PBL Netherlands Environmental Assessment Agency

# SOCIAL IMPACTS OF MINING CRITICAL RAW MATERIALS

## Challenges and entry points for governance

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## Colophon

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# Table of Contents

# Main Findings

### *The social risks embedded in critical raw material supply chains are systemic, diverse, and directly relevant to security of supply*

The growing global demand for critical raw materials (CRMs) is deeply connected to the accelerating energy transition, advances in defence technologies, medical innovation, and the rapid expansion of digital infrastructure. The extraction of CRMs takes place across many countries and often leaves long-lasting environmental and socio-economic impacts, which persist well after mining operations have ended. The social impacts include forced displacement, loss of productive land, child labour, low-wages, lack of adequate compensation, water conflicts, and more. Increasingly, they are recognised not as isolated incidents, but as source of structural challenges within global supply chains.

- In Guinee for example, where 30% of global bauxite is extracted, community protests over land and water pollution and lack of financial compensation have temporarily disrupted bauxite operations. Ongoing unrest creates a persistent risk for global aluminium supply.
- In Chile, social unrest around copper mining has centred on water scarcity and environmental degradation, with Indigenous communities and local residents protesting mining projects. These conflicts have led to road blockades, operational disruptions, and growing risks of production delays, threatening the stability of Chile's copper supply to global markets.
- In the Philippines, more than a quarter of nickel concessions overlap with Indigenous territories, contributing to social unrest and raising risks for environmental defenders. These tensions can undermine investor confidence, delay mining projects, and threaten the stability of supply chains.

Addressing these challenges is crucial not only from an ethical perspective, but also to safeguard the resilience of global supply systems. The Organisation for Economic Cooperation and Development (OECD) and the International Energy Agency (IEA) have both warned that social and environmental pressures around mining sites can disrupt the supply of CRMs, with serious implications for the energy transition and technological development. These risks are especially pronounced in low- and middle-income countries (LMICs), where mining often takes place amid lower governance capacities and more severe local impacts.

### *Social impacts vary by metal and region, underscoring the need for context-specific responses and improved knowledge*

There are several common social impacts related to CRM mining (Figure 1). However, impacts linked to CRM extraction (and their severity) do not manifest uniformly across countries or materials. This report highlights distinct social impacts across eight metals in a wide range of producer contexts. The metals are copper, manganese, nickel, bauxite, cobalt, graphite, rare earth elements and silicon metal. In Chile, for example, copper mining drives water stress and land conflict in arid regions, despite relatively strong institutions, while in Mozambique, graphite extraction is linked to involuntary resettlement and regional inequality, intensified by political instability. In China and Myanmar, rare earth elements are associated with environmental degradation, health issues and opaque supply chains. Such diversity in impacts reinforces the importance of tailored, evidence-based approaches. Strengthening data collection, investing in

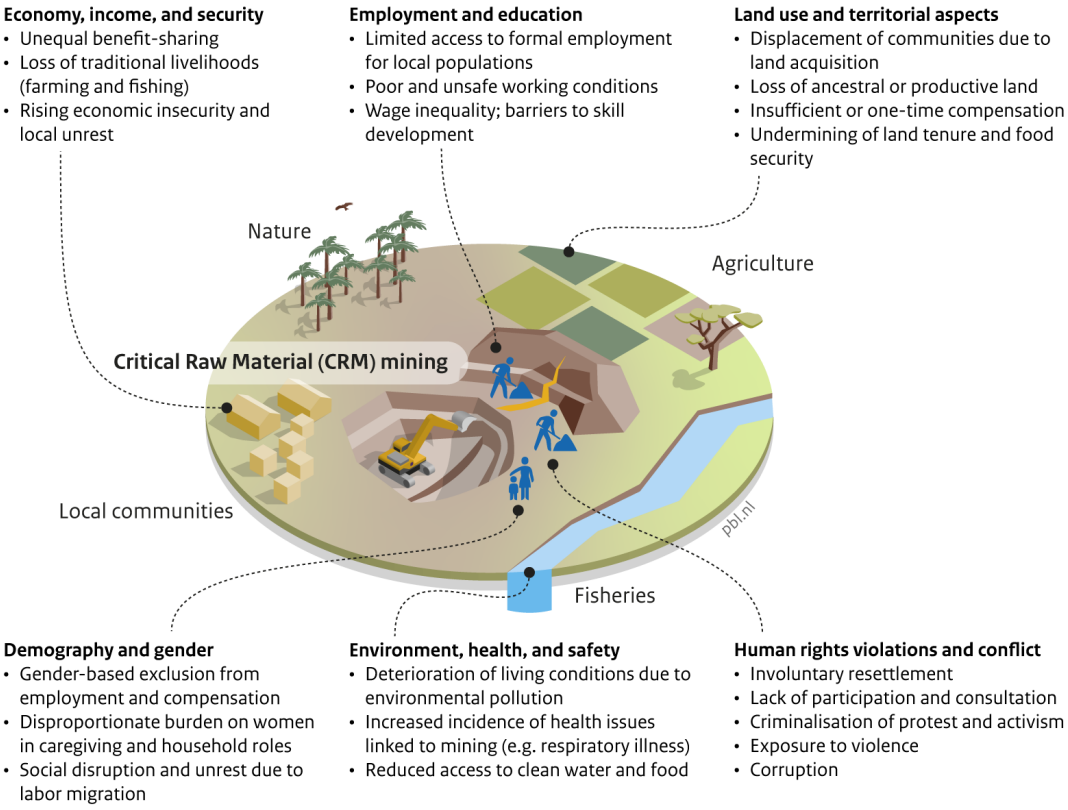
local expertise, and supporting research are important steps towards more informed and legitimate policymaking.

### *Limited governance capacities and limited civic space in resource-rich countries amplify the risks of social harm and unrest*

In many LMICs which are also resource-rich, or considered producing countries, governance constraints (such as low enforcement capacity, corruption, and limited space for civil society) undermine efforts to ensure responsible mining practices. In the Democratic Republic of the Congo (DRC), for example, both artisanal and industrial cobalt mining are linked to unsafe working conditions, forced resettlement, and environmental pollution. Despite formal regulation, enforcement remains inconsistent, and efforts to improve conditions are often undermined by a lack of transparency. In Mozambique, grievances around forced resettlement in the graphite sector contribute to mine shutdowns and broader tensions on a regional level. These dynamics are compounded when communities lack access to information or mechanisms to voice concerns. Shrinking civic space in key producing regions limits the possibilities for public accountability, which in turn weakens the prospects for long-term cooperation. Therefore, to have a sustainable supply strategy, including support for civil society and local governance in partner countries is important.

**Figure 1**

**Common Social Impacts of Critical Raw Material (CRM) Mining**




Source: PBL

### *The costs and benefits of CRM extraction remain unevenly distributed across and within countries*

CRM extraction generates significant value, but the case studies included in this report demonstrate that this value is rarely equitably shared. While economic gains flow primarily to mining companies,

national governments, investors, and downstream actors, often headquartered in high-income countries, local communities frequently face degraded environments, health risks, and limited employment opportunities. In Indonesia's nickel sector, small-scale farmers have lost access to productive land, while local fishermen have been pushed further offshore due to habitat destruction. In South Africa, communities living near manganese mines face poor water access and respiratory illnesses. Even in high-income countries with advanced mining industries such as Chile, mining regions experience persistent socio-environmental conflict, suggesting that economic returns at the national level do not guarantee local benefits. These examples highlight the need to assess CRM value chains not only in terms of maximizing efficiency or reliable access, but also in terms of fair compensation, local value distribution, and inclusion.

### *While the Dutch economy is closely connected to supply chains with high social and environmental risks, policy can help mitigate these risks*

The metals powering Dutch clean energy systems, vehicles, and defence/medical/digital technologies often originate from high-risk regions. Cobalt from the DRC, copper from Chile, and rare earths from China are all examples of minerals that have documented links to adverse social and environmental outcomes. Despite the fact that the Netherlands does not import many of these materials directly, as a consumer of upstream products, an investor/financier, and EU policymaker, they are not without responsibility and leverage.

Recent regulatory initiatives provide new opportunities to address these risks. The EU Battery Regulation includes mandatory due diligence for environmental and human rights impacts, while the Corporate Sustainability Reporting Directive (CSRD) and the forthcoming Corporate Sustainability Due Diligence Directive (CSDDD) require companies to report on and mitigate negative impacts in their supply chains, even though the EU's omnibus package risks slowing down the implementation of these regulations. Similarly, the Conflict Minerals Regulation aims to stop the trade in minerals linked to conflict, but poor enforcement in the DRC and loopholes in transit hubs like Rwanda and UAE undermine its impact. At the national level, the Dutch Raw Materials Strategy integrates social criteria into its vision for secure and responsible sourcing. However, it's effectiveness will depend on further development of concrete measures, robust implementation, support for local monitoring mechanisms, and alignment with broader trade and sustainability goals.

