 2024).

Waste from nickel mining and smelting operations has also contaminated the subsoil, streams, rivers and the ocean off the coast of Indonesia, an island country made up of more than 17,000 islands. This has resulted in heavy metal contamination of the local fauna and population, as well as damaging the livelihoods of communities that depend on fishing and agriculture (Sawal, 2022). In addition, due to precarious working conditions, 47 Indonesian workers died in nickel mines in the country between 2015 and 2022, as well as another ten foreigners (Chinese) whose deaths were recorded as suicides (Amindoni, 2023).

A report entitled Nickel Unearthed: The Human and Climate Costs of Indonesia's Nickel Industry, based on interviews and fieldwork conducted by the international organization Climate Rights International (CRI), denounced that multinational companies, in coordination with the Indonesian state (police), have appropriated territories belonging to indigenous peoples and other communities through coercion and intimidation, with the aim of implementing nickel mining and smelting projects (CRI, 2024). Furthermore, the country is the second largest producer of cobalt, second only to the Democratic Republic of Congo (Table 1). In Indonesia, cobalt is often extracted as a by-product of nickel mining, generating the same problems mentioned in the previous paragraphs (Decena, 2023).

The Philippines, Indonesia's neighbor, is the world's second largest nickel producer, accounting for around 10% of global production (Table 1). Made up of more than 7,000 islands, the Philippines was a colony for more than four centuries, a period that lasted until 1946 (Asuncion et al., 2022). A report by Electronics Watch (2022) – a non-profit organization that promotes and monitors labor rights in global

electronics industry supply chains – revealed that nickel mining in the Philippines is associated with several environmental and social impacts, including the pollution of water bodies with unsafe levels of hexavalent chromium, a carcinogenic chemical. The minerals extracted in the region are destined for companies such as Panasonic in Japan and car manufacturers Toyota (Japan) and Tesla (United States) (Electronics Watch, 2022).

COPPER

Copper is the non-precious metal with the highest electrical conductivity, playing an essential role in the manufacture of wind turbines, solar panels, electric vehicles and the modernization of electricity grids (ICA, 2024). Due to its wide application and relevance to the energy transition, global copper production has grown significantly, from 16 million metric tons in 2010 to 22 million in 2023, with forecasts of continued growth over the coming decades (Statista, 2024f).

Chile is currently the world's largest copper producer, accounting for approximately 24% of global production, followed by Peru and the Democratic Republic of Congo, each with 10% (Table 1). Although most copper reserves are concentrated in the Global South, the main copper mining companies are multinationals from the Global North. Among the eight largest companies in the sector, the US mining company Freeport-McMoRan stands out, followed by companies from Australia, Chile, the United Kingdom, Switzerland, Poland and Canada (Statista, 2024g).

In the context of Chile, the leading producer of around a quarter of the world's copper, an investigation by Zanetta-Colombo et al. (2022) revealed that indigenous communities in the north of the country are exposed to toxic metals from the tailings dams used to extract this mineral. The study indicated that dust emissions generated during the exploration, processing and disposal of copper tailings can be airborne for up to 50 km, impacting neighboring villages. This exposure puts the local population at risk of developing various disorders, including cancer, due to the high concentrations of toxic metals that are harmful to human health (Zanetta-Colombo et al., 2022).

On the central coast of Chile, the Ventanas Copper Smelter, located near Quintero and Puchuncaví and operated by the Corporación Nacional del Cobre (Codelco), one of the largest copper producers in the world, was closed down in 2023 after decades of popular pressure and almost sixty years of recurring pollution episodes (Balcazar, 2016; Milesi, 2022). These incidents turned the surrounding areas into "sacrifice zones" (Gorena et al., 2020), resulting in serious consequences for the local population, who faced recurring outbreaks of disease in both children and adults due to chemical contamination of the air (Balcazar, 2016; Milesi, 2022).

In Peru, the world's second largest copper producer, an investigation by the non-governmental organization Amnesty International (2021) examined 150 people living in the area of influence of the mining project of the Anglo-Swiss transnational Glencore, located in the province of Espinar. The research revealed that 117 of these people had high levels of metals and toxic substances, such as arsenic, lead, mercury, cadmium and manganese, highlighting the inability of both the corporation and the state to guarantee the right to health of this population (Amnesty International, 2021). Subsequent studies have indicated that local communities face a variety of problems, such as the pollution of water for human, animal and agricultural consumption, the dust generated by mining activities, the unpleasant odor that pollutes the air, the difficulty in marketing their products due to the associated contamination, as well as frequent bodily pain, permanent fatigue and the lack of adequate social and economic compensation (Custodio, 2022).