### *A sustainable raw materials strategy requires shifting from risk avoidance to long-term value creation and partnerships*

Dutch and European strategies often focus on mitigating supply chain risks through diversification, stockpiling, and diplomatic agreements. While these tools are important, they are insufficient on their own. Long-term resilience will depend on building equitable partnerships that support not only access to materials, but also local development, institutional strengthening, and shared value creation. This includes investing in upstream capacity for responsible mining, refining, and recycling; promoting inclusive decision-making processes; and supporting communities' rights to information and consultation. The development of strategic partnerships, as promoted in both the EU Critical Raw Materials Act and the Dutch Raw Materials Strategy, could therefore be guided by social as well as economic considerations: do the agreements align with national but also local visions of LMIC partners? Civil society plays an important role in drafting equal partnerships. Nationally, aligning raw materials policy with development cooperation, human rights diplomacy, and the circular economy agenda offers a path forward that addresses both ethical responsibilities and structural dependencies.

# 1. Introduction

The global transition to cleaner energy production and advanced digital technologies drives the high demand for critical raw materials (CRMs) such as nickel, cobalt, and rare earth elements (IEA 2024a). These materials are essential components of renewable energy technologies and critical applications like medical equipment and defence systems (Berenschot 2023; HCSS 2023). Each technology depends on specific materials that are not always readily available, creating issues of criticality, a concept that reflects the risks of supply shortages and the economic importance of the material in question (European Commission et al. 2020).

The mining of CRMs is a high-risk activity due to its complex and often disruptive nature. It typically involves large-scale, capital-intensive operations in remote areas, requiring long-term planning under uncertain market and regulatory conditions. The sector is strongly associated with environmental degradation, and mining projects can have profound (social and environmental) impacts on local communities Frequently reported issues in mining regions include low wages, serious health and safety risks, displacement of communities, and environmental degradation (Global Witness 2023).

Environmental and social issues often lead to protests, which can contribute to mine disruption or even closures and associated price volatility and supply chain disruptions. They can also deter investment, damage company reputations, and ultimately hamper the global energy transition while threatening other strategic sectors (IEA 2024b). For many CRMs, extraction locations are concentrated; sometimes, a disruption at a single mine or region can have an impact on the overall security of supply (van den Brink et al. 2020).

A key challenge in the energy transition is to meet the surging demand for critical minerals and metals while simultaneously minimising the environmental and social harm associated with their extraction. This balance is acknowledged by amongst others, the EU and the Netherlands, as being central to the success of a sustainable, low-carbon future (de Haes & Lucas 2024). The European Critical Raw Materials Act (CRMA) and the Dutch Raw Materials Strategy (NGS) emphasise the importance of securing supply while minimising environmental and social impacts. Other policies, such as the Battery Regulation and the Conflict Mineral Regulation, demonstrate that there is an increased willingness within Europe to push companies towards better environmental, social, and governance (ESG) practices, also in metal supply chains.

At the request of the Dutch Ministry of Foreign Affairs, this report synthesises key insights into the social impacts of the extraction of CRMs, identifies relevant factors that influence these social impacts, and entry points for governance of sustainable supply chains. The report analyses eight CRMs, in ten different countries (table 1). In reporting on the social impacts of a selection of CRMs and key drivers of negative impacts, this report supports further development of the NGS, by exploring how better insights into these issues can contribute to more responsible and resilient supply chains, thereby ensuring that the benefits of CRMs are shared more equitably and sustainably across the globe. In doing so, this report aims to provide a starting point for informed discussion and practical solutions that balance economic, environmental, and social priorities.

## 1.1 Research approach and structure of the report

This study investigates the following questions:

- What socio-economic impacts are typically associated with mining activities in key production regions?
- What are important local, regional, national and global factors contributing to the adverse impacts associated with CRM extraction?
- What are key entry points for governance of sustainable supply chains of CRM?

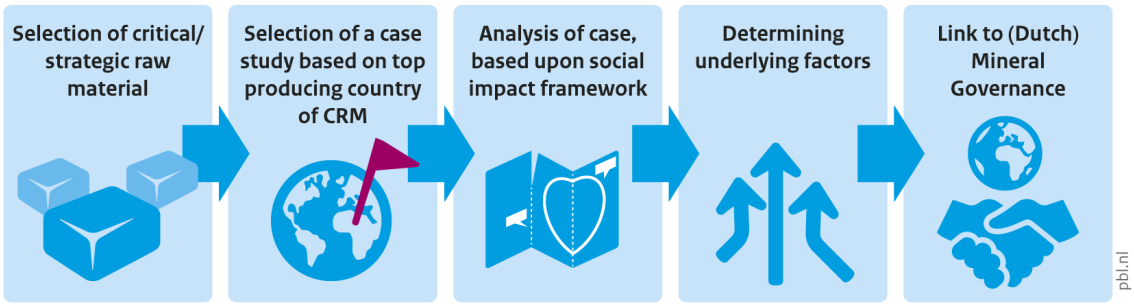
In a previous PBL-report on the environmental impacts of mining critical or strategic raw materials, we assessed similar metals (de Haes & Lucas 2024). These metals were selected based on several criteria, including strategic importance and production areas. For this report, we made a smaller selection of critical or strategic raw materials (from now own CRM) based on presence in vulnerable areas and LMICs, and the availability and diversity of literature on the associated social impacts. Because limited quantitative data is available on social impacts of CRM, we adopted a qualitative, descriptive approach. Rather than seeking to establish definitive causal relationships, our research focuses on providing a broad set of case studies that illustrate the different ways in which mining affects local and regional communities, as well as various specific stakeholder groups in LMICs.

### *Structure of the research*

The first part of the study is focused on background and context, by describing the global CRM market and identifying countries and organisations that are key players in this market. To do so, we performed a literature review and assessed mining data. To describe key players, we used mining reports and data by S&P Global, which is currently the most comprehensive database on minerals and formal mining as well as key players. A key source for describing important CRM resources for strategic sectors is the International Energy Agency. The data per metal is further discussed in Chapter 2.

**Figure 1.1**

**Structure of Social Impact Analysis of Critical Raw Materials**




Source: PBL

In Chapter 2 we describe the social impacts associated with the extraction of critical raw materials, with a focus on metal mining. Our analysis is guided by the question: What socio-economic impacts are typically associated with mining activities in key production regions? To provide an illustrative overview, we use a social impact framework for mining (Appendix I), which guides the identification of impacts per metal. Given the context-specific nature of mining-related social impacts, we base our analysis on country-level case studies. For selected metals, we chose one or two countries among the top global producers for an analysis of local social impacts (see Table 1). We based our case selection on two criteria: (1) the country ranks among the top producers of the selected CRM, and (2) is either a low-income country (LIC) or a middle-income country (MIC). Chile

is the exception in our list as a high-income country (HIC). It was selected because it is an important mining country where adverse impacts are nonetheless observed. Each case study involves a review of scientific literature and relevant reports to assess how mining activities affect the social and economic well-being of local communities (see Figure 1.1 for an overview of the steps).
The chapter concludes with knowledge gaps around social impacts identified during the literature review.

**Table 1**
Case study countries and Critical raw materials (CRMs)

| CRM | Selected producer countries |
|---|---|
| Bauxite | Guinee |
| Cobalt | The Democratic Republic of Congo |
| Copper | Chile |
| Graphite | Mozambique |
| Manganese | South Africa |
| Nickel | Indonesia, the Philippines |
| Rare earth elements | China, Myanmar |
| Silicon metal | China |

To explore patterns or shared pressures that influence these impacts, Chapter 3 presents a literature review complemented by findings from the case study assessments. This helps to describe and categorise significant contextual factors that are seen in various cases, in different contexts. We subsequently answer the question: *What are important local, regional, national and international factors contributing to the adverse impacts associated with CRM extraction?*

Finally, in Chapter 4, the report flags potential entry points for the EU and the Netherlands to address the social impacts associated with CRM production. By briefly examining relevant policy developments at global, European, and national levels in light of the findings presented in this report, we identify opportunities for policymakers to enhance current approaches and promote more socially responsible supply chains. Ultimately, a more in-depth analysis from a governmental perspective is needed to elaborate on entry points for mitigating social impacts within CRM supply chains.

### *Limitations of this study*

While the methodology offers valuable insights, certain limitations must be acknowledged. The highly localised nature of mining impacts means that studies might not fully capture the diversity of experiences across all regions and metals. This study is not intended to provide an exhaustive description of social impacts in CRM mining, neither does it aim to identify causal relationships between drivers and impacts. The purpose of the study is to contribute to the understanding of the negative social impacts of CRM mining in lower/middle income countries, and how these impacts are connected to developments in consuming high income countries. The literature on certain metals and regions is limited, in some cases relying on older or generalised data which can be a drawback. Finally, the study addressed formal mine databases and tackled the most visible social impacts, which may have resulted in an oversimplified view of broader dynamics and a lack of insights on informal or artisanal mining activities.

# 2. Understanding CRM extraction and impacts

This chapter explores the social impacts associated with CRM extraction. Section 2.1 gives a brief overview of the global mining industry for CRMs, forming the base for the selection of one or two production regions per CRM. In the remaining sections, we discuss global supply and demand trends, as well as examples of typical social impacts seen in the extraction of eight CRMs: aluminium, copper, cobalt, graphite, manganese, rare earth elements, and silicon metal. Then, we describe the results of the social impact study per selected production region.

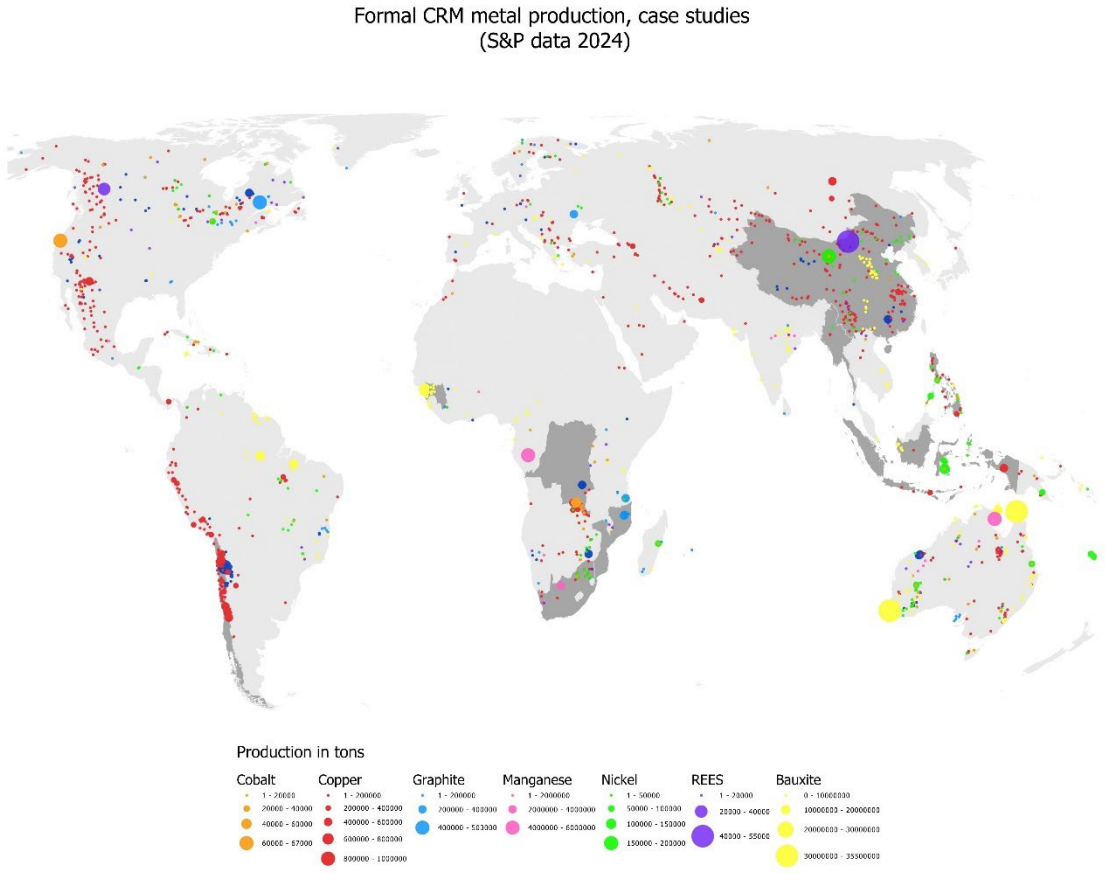
As discussed in Chapter 1, our aim is not to be exhaustive in describing all relevant impacts, but to understand impacts that typically occur in selected countries by analysing case studies based on recent localised research. In the case of several CRMs, research on social impacts is well developed; for others, very little information is available. Our findings reflect these differences. The concluding subsection brings together the lessons learnt about the different types of impacts and the commonalities per metal and region.

## 2.1 Important production sites

Several low- and middle-income countries (LMICs) are major extraction hubs for critical raw materials (Figure 2.1). The most comprehensive database of formal mines, S&P Global, contains a total of 15,038 registered mines of the metals assessed in this study (S&P Global 2025). Chile leads in copper production, although declining ore grades and limited new projects threaten long-term supply. The Democratic Republic of the Congo (DRC) dominates in cobalt mining, with foreign companies, particularly Chinese firms, controlling much of this sector. Indonesia has emerged as the top nickel producer, supplying 61% of the global refined nickel. South Africa remains a leading producer of manganese and platinum group metals, while Guinee holds the world's largest bauxite reserves, thereby supplying aluminium production. Also in Africa, Mozambique is expanding their graphite mining operations in an effort to reduce dependence on Chinese supply. Other countries are following suit with their own operations.

Though localised in South America and Africa, in most of these countries, Western mining giants such as BHP, Rio Tinto, Glencore, Anglo American, and Barrick Gold control the vast reserves of copper, nickel, and other critical minerals, while Chinese state-backed enterprises, including China Northern Rare Earth Group, play a central role in rare earth production and high-quality silicon metal (S&P Global 2025).

**Figure 2.1**
Case studies (in dark grey) and important production sites per selected CRM (Source: PBL and S&P Global)






## 2.2 Bauxite mining in Guinee

### *Trends in demand and supply*

Global demand for aluminium is expected to grow by almost 40% by 2030 (IAI 2025). The aluminium industry is expected to increase from 86 Mt in 2020, to 120 Mt in 2030. Most of this demand, about 75%, will come from transportation, construction, packaging, and the electrical industries. Decarbonisation and a move away from fossil fuels will drive EV production to 31 Mt by 2030, up from 20 Mt in 2020. Renewable energy will also increase aluminium demand for solar panels and power cables, adding another 5.2 Mt. The construction sector will need about 5 Mt more by 2030, with urbanisation in Asia accounting for much of the growth. Aluminium packaging demand will grow from 7 Mt in 2020 to 10 million Mt in 2030, driven by the rising popularity of canned drinks and environmentally friendly packaging in North America, Europe, and China (IAI 2025).

Aluminium is extracted from bauxite. The African country of Guinee has the largest bauxite reserves in the world, with about 7.4 billion dry tonnes as of 2023. Vietnam has the second largest reserves, with 5.8 billion dry tonnes. Altogether, the world's bauxite reserves totalled 30 billion dry tonnes in 2023 (S&P Global 2025).

In terms of supply of aluminium, China is by far the world's largest aluminium producer, making over 35 Mt each year. That is more than ten times what the second-largest producer, Russia, produces. Russia, India, and Canada produce similar amounts, with 3.5 million, 3.4 million, and 3.2 Mt per year, respectively (S&P Global Market Intelligence 2025)

### *The social impacts of extraction in the Boké region of Guinea*

Large scale bauxite mining in Guinee is concentrated in the Boké region, known for its abundant bauxite reserves and a landscape now transformed by dozens of sprawling open-pit mines, mining roads, and industrial ports. This region has become an important centre of Guinee's booming mining industry. Prominent operators like La Société Minière de Boké (SMB), a consortium with Chinese partners, and La Compagnie des Bauxites de Guinée (CBG), co-owned by the Guinean government and multinationals such as Alcoa and Rio Tinto, dominate the sector. These companies operate under agreements with the Guinean government, which grants mining concessions and collects revenue through taxes and royalties (Camara et al. 2021). Bauxite deposits in Guinee are very large, relatively shallow, and require heavy machinery and significant capital to extract and transport the ore efficiently. For this reason there is barely to no artisanal and small scale mining (ASM) for bauxite.

#### *Economy, income, and security*

The bauxite industry has brought economic growth, generating significant government revenue, foreign investment, and thousands of jobs. However, much of the profit is captured by multinational companies and their shareholders, leaving little local benefits (Wilhelm, 2023a).

On a local level, despite industry growth, mining has not generated the expected job opportunities for local communities. In Boké, an estimated 70% of young people remain unemployed. Many residents argue that mining operations primarily benefit outsiders, as companies often hire workers from other regions and countries. Locals struggle to secure mining jobs, with employment opportunities often dependent on personal connections rather than community inclusion. Mining companies frequently recruit externally, citing a lack of local expertise and skills (Camara et al. 2022).

#### *Environment, health, and safety*

Bauxite mining relies heavily on large machinery and generates significant amounts of mineral dust, contributing to severe air pollution. A typical issue with bauxite mining is the amount of tailings produced in the form of red mud, also known as bauxite residue. This byproduct is corrosive and  contains toxic heavy metals. Red dust can pollute vast areas at a time (Dibattista et al. 2023).

For local communities in the Boké region, the impacts are therefore profound. Thousands of individuals have lost access to ancestral farmland due to land expropriation, which was their primary source of food and income. Blasting near villages by SMB has cracked homes. Environmental degradation has reached critical levels, with red dust from mining operations covering homes and agricultural fields, and water sources becoming polluted or depleted. This contamination has directly impacted public health, agricultural productivity, and local fisheries, undermining the livelihoods of farmers and fishermen (Dibattista et al. 2023).

Public health experts note that, without reliable local health data, establishing a direct link between mining and respiratory illnesses remains difficult. However, healthcare providers serving communities like Djoumayah observe a rise in respiratory issues that may be linked to declining air quality. In February 2018, a government inspection in Djoumayah measured fine particulate matter levels more than ten times higher than World Health Organisation (WHO) guidelines, indicating significant health risks from airborne dust (Wormington 2018).

These challenges have made essential resources like water and food scarcer, lowering the overall quality of life for many residents. Protests in Boké highlight frustrations with unmet promises of development and limited access to the economic benefits of mining (Wormington 2018). In 2019, these issues led to more than 100 conflicts in the Boké region alone (Camara et al. 2021). Although environmental damage is not always seen as the main cause of conflict, it plays a significant role in fuelling tensions. The rapid expansion of bauxite mining has led to violent protests over environmental damage, unfair benefit-sharing, inadequate compensation for displaced farmers, and rising youth unemployment, which increased from 30% in 2012 to 35% in 2020. The lack of basic services and harsh responses to protests, including the use of live ammunition by security forces, have further escalated tensions (Camara et al. 2021).