In the Democratic Republic of Congo, which shares second place as the world's largest copper producer with Peru, the challenges related to the extraction of this mineral are similar to those faced in the extraction of cobalt, discussed above. Between 2010 and 2023, copper production in the country increased around sevenfold (Statista, 2024h). However, this expansion has been accompanied by serious social and environmental problems, such as extremely low pay, lack of basic safety equipment, exploitation of child labor and the high levels of contamination affecting workers, soil and water resources, conditions that have resulted in illnesses and deaths among the population involved (Sovacool et al., 2020; Amnesty International, 2023; Maconachie, 2024; Raid; Afrewatch, 2024).

LITHIUM

Global consumption of lithium has increased systematically in recent years, with growth of around 686% between 2010 and 2023 (Statista, 2024i). To a large extent, this increase is due to the growing use of lithium-ion batteries in electric vehicles, which will account for 87% of global lithium consumption in 2023 (Statista, 2024i). Estimates suggest that global demand for these batteries could increase around sevenfold by 2030, driving a market that is expected to reach more than 250 billion dollars (Statista, 2024j).

Currently, global production of the mineral is fairly concentrated, with Australia (46.6%), Chile (23.8%) and China (17.9%) accounting for 88.3% of world production (Table 1). Argentina (5.2%), Brazil (2.7%) and Zimbabwe (1.8%) contribute another 9.7%, making up practically all global production (Table 1).

Although Australia currently leads production, around 60% of all known lithium reserves on the planet are found in Latin America, especially in the "Lithium Triangle," a region comprising the salt flats of Chile, Argentina and Bolivia (López-Calva, 2022). The process of extracting lithium in the salt deserts of the Lithium Triangle, one of the driest regions on Earth, involves drilling holes in the salt flats and pumping the mineral-rich brines to the surface (Ahmad, 2020). The mixture is then placed in large open-air evaporation pools, where it remains for months, allowing the water to evaporate naturally. After evaporation, the lithium is separated and purified (Ahmad, 2020).

An investigation by Liu and Agusdinata (2020) revealed that lithium mining has significantly impacted water availability in San Pedro de Atacama (SPA), located in the Atacama Desert in northern Chile, where the world's largest brine-based lithium extraction takes place. In a region traditionally marked by severe water scarcity, lithium mining has continuously increased water consumption, which is already around 50 times higher than domestic use, compromising local livelihoods such as agriculture and animal husbandry (Liu; Agusdinata, 2020; Mazzieri; Montanari, 2024).

The problems extend to various parts of Chile, Argentina and Bolivia that make up the Lithium Triangle. In addition to the issue of water availability, there are complaints about the pollution of water, soil and ecosystems, as well as the low generation of jobs and royalties, issues that have led to social conflicts (Ahmad, 2020; Mazzieri; Montanari, 2024). The economic interest in the coveted mineral has also had geopolitical repercussions. In July 2020, US billionaire Elon Musk, currently (2025) the richest person in the world and CEO of one of the largest electric vehicles manufacturers, Tesla, became embroiled in a controversy on Twitter. Musk was accused of supporting a coup d'état in Bolivia to secure access to the country's lithium. In response, Musk provoked even more controversy by saying: "We will coup whoever we want! Deal with it!" (Cota, 2022).

RARE EARTHS

Rare earth elements (REE) are a group of seventeen metals which, due to their unique properties, are indispensable in a wide range of high-tech devices (GAAG, 2024). They are used in magnets and supermagnets, metal alloys, electronic and computer equipment, batteries, catalytic converters, special glasses and ceramics, among others, and play a key role in energy transition technologies such as solar panels, wind generators and electric vehicles (Balaram, 2019; GAAG, 2024).

Global production of rare earths increased from 133,000 metric tons in 2010 to 350,000 tons in 2023, showing growth that is expected to continue over the coming decades (Statista, 2024k). China currently accounts for 68.3% of global production, followed by the United States (12.3%), Myanmar (10.6%), Australia (5.1%), Thailand (2.0%) and India (0.8%), which together account for almost all world production (Table 1).

The case of China is emblematic because, as well as being the largest extractor of rare earths in its own territory, the country also stands out as one of the main producers of equipment for the global supply chain aimed at the energy transition, such as devices for solar and wind energy and electric vehicles (Zhang et al., 2022). This extraction, processing and manufacturing has caused environmental impacts at the domestic level, estimated at billions of dollars a year (Lee; Wen, 2016; Zhang et al., 2022).