*Land use and territorial aspects*

Mining operations have expanded into fields that communities rely on for food, reducing access to fertile land (Dibattista et al. 2023). In Boundou Waadé, a village surrounded by five CBG mines, residents report significant losses of productive farmland. Efforts to compensate affected residents have been made, primarily through one-time financial payments. However, these payments rarely address the long-term challenges of losing ancestral land or rebuilding sustainable livelihoods (Wormington 2018).

*Demography and gender*

Women actively participate in farming, yet men in family or community leadership roles receive most of the compensation for the loss of farmlands. Women report that their husbands distribute earnings as they see fit, regardless of the fact that all family members rely on the land's resources(Wormington 2018). When mining companies acquire land, at least some men secure jobs as compensation, but employment opportunities for women remain scarce. In September 2018, SMB employed over 7.600 people, but only 274 were women. Similarly, in May 2018, women made up just 10% of CBG's direct workforce. Despite being disproportionately affected by land loss and mining operations, women have little influence over compensation decisions or community development projects, further reinforcing gender inequities (Wormington 2018).

## 2.3 Cobalt mining in the DRC

### *Trends in demand and supply*

Global cobalt demand has grown significantly, driven by increased use of EV batteries and also more traditional uses like electronics. In 2023, 70% of cobalt consumption had not yet been used for clean energy technologies, yet EV batteries are set to dominate in the future, reaching 60% of demand by 2040 in a Net Zero Scenario (IEA 2024).

Samarium-cobalt (SmCo) magnets play a crucial role in applications requiring high reliability under extreme conditions, particularly in defence, aerospace, and maritime sectors. Although their contribution to global cobalt demand remains relatively small compared to the dominant use of

cobalt in lithium-ion batteries, their strategic significance is substantial. The demand for SmCo magnets is expected to grow steadily, driven by their superior performance at high temperatures and in corrosive environments (IMARC Group 2024). This niche but critical use contributes to the overall pressure on cobalt supply chains. As the demand for resilient and high-performance materials increases, ensuring a sustainable and diversified supply of cobalt becomes even more essential (IMARC Group 2024).

EV cobalt demand will grow 3 to 4.5 times by 2040, but trends towards low-cobalt or cobalt-free batteries, like lithium-iron-phosphate (LFP) and sodium-ion, are gradually slowing its growth. By 2050, cobalt use in battery storage will drop to near zero as cheaper alternatives gain traction. Cobalt remains essential in superalloys for aerospace and defence, where demand is stable due to less price sensitivity and the need for high-performance materials (IEA 2024).

For the time being, the cobalt market has plenty of supply, with oversupply likely to continue in the near future thanks to new mines and stockpiles, especially in the Democratic Republic of the Congo (DRC) (IEA 2024). However, long-term supply could face challenges as DRC reserves are expected to run low after 2030. Indonesia's fast-growing cobalt production will help offset this decline, but low cobalt prices may make it harder to fund new projects (IEA 2024).

The DRC is still the leading cobalt producer, with major growth expected from new mines like Tenke Fungurume and Kisanfu. By 2040, however, the country's output could drop by 15% due to lower ore quality and higher costs. Meanwhile, Indonesia has become the second-largest supplier, with production set to account for 23% of global supply by 2030, reducing the DRC's share from 65% in 2023 to 50% by 2040. Cobalt is mostly a by-product of copper and nickel mining. Copper has traditionally been the main source, but its share is expected to fall below 60% by 2040 as DRC copper mines decline. Nickel's role is growing, driven by Indonesia's expansion, with its share of cobalt production rising from 30% today to about 40% by 2040 (IEA 2024).

### *Social impacts of cobalt mining in the DRC*

In the DRC, copper and cobalt are mainly mined in the southern Copperbelt region, especially in the Lualaba and Haut-Katanga Provinces, where cobalt is primarily extracted as a by-product of copper mining. While these regions are not typically directly involved in the armed conflict in other parts of the country, particularly in eastern provinces, the long history of armed conflict and political instability in the DRC does make the situation particularly challenging at the national level. Conflict in the DRC should be viewed in the context of the DRC's vast mineral wealth, including the recently escalated conflict in the eastern DRC since early 2025 (Africa Centre 2025).

#### *Economy, income, and security*

Mining is central to the DRC's economy, with copper and cobalt accounting for 85% of mineral sales in 2018. Resource extraction provides about one-third of government revenue and over 90% of export earnings. Although the majority of the DRC's mine production comes from industrial mines, BGR[1] estimates for 2019 put the share of artisanal production in total cobalt exports at around 15%, or at about 12,500 tonnes of cobalt content (BGR 2019).

[1] Bundesanstalt fur Geowissenschaften un Rohstoffen (German Federal Institute for Geosciences and Natural Resources).

Chinese companies own 8 of the 14 largest cobalt mines in the DRC and manage operations, often through joint ventures with Gécamines. Chinese traders also dominate the artisanal cobalt market, buying through local depots and selling to crude refiners. After basic refining in the DRC, most cobalt is then shipped to China for further processing (World Bank 2021). This strong dependence, combined with low foreign exchange reserves, leaves the DRC highly exposed to global price fluctuations. In addition, Chinese companies often rely on low-cost expatriate labour, instead of investing in the training of local workers (Wegenast et al. 2019).

### *Human rights and conflicts*

Human rights abuse in the DRC mining sector has been a serious problem for a long time, in part due to the country's low governance and development ratings (Gulley 2022). In the DRC, it is important to distinguish between artisanal and industrial mining operations. While human rights abuse occurs in both types of mining, some are more typical in one than the other. In industrial mining operations, forced evictions, forced labour, inadequate compensation and resettlement, and violence by security forces are common occurrences (ILO 2019; Sovacool 2019; US Department of Labor 2023; Umpala & Dummet 2024).

In artisanal and small scale mining (ASM), dangerous working conditions, child labour, health issues, and corruption are common issues (Faber et al. 2017; ILO 2019). For example, research from 2016 estimated that in the Haut-Katanga region in the DRC, around 40,000 children mine cobalt in tunnels deep underground, frequently without protective equipment (Ten Kate & Kiezebrink, 2016).

Large-scale mining companies, traders, and processors in the DRC face growing pressure to supply cobalt free from ASM due to concerns about child labour. In response, many companies have moved to exclude ASM material entirely, rather than engaging with ASM communities to improve safety and environmental practices. This approach risks harming the livelihoods of an estimated 200,000 ASM miners in the Katanga-Lualaba region and may undermine development efforts by increasing poverty, conflict, and instability. There are some exceptions where some companies, such as Glencore, have supported more responsible ASM practices (World Bank 2021).

In both artisanal and industrial mining, a weak state paired with high levels of corruption, criminal activity, and very little transparency and accountability, exacerbates existing problems (Amnesty 2019; Sovacool 2019; Umpala & Dummet 2024). Miners are often forced to pay bribes to access illegal sites, which mostly sit on privately owned mining concessions. Powerful individuals, frequently with political connections, often control the miners' cooperatives that organise the diggers and manage their business relationships (Umpala & Dummet 2024). Despite the existence of mining regulations, almost all artisanal mining remains unsupervised (Umpala & Dummet 2024).

### *Land use and territorial aspects*

Forced resettlement in the DRC has taken place to remove villages from areas where mining companies want to expand or start new operations. In addition, valuable cobalt mining concessions have led to the closing of hunting areas and the expropriation of agricultural land. It is estimated that tens of thousands of people were evicted after cobalt was discovered near the city of Kolwezi in 2022 (Carr-Wilson et al. 2024). This is problematic because communities rarely receive adequate compensation for their losses (Billon & Middeldorp 2021).

*Environment, health and safety*

Cobalt mining in the DRC poses significant environmental and health-related risks due to widespread environmental destruction, deforestation, and pollution. In particular, pollution of air, water, and soil has led to high levels of heavy metal contamination in local populations (Banza Lubaba Nkulu et al. 2018; Muimba-Kankolongo et al. 2022). Additionally, especially in the case of artisanal mining, mine workers face a variety of health risks. Exposure to cobalt can cause damage to the heart, thyroid, lungs, and skin. Other conditions include tumours, infections, metabolic and respiratory problems, burning sensations in eyes and throat, genetic deformations, and sterility (Galantich 2019). Cobalt mining in the DRC poses significant environmental and health-related risks due to widespread environmental destruction, deforestation, and pollution. In particular, pollution of air, water, and soil has led to high levels of heavy metal contamination in local populations . Additionally, especially in the case of artisanal mining, mine workers face a variety of health risks. Exposure to cobalt can cause damage to the heart, thyroid, lungs, and skin (Galantich 2019).

*Demography and gender*

Up to half of the ASM workforce in the DRC is women. However, gender discrimination is rampant in ASM cobalt mining (Carr-Wilson et al. 2024). Women often receive the worst jobs, such as digging in extreme weather, and are paid less than men, sometimes for unlawful working hours. Poor working conditions for women are also observed in formalised setups (Mishra et al. 2024). ASM cobalt mining in the DRC involves gender-based risks and heightened levels of gendered violence, including sexual assault. Violence against women has been reported in mining areas, both at home and at work. In remote and isolated mining areas, where legal safeguards are less developed, women's vulnerability to violence is exacerbated (Carr-Wilson et al. 2024; Mishra et al. 2024). Up to half of the ASM workforce in the DRC is women. However, gender discrimination is rampant in ASM cobalt mining. ASM cobalt mining in the DRC involves gender-based risks and heightened levels of gendered violence, including sexual assault. Violence against women has been reported in mining areas, both at home and at work. In remote and isolated mining areas, where legal safeguards are less developed, women's vulnerability to violence is exacerbated.

## 2.4 Copper mining in Chile

***Current trends in demand and supply***

Copper is essential for clean energy technologies (including electric vehicles, solar panels, wind turbines, and electricity networks), because of its high conductivity, durability, flexibility, and resistance to corrosion. A stable copper supply is therefore critical for the energy transition, especially as global demand is rising rapidly. In 2023, copper demand reached 26 megatonnes (Mt), combining newly mined and recycled refined copper, along with 6 Mt from direct scrap use (IEA 2024b). Construction and electricity networks have traditionally been the largest consumers, accounting for 30% and 15% of demand, respectively, followed by industrial machinery (12%) and transportation (15%). However, electric vehicles (EVs) are driving the fastest growth, with their share of copper demand expected to increase from 2% in 2023 to 12-13% by 2050. Electricity networks will also become a major driver, surpassing construction in some scenarios by 2030, although construction is estimated remain the largest overall consumer (IEA 2024b).

Copper production is more diversified than other critical minerals. In 2023, Chile remained the top producer, supplying 25% of global output, though its share has since declined due to ageing mines and lower ore grades. The DRC has doubled its production since 2015, now supplying 12% of the global output, primarily because of high-grade deposits like the Kamoa-Kakula mine. This mine

has significantly lower costs and emissions. The DRC is followed by China and Russia, supplying 8% and 5%, respectively, while Indonesia has doubled its share to 5% since 2020. The world's three largest mines, Escondida and Collahuasi in Chile, and Grasberg in Indonesia, accounted for over 10% of global production in 2023 (IEA 2024b).

Mined copper supply is expected to peak at 25 Mt by 2026, before declining due to ageing mines and lower ore quality. By 2040, the top three producers are expected to be Chile, the DRC, and China. As demand surges, securing new sources and improving recycling will be essential to meeting long-term supply needs (IEA 2024b).

### *Social impacts of copper mining in Chile*

Chile's copper production is concentrated in the dry northern region and is primarily sourced from iron oxide copper gold systems, as well as from deposits also enriched with molybdenum, gold, and silver by-products. In 2020, despite operational disruptions from extreme weather, labour strikes, and the COVID-19 pandemic, national output reached 5.7 million tonnes (Pistilli 2021). Chile also holds an estimated 200 million tonnes in copper reserves, reinforcing its long-term strategic relevance (Pistilli 2021).

The country remains a leading destination for exploration and large-scale production. Multinational companies, including Antofagasta, BHP, Freeport McMoRan, Rio Tinto, and Albemarle, have maintained a strong presence. The state-owned producer Codelco, responsible for 1.73 million tonnes in 2020, manages key assets such as El Teniente, the world's largest underground copper mine, and Chuquicamata, among the largest and deepest open pit operations globally (Pistilli 2021).

#### *Human rights violations and conflict*

Over the last 13 years, according to the Business and Human Rights Resource Centre (BHRRC), copper mining is associated with the highest number of human rights allegations for transition minerals. This reflects both the high demand for copper and amount of copper mines, as well as the fact that it is often mined in South American regions where civic freedoms are not sufficiently protected, or in African countries with poor human rights protections (BHRRC 2024).

#### *Environment, health, and safety*

In Chile, mining is concentrated in the arid central and northern regions where water scarcity is a serious challenge. Indeed, copper extraction in the north particularly demands significant water resources. In these Chilean regions, the mining sector is the largest water user (51%) and often competes with other needs, contributing to longstanding conflicts with local populations (Akchurin 2020, Garcia-Zaval et al. 2023). Groundwater pollution by copper mining is a similar catalyst for social challenges. Particularly the discharge of heavy metals and metalloids poses a severe threat to ecosystems and human health, even decades after mine closure (Campos & Mardones 2023).

#### *Employment and education*

A literature review on the health of mine workers in Chilean copper mining found that the main health issues of mine workers are problems related to high-altitude work, the inhalation of silica dust, and noise exposure (Pizarro et al. 2021). These issues are connected to eating and musculoskeletal disorders, cardiovascular and respiratory disorders, accidents, and lower back pain. The literature also identifies mental health conditions, such as the impact on sleep quality due to shift work, fatigue, anxiety, depression, violence towards subcontractors, and worsening of

living standards after relocation due to respiratory illness (Akchurin 2020; Pizarro et al. 2021). In 2024, after several high-profile mining accidents, the Chilean government ratified the International Labour Organisation (ILO) Safety and Health in Mines Convention to improve worker safety in mines (ILO 2024). Research has found a positive correlation between mining fatalities in the copper mining industry in Chile and the international price of copper, likely due to increased production pressure and a rise in inexperienced workers when production increases (Arratia-Solar & Paredes 2023). In the copper mining regions, the mining sector is the most important source of employment and generator of new jobs. Mining companies are popular as employers, mainly because of their comparatively high wages (Reisch 2023). The Chilean mining sector has launched significant efforts to attract women at multiple educational and professional levels. However, while these initiatives reflect a commitment to gender diversity and equity, they are also criticised for the tendency to be regionally focused, and not integrated into a cohesive national strategy (Suzuki Morales & Mery 2024).

### *Socio-environmental conflicts and community resistance*

Although Chile is considered a frontrunner regarding the way sustainability concerns are addressed in the mining industry, there is still a lot of room for improvement with ongoing environmental and social conflicts (Campos & Mardones, 2023; Guzmán et al. 2023; Reisch 2023). Allegations of social and environmental violations regarding copper mining in Chile follow a similar pattern to that of other South American countries. In many cases, difficulties arise when environmental violations, such as water pollution or competition, occur in tandem with limited or insufficient consultation with local stakeholders. This in turn leads to lengthy conflicts between various local communities, including Indigenous groups and mining operators (Akchurin 2020; BHRRC 2024). The Institute of Strategic Dialogue (ISD) estimates that approximately 60% of all medium- and large-scale mining in Chile is embroiled in socio-environmental conflict of some kind (Marin 2023).

## 2.5 Graphite mining in Mozambique

### ***Trends in demand and supply***

Graphite, once mainly used in steelmaking and as a lubricant, is now in high demand for batteries, especially in electric vehicles. By the late 2020s, batteries are expected to use more than half of the world's graphite (IEA 2024b. Demand for the resource is set to double by 2030 and could grow up to four times by 2040, largely driven by EVs and energy storage. By then, battery-related uses could make up 65% of total graphite demand, compared to 33% today (IEA 2024).

Although alternatives like silicon-based materials are being developed, graphite will stay essential for EV batteries in the near future. Steelmaking will also keep needing graphite, with demand growing as industries adopt cleaner technologies.

Global graphite production has steadily increased, rising from 1.35 Mt in 2018 to 1.65 Mt in 2023 (IEA 2024b). Most natural graphite is mined in China, which produces 80% of the world's supply and leads production with upgrades and expansion. While other countries like Mozambique, Madagascar, Canada, India, and Tanzania are starting to mine more graphite – and Mozambique is home to the world's largest natural graphite mine, expected to operate for another 50 years – nearly all of the refined graphite used in batteries (spherical graphite) still comes from China (USGS 2022). Efforts are being made to expand production elsewhere, but China is expected to remain the top supplier for the coming decades.

Because natural graphite is in limited supply and needs special processing for batteries, synthetic graphite is becoming more popular. It is made from materials like petroleum by-products and is already used in many batteries, with its share expected to grow to over half by 2040. Synthetic graphite helps meet demand but is also mostly made in China. In short, while new projects around the world aim to reduce reliance on China, most battery graphite production still heavily depends on Chinese supply and expertise (IEA 2024).

### *Social impacts of graphite mining in Mozambique*

Mozambique possesses substantial graphite sources, particularly in the Cabo Delgado province. As such, the country is a significant global producer of natural graphite (Mitchell & Deady 2021). Mozambique's graphite production has increased significantly in recent years: in 2019, production was 113,803 tonnes, and, by 2022, it was the second-largest producer of natural graphite, accounting for 12% of global production. Mozambique's graphite mining industry is predominantly operated by foreign companies, with limited involvement from domestic firms. Foreign involvement mainly comes from Australian, English, and Chinese companies (APO Feed 2024). The government has established the state-owned Mozambique Mining Exploration Company to enhance domestic participation in the extraction and processing of critical raw materials.

#### *Economy, income, and security*

Graphite mining has contributed to Mozambique's revenue and employment. However, there are missed economic opportunities due to the export of raw graphite concentrate rather than value-added product. Most of the graphite concentrate is exported, often to China, for further processing. Mozambique currently lacks the capacity for manufacturing specialist products like spherical graphite or battery components (Mitchell & Deady 2021). In addition, research in Cabo Delgado graphite mines has shown that most employees are not locals and that they earn more than those workers that are hired locally. This was found to contribute to long-standing regional tensions between less-developed and more developed regions of the country (Namaganda 2023).