The process of extracting these elements involves the intensive use of chemicals, resulting in extensive pollution of surface water, groundwater and soil in various regions of the country (Liu et al., 2019; Caixin Global, 2022). This contamination has harmed local activities, such as agriculture, as well as posing health risks to the populations living in the affected areas (Standaert, 2019; Caixin Global, 2022).

Myanmar, a neighboring country to China that was a British colony until 1948, has also seen a significant increase in the production of rare earths in recent years. Between 2018 and 2023, this production doubled (Statista, 2024l), making the country the third largest global producer (Table 1).

However, the extraction of these minerals is surrounded by serious problems. Investigations by the international NGO Global Witness (2022; 2024) reveal that most mining in the country is illegal, does not follow regulatory standards and is controlled by militias allied to the military government, which took power in 2021. This unbridled exploitation has caused devastating environmental impacts and serious consequences for the health of local communities, with workers falling ill due to direct and indirect exposure to the toxic chemicals used in mining. Deaths from landslides, caused by the lack of adequate infrastructure, have become frequent (Naing, 2024).

Furthermore, many abandoned mines were left without the necessary remediation efforts, resulting in toxic waste and widespread environmental pollution. The social situation in mining regions also deteriorated, with increased drug use, prostitution and violence (Global Witness, 2022; 2024).

A detailed investigation by the Associated Press (Kang et al., 2022) exposed that the minerals extracted in these conditions of illegality and political instability, which generate pollution and serious social problems in Myanmar, are sold directly or through intermediaries to large state-owned mining conglomerates in China. These materials then enter the supply chain of some of the largest companies in the world (Kang et al., 2022).

CONCLUSIONS

This study explored the intrinsic relationship between the energy transition and the increase in mining in the Global South, emphasizing the problems arising from this reality.

Although often promoted as clean and renewable, the technologies associated with the energy transition have characteristics that limit their sustainability, such as lower energy density, short useful life and difficulties in the recycling process. These factors result in a greater dependence on minerals, especially as compared to fossil energy sources. As a result, minerals such as cobalt, nickel, copper, lithium and rare earth metals have become essential and are classified as “critical” for making this transition viable.

The tabulation and analysis of the data indicated that the countries of the Global South – a term that has been replacing expressions such as “underdeveloped countries” or “third world” – are the main suppliers of minerals essential to the development of new energy technologies. The discussions and evidence reinforced the premise that mineral exploration in these countries has always attracted large international corporations. Taking advantage of a globalized scenario in which capital and resources circulate freely, but where policies, regulations, inspections and sanctions vary drastically, these corporations choose to extract minerals in countries with fewer resources and regulatory frameworks.

Due to their low levels of income, development and adverse living conditions, these countries tend to relax their environmental, social and economic regulations, favoring the profitability of corporations in exchange for minimal compensation, such as royalties and direct investments. However, they are the ones who bear the heavy burden of these activities. Moreover, a continuous cycle of dependence and exploitation is created, since a large part of the technological infrastructure and dominant companies along the production chain come from developed countries, which appropriate most of the profits from mineral processing, the manufacture of advanced technologies and their commercialization.

The analyses indicate that the extraction of critical minerals in the Global South has contributed little to improving the living conditions of workers and local communities. On the contrary, when examining how this extraction takes place in the main producing countries, we find that it is often

associated with various problems, such as widespread environmental pollution (soil, water and air), precarious working conditions, child labor, occupational deaths and accidents, contamination of workers and residents, human rights violations, an increase in illegal activity and social problems, including drug use, prostitution and violence, as well as the financing of militias linked to authoritarian military regimes, among various other violations.

Given this panorama, it is imperative to rethink the direction of the energy transition so that it does not reproduce – or even exacerbate – historical patterns of exploitation in the Global South. Promoting a just transition requires the effective inclusion of the territories of the South, not just as suppliers of abundant resources under weak environmental and labor regulations, but as players in the construction of a new development model. To this end, it is essential to tackle the structural asymmetries that mark the dynamics of production and development on an international scale. As a contribution to the debate, we highlight the need to: (i) strengthen traceability mechanisms for critical minerals; (ii) establish stricter regulatory frameworks, with effective environmental monitoring systems and corporate accountability; (iii) ensure the effective participation of local communities in decision-making processes; (iv) encourage the development of local value chains, adding value to mineral production; (v) convert mining compensation and royalties into investments in social infrastructure and economic diversification strategies that reduce mineral dependence; (vi) encourage technological innovation aimed at recycling and reusing critical minerals; and (vii) rethink current global production and consumption patterns, recognizing the planet's ecological limits. Only through such efforts will it be possible to achieve an energy transition that truly promotes socio-environmental justice on a global scale.

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