#### *Human rights and conflict*

Since 2017, Mozambique has experienced political instability and a violent insurgency in the Cabo Delgado province, where most graphite mines are located. In regions with weak governance, there is a heightened risk of human rights violations within the graphite mining sector (BHRRC 2022; BHRRC 2023). Cabo Delgado is also the region with the lowest level of education in Mozambique, a lot of unemployment, and regional asymmetries, which have been implicated in driving youth to join local armed groups (BHHRC 2022).

#### *Land use and territorial aspects*

Graphite extraction is associated with involuntary population resettlement (Namaganda et al. 2023). The government of Mozambique considers mining a national interest and has legislation in place that allows them the legal right to forcibly resettle communities for mining projects (Wiegink & Garcia 2022). Forced resettlement has contributed to unrest, and even to the temporary closure of a graphite mine in Cabo Delgado in December 2024. Amid post-election unrest, the Balama graphite mine was forced to halt operations after a group of farmers with historical land resettlement grievances initiated protests (Mining Technology 2024). This has serious implications for the owner of the mine, Syrah Resources, as all sales in that quarter were from existing inventories. This triggered company  defaults on U.S. government-backed loans and meant that the company struggled to meet contracted deliveries to customers (Govind 2025).

*Environment, safety, and health*

Water and air pollution are major issues in graphite mining, stemming from mineral dust and the use of chemicals like hydrofluoric acid in purification processes. This can lead to heavy metal contamination of soil, water, and air (Liu et al. 2022). Furthermore, the large volumes of waste produced, combined with the use of chemicals in graphite purification and the storage of tailings in dams, create additional environmental and social risks, especially in case of dam collapse (Liu et al 2022).

A particularly severe health risk is graphite pneumoconiosis, a lung disease caused by inhaling graphite dust. This condition is comparable to coal workers' pneumoconiosis and can cause inflammation, coughing, and fibrosis, and is potentially fatal (Akira & Suganuma 2023). Both miners and communities living near mining operations are vulnerable to this risk (Namaganda 2023).

## 2.6 Manganese mining in South Africa

### *Trends in supply and demand*

Manganese, while primarily important for steel production, is now increasingly becoming a key ingredient in electric vehicle (EV) batteries. With manganese's important role in existing and new battery chemistries, demand is expected to grow 3 to 5 times by 2030 and more than 10 times by 2050 (IEA 2024). By 2050, clean energy technologies could make up 15–17% of total manganese demand, a significant increase compared to 1% today (IEA 2024).

The global supply of manganese does face numerous challenges. South Africa, Gabon, and Australia produce 75% of the world's mined manganese, but political instability, extreme weather, and infrastructure issues are straining production. Gabon, known for its high-grade manganese, has seen declining exports due to a military coup and railway damage, while Australia's second-largest mine is offline until 2025 following severe cyclone damage. South Africa, despite holding the largest manganese reserves, struggles with underinvestment and weather disruptions (IEA 2024b).

For battery-grade manganese, only 1% of global manganese is suitable for batteries, and China dominates this niche, processing 97% of the world's high-purity manganese sulphate. While new projects in Canada, South Africa, Australia, and the U.S. aim to diversify supply, China's cost advantage makes competition tough. Analysts warn of potential shortages as early as 2027, adding urgency to efforts to expand supply (IEA 2024b; Quiroz et al. 2024).

### *Social impacts in South Africa*

In South Africa, manganese mining is predominantly concentrated in the Northern Cape Province. Here lies the Kalahari Manganese Field, which holds approximately 80% of the world's known manganese reserves. This region includes significant mining areas such as Hotazel, Postmasburg, and Kuruman. South African mining companies hold significant stakes in the country's manganese mining industry, often through joint ventures with international firms. Australia, China (via Hong Kong), and Russia are the main foreign countries active in South Africa's manganese mining sector (S&P Global 2025).

*Economy, income, and security*

Despite holding the world's largest manganese reserves, South Africa only processes 2% of its ore domestically (CNN 2024). High electricity costs and an unreliable energy supply make local refining expensive and logistically challenging, making it more economical to export raw ore than to invest

in costly domestic processing infrastructure. Additionally, limited domestic demand for refined manganese products further discourages local production. Most high-purity manganese chemicals used in batteries are processed in countries like China, where established facilities dominate the market. Research traces South African manganese ore through global supply chains, indicating that it is refined in Japan, South Korea, or China, then used by manufacturers like Panasonic and Samsung to produce batteries for electric vehicles sold by major car manufacturers, including Volkswagen, BMW, and Toyota (Quiroz et al. 2024).

*Human rights*

The Northern Cape is the fourth richest mineral province in South Africa, but has one of the country's highest levels of poverty and unemployment rates, and lowest education levels. People living in the communities of Magojaneng, Maipeng, and Vergenoeg in the Kalahari Manganese Field face violations to their rights to water, health, and free and prior informed consent (Quiroz et al. 2024). Under South African mining legislation, mining companies must consult interested and affected communities when applying for a mining right and develop a Social and Labour Plan (SLP) detailing how they will support surrounding communities. 94% of those surveyed said they had never been consulted by a mining company, and 98% did not know what a SLP is (Quiroz et al. 2024).

*Environment, health, and safety*

Manganese mining depletes already scarce water resources and degrades water quality in local communities. Many residents report struggling with inconsistent access, often traveling long distances to find water (Quiroz et al. 2024). Concerns about contamination are widespread, with people noting issues such as high lime content, salinity, discoloration, and pollution. Health risks are also a major concern, as most residents believe mining activities are harming their well-being, with respiratory illnesses being particularly common (Quiroz et al. 2024). In terms of health, a study found that manganese miners in South Africa were associated with higher risk of Parkinson's disease (Dlamini et al. 2020).

*Gender and demography*

Black, working-class women in mining-affected communities face exclusion from economic opportunities, increased insecurity, and a disproportionate caregiving burden. Despite policies promoting gender inclusion, barriers like skill requirements, corruption, and discrimination keep most women out of formal mining jobs, forcing them to rely on informal hustling and state grants for survival. Women also bear the added burden of caring for those affected by pollution and poor living conditions, with weak state support, leaving them isolated. Hustling emerges as a crucial strategy, providing financial independence while allowing them to balance work and caregiving (Gibertini 2025).

## 2.7 Nickel mining in Indonesia and the Philippines

***Demand and supply trends***

Nickel is vital for making stainless steel, alloys, and supporting clean energy, especially for EV batteries and renewable power. Demand rose from 2.4 Mt in 2020 to 3.1 Mt in 2023, and is expected to grow to 4.5–5.6 Mt by 2030, driven largely by the rise of electric vehicles. Clean energy now makes up over 15% of nickel demand, surpassing traditional uses. By 2040, clean energy's

share could reach 40–55%, though recycling might reduce demand slightly. EV batteries are the biggest driver of growth, with demand set to grow ninefold by 2050 (IEA 2024b).

Nickel comes from two types of ores: laterite, found in Indonesia, the territory of New Caledonia, the Philippines, and Australia, and sulphide, found in Australia, Canada, Russia, and China. From 2018 to 2023, nickel mining increased by 1.5 times, reaching 3.5 Mt, with Indonesia tripling its output. This growth was primarily driven by laterite mining, which now makes up 80% of supply, a share expected to hit 90% by 2040 as Indonesia continues to expand production (IEA 2024b).

Nickel mining is projected to grow by a third to 4.4 Mt by 2040 in the base case and could nearly double to 6 Mt if new projects succeed. However, production is becoming more concentrated, with the top three countries/regions (Indonesia, Philippines, and New Caledonia) expected to control 83% of supply by 2040. If mining diversifies, with new projects in Australia and Brazil, this share could reduce slightly (IEA 2024b).

### *Social impacts of nickel mining in Indonesia and the Philippines*

In Indonesia, nickel mining is concentrated in Sulawesi, especially in the provinces of Southeast Sulawesi and Central Sulawesi, as well as on Halmahera Island in North Maluku. In the Philippines, key nickel-producing regions include the Caraga region in northeastern Mindanao and Palawan. Both countries are among the world's top nickel producers (S&P Global 2025). In Indonesia, Chinese companies have heavily invested in nickel smelting and processing facilities, particularly following the country's ban on raw nickel ore exports, which was designed to encourage domestic processing. In the Philippines, Chinese firms have also invested in nickel mining operations, often through joint ventures with local companies. Additionally, Japanese and South Korean companies have engaged in long-term supply agreements and joint ventures in both producing countries (Camba 2025).

#### *Employment and education*

The nickel mining industry in Indonesia employs about 1.3 million people. In 2021, over a million tonnes of nickel was produced, which is a four-fold increase within just a decade (Lo et al. 2024). The positive impact on employment has been used as a justification for easing business and further foreign investments. However, this is increasingly criticised for overlooking environmental and social impacts on communities that are directly affected by mining operations (Lo et al. 2024). Moreover, nickel mining relies heavily on machinery, requiring a workforce with specialised skills and higher levels of education compared to more labour-intensive forms of mineral extraction. Nickel mining may have limited local employment opportunities if communities do not match the required human capital (Saputra et al. 2023).

#### *Economy, income, and security*

Researchers in Halmahera found that domestic labourers in particular faced numerous issues. First of all, the wages for fieldwork such as operators of light machinery (crawlers, trucks, cranes) and security positions, which are mostly given to domestic labourers, are considered insufficient to cover their minimal daily expenses (Saputra et al. 2023). This causes them to struggle and sometimes forces them to borrow from grocery stores or food stalls. Additionally, the accommodation facilities provided by mining companies are considered uninhabitable or even slum-like. There is no differentiation between washing facilities for men and women, for example, leading to numerous cases of sexual abuse (Saputra et al. 2023). Finally, inadequate and improper

implementation of safety measures has led to accidents, causing the deaths of dozens of employees (Saputra et al. 2023).

### *Land use and territorial aspects*

Compared to western Indonesian islands, small-scale agriculture and other subsistence-based livelihoods are more dominant in Sulawesi and Halmahera, and commodities such as coffee, cacao, and coconut are more commonly grown than industrial-scale products such as palm oil. Researchers (Saputra et al. 2023) assessed land acquisition processes by nickel mines in Halmahera, which have led to direct loss of farmlands and livelihood space. Many inhabitants of Halmahera oppose this acquisition and the low prices at which mining companies are able to purchase the land (Saputra et al. 2023). Companies are able to neglect agrarian regulations and calculate costs of land area without considering the economic value of land. The process of this calculation is opaque and does not involve both parties, as there is no room for negotiation by the residents. This is perceived as unfair, because much of the land is of high economic value to farmers growing crops and who have depended on these sites for decades. Villagers who refuse to give up their farmlands are sometimes forced to leave because their land is surrounded by infrastructural projects, reducing the accessibility and quality of their lands (Saputra et al. 2023).

### *Environment, health, and safety*

Construction of mining infrastructure, office buildings, and power plants has led to widespread loss of mangroves and coral reefs along the coast, moving fishermen's fishing ground further away, up to 20-30 kilometres at times. They now require more capital for a single fishing trip, without any guarantee of catching enough fish. The loss of plantations and fishing area is an important driver of many tenurial conflicts and for poverty, due to the lack of alternative sources of income for the villagers (Lo et al. 2024).

Lo et al. (2024) evaluated the overall impacts of 7,721 villages in the Sulawesi region affected by nickel mines. They found that pollution caused by nickel mining has led to a slight decline in overall well-being. For example, groundwater that used to be clear and suitable for daily needs, has become muddy and salty because of increased use, causing depletion and allowing salty water to infiltrate the soil. This has led to reduced health and an increased dependency on costly commercialised water. Additionally, dust pollution has led to respiratory infections. This is worsened by high deforestation: nickel mining has caused significant deforestation in Indonesia since its expansion around 2011, nearly doubling forest loss compared to similar areas without mining.

### *Gender and demography*

The impacts identified in the Lo et al. study (2024) vary significantly across villages, making it challenging to draw definitive conclusions. Some villages experienced positive changes, such as improved living conditions and infrastructure, likely due to mining-related investments in transportation and water systems. Revenues from nickel mining may have enabled local governments to fund community development. Migration may have also been influenced by nickel mining, leading to changes in well-being. The in-migration effect from large-scale nickel mining is related to both improvements in social cooperation and worsening living conditions.

While there is some evidence evaluating the impact of nickel mining, the highly localised context of social impact studies makes it challenging to derive general and conclusive insights. Some case studies have found that nickel mining has contributed to increasing local income, while in others,

waste from nickel-mining extraction damaged local fishing and farming production, resulting in greater economic losses overall (Lo et al. 2024). Some mines are too close to villages (less than 100 metres), exposing residents to dust and noise. These mixed effects suggest that, while some communities benefit, others face challenges, reflecting the complex and uneven impact of nickel mining across Sulawesi (Lo et al. 2024).

*Human rights*

Under the administration of President Ferdinand Marcos Jr., following the recent lifting of a longstanding ban on open-pit mining, the Philippines is significantly expanding its transition mineral mining sector. As of 2024, one-fifth of the country's landmass is already under mining or exploration permits, with the government now fast-tracking approvals to accelerate extraction. However, this rapid expansion is having severe social and environmental consequences. Research by Global Witness (2024) highlighted that more than a quarter of all transition mineral concessions overlap with protected areas, biodiversity hotspots, or Indigenous territories. Over the past three decades, Indigenous Peoples in the Philippines have lost more than one-fifth of their officially recognised lands to mining. Resistance to these projects is often met with violence and repression, contributing to the Philippines' status as the most dangerous country in Asia for environmental defenders. Since 2012, mining has been linked to roughly one-third of all documented killings of land and environmental activists in the country. These developments raise serious concerns about the erosion of Indigenous rights, the shrinking of civic space, and the growing social toll of the green transition (Global Witness 2024b).

## 2.8 Rare earth elements mining in China and Myanmar

### *Demand and supply trends*

Clean energy technologies, including EVs, wind energy, and battery storage, are driving much of the rare earth elements (REE) demand. Magnets, making up 30% of the REE market, are in high demand due to their use in devices like speakers, sensors, wind turbines, EVs, and communication technologies (IEA 2024b). Offshore wind energy, in particular, requires essential REEs like neodymium and dysprosium to improve turbine efficiency. Larger turbines are becoming more common, further increasing demand. EVs and battery storage are expected to drive half of the mineral demand growth in clean energy technologies over the next 20 years, with neodymium demand for EVs projected to grow elevenfold by 2032 (IEA 2024b).

China dominates the rare earth element market, extracting 62% of the global supply, followed by Myanmar, Australia, and the USA. More significantly, China refines 87% of the world's REEs, with China Rare Earth Group responsible for 30% of the country's output. They have near-total control over heavy REE (HREE) production, while light REE (LREE) production includes four plants outside of China. The EU currently imports about 80% of its REEs from China, though mining efforts are underway in Sweden. Extracting REEs is resource-intensive, requiring 1 tonne of ore to produce just 20 kg of REE (IEA 2024b).

### *Social impacts of REE mining in China and Myanmar*

China's rare earth reserves are primarily located in Inner Mongolia, Sichuan, and Jiangxi provinces. Jiangxi Province is a significant contributor to China's rare earth element industry, particularly in the extraction of heavy rare earth elements. In 2019, it was reported that Jiangxi's HREEs accounted for

80% of China's total stock. In 2023, Jiangxi produced 16,000 tonnes of rare earth metals. Myanmar has large REE deposits as well, which are, however, increasingly extracted by China due to stricter in-situ leaching criteria for HREE mining in China (Qiao et al. 2022).

*Human rights*

In some regions, illegal mining operations are reported, alongside poor working conditions and human rights violations. A higher risk of low worker safety is present here, highlighting the need for stricter regulations and ethical oversight in the REE supply chain (Vahle et al. 2022). For example, Myanmar is one of the world's largest exporters of REEs, but the government does not officially license or disclose the extraction or export of these resources. However, China's trade data confirms substantial imports of REEs from Myanmar, indicating widespread unregulated activity. Illegal mining of REEs is particularly common in Kachin State's Chipwe and Hsawlaw townships near the Chinese border. The export of these resources has grown rapidly in recent years, largely benefiting China. Communities in Kachin State face serious environmental harm from toxic waste produced by mining, with little to no benefit reaching the local population (KNG 2024).

*Environment, health, and safety*

The extraction of REEs relies heavily on the use of acids, which leaves behind toxic sludge in the ground, posing a lasting environmental threat. Many rare earth ores also contain radioactive substances, creating a permanent risk of radioactive leaks into the surrounding environment (H. Liu et al., 2016). Additionally, the process is extremely wasteful, generating between 2,000 and 20,000 tonnes of waste for every tonne of REE produced. Workers and surrounding regions are exposed to contamination of REE mines, which increases health risks. However, these health risks do require more research (Qiao et al. 2022).

Rare earth mining in southern Jiangxi has caused significant environmental damage over decades of largely unregulated activity. Starting in the 1990s, mining has since then intensified. The extraction process involves chemicals and water, and has led to widespread soil erosion, water pollution, and contamination with toxic substances like ammonia, cadmium, and lead. In some areas, radioactive materials from nearby uranium deposits compounded the damage (Liu et al. 2019).

Efforts to clean up the region began in earnest after the Chinese government shut down illegal mining operations and tightened regulations in 2016. Cleanup measures include building wastewater treatment facilities, replanting vegetation, and consolidating mining operations into controlled industrial parks. Despite these efforts, the damage is vast, and experts estimate it could take 50 to 100 years for the environment to fully recover. The estimated cleanup cost for Jiangxi province is 5.5 billion USD, but only a fraction of this has been spent so far (Cho 2023).

## 2.9 Silicon metal mining in China

### *Demand and supply trends*

The silicon market is expanding rapidly, driven by clean energy technologies. Very pure quartz is used for silicon in solar panels. Indeed, solar panels are the main driver of demand, requiring up to 2 Mt by 2030. EV batteries are the second driver, with over 1 Mt needed by 2050, as silicon is increasingly used as a high-performance alternative to graphite in battery anodes, despite some technical challenges during charging cycles (IEA 2024b).

High-purity quartz (HPQ) is essential for advanced industrial applications, but its natural occurrence is rare (Jennings et al. 2024). While quartz itself is abundant, most deposits contain impurities like aluminium, lithium, and iron, making them unsuitable for high-tech uses. To qualify as HPQ, quartz must have at least 99.9% $SiO_2$, with ultra-high purity grades reaching 99.998%. Natural crystals are the preferred source due to their purity and transparency, but these deposits are scarce and increasingly depleted. Major sources of HPQ include the US (especially North Carolina), Norway, Russia, Australia, and Mauritania, though China dominates processing, refining over 80% of the world's solar-grade silicon (Jennings et al. 2024). Lower-quality quartz requires complex and energy-intensive purification involving strong acids and precise processing conditions. As natural reserves decline, the industry faces growing pressure to refine common quartz ores. Efficiency improvements, such as reducing silicon use in solar panels, help manage supply constraints, though recycling remains costly. In many regions, quartz mining remains underreported, as it is classified as an industrial commodity with limited publicly available production data (Jennings et al. 2024).

### *Social impacts of silicon mining in China*

Silicon mining in China mainly occurs in the Jiangsu and Jiangxi provinces, known for their abundant quartz reserves.

#### *Environment, health and safety*

Silicon mining frequently causes health and safety risks for workers. A large concern is exposure to silica dust, which can lead to serious respiratory issues such as silicosis, lung cancer, and other lung-related diseases. Silicosis is a severe lung disease caused by inhaling fine dust particles, a major risk for miners working in underground and surface operations. Mining activities such as extracting, transporting, and processing coal, ore, or stone release large amounts of fine dust into the air. If inhaled, these particles settle in the lungs, causing long-term damage. Since there is no cure for silicosis, prevention through dust control is essential. Additionally, prolonged contact with materials containing silica may increase the risk of skin conditions. Examples of these risks include workers inhaling fine silica particles during mining or processing activities and developing chronic respiratory diseases, or experiencing skin irritation from handling raw silica materials over extended periods (Chen et al. 2012).

A long-term study of 74,040 workers in metal mines and pottery factories in China examined the health effects of silica dust exposure over an average of 33 years. Researchers found that workers exposed to silica dust had significantly higher death rates than those who were not exposed, with 993 deaths per 100,000 person-years compared to 551 in the non-exposed group. Exposure to silica dust increased the risk of death from all causes, particularly respiratory diseases, tuberculosis, and heart disease. The study estimated that 15% of deaths in the study group and 4.2% of worker deaths nationwide were linked to silica exposure. Even low dust levels significantly raised the risk of fatal heart and lung diseases such as pneumoconiosis (Chen et al. 2012).

## 2.10 Knowledge gaps

A significant limitation in the current understanding of mining impacts is the lack of comprehensive and systematic documentation, regarding mines, and regarding social and health-related effects. It is estimated that the impacts of approximately half of global mining operations remain undocumented (Maus & Werner 2024). This data gap stems from several factors: the opacity of international supply chains, the prevalence of informal and illegal mining activities, and the restricted availability of information from key producer countries such as China, which often

operates as a geopolitical and informational 'black box' in the global raw materials system (OECD, 2021; BGR 2020).

Scientific research has predominantly focused on a limited number of geographical regions, notably high-income countries, parts of Sub-Saharan Africa, and Latin America (Carr-Wilson et al. 2024). In parallel, scholarly attention has concentrated on a narrow range of commodities, especially the so-called 3TGs (tin, tantalum, tungsten and gold), as well as lithium and copper (Lèbre et al. 2020). This regional and material selectivity is reflected in both qualitative and quantitative studies and has led to a highly fragmented evidence base. Consequently, impacts in other world regions or associated with less prominent critical raw materials remain largely unexplored in the academic literature.

Developing a comprehensive overview of social impacts per metal proves particularly challenging. Mining practices differ substantially between countries and even between sites within the same country, depending on geological, political, technological, and socio-economic conditions (Bridge 2004; Bebbington et al. 2018). As a result, the associated impacts are highly context-dependent. Most social science research does not attribute social impacts to specific metals, but instead documents them in relation to individual mines or mining regions (Mancini & Sala 2018). This makes it difficult to identify generalisable patterns or causal relationships at the level of individual raw materials.

In addition, the social sciences have produced relatively few systematic overviews or meta-analyses on this topic. Instead, the literature is dominated by case study approaches, which are valuable for in-depth understanding but limit the potential for broader generalisation (Parra et al. 2021).

Furthermore, the emerging field of geo-health, which seeks to analyse the links between mining activities and public health outcomes, is still in its early stages (Eckley et al. 2021). As such, the scale, nature, and severity of mining-related health impacts remain largely unknown or poorly quantified. Where health effects are mentioned, they are often anecdotal, based on local observations, or derived from limited epidemiological studies with unclear external validity (Pieters et al. 2025).

This study itself was subject to several methodological constraints. Due to time and resource limitations, the scope of the literature review was necessarily selective, and the number studies assessed was limited. These constraints may have led to gaps in the identification and interpretation of existing knowledge, particularly concerning less-documented materials or regions.

# 3. Synthesis of impacts and underlying dynamics

This chapter synthesises the previous chapter: which patterns and commonalities do we see in terms of social impacts and mining of critical raw materials? Then, to better understand what drives these impacts, and how these can be addressed, underlying factors from a local to international level are summarized.

## 3.1 Impacts identified

The case studies described in Chapter 2 show that, despite generating significant revenue, jobs, infrastructure and foreign investment, mining comes with multiple negative impacts which can be categorized into 6 different categories. In this assessment around 40 different impacts were distinguished. The impacts that were most common are summarized in figure 3.1 below. For a complete overview of the impacts, appendix 2 be consulted.

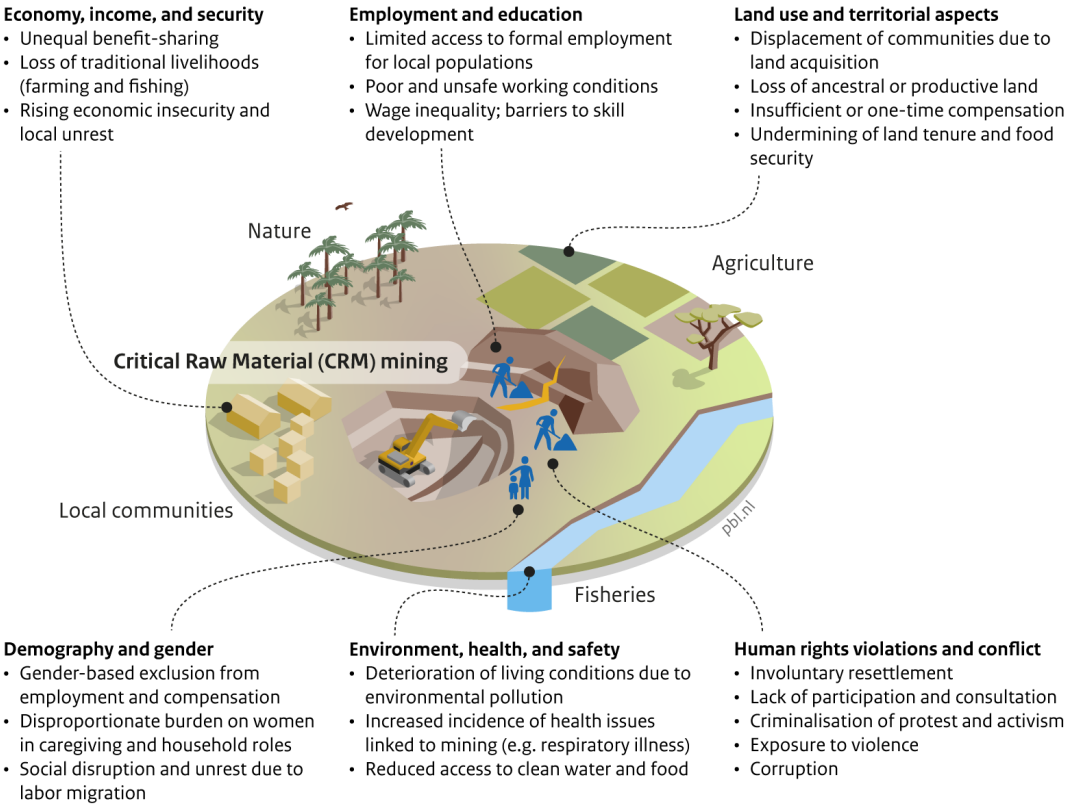
A pattern seen frequently is that national governments and companies fail to distribute benefits equitably, leaving local communities (e.g. in Guinee and the DRC) impoverished and unemployed. Employment opportunities vary widely, with dangerous working conditions and exploitation in artisanal mining contrasting with better-paid, though still very risky, jobs in formal operations, such as copper mining in Chile. Land-related conflicts and displacement are prevalent, with frequent reports of inadequate compensation and loss of ancestral lands, affecting food systems (e.g. in Indonesia, South Africa and Guinee) and cultural cohesion (e.g. in Mozambique). Demographic changes and gender inequalities are exacerbated, as women often bear the brunt of environmental degradation and caregiving burdens without equitable access to compensation or employment (e.g. in South Africa and Guinee). Environmental degradation and health risks persist as severe issues, with mining activities causing pollution and long-term health impacts across multiple regions. Human rights violations are widespread, particularly where governance capacities are small, with reports of child labour (e.g. in DRC), forced evictions, and violence against local communities (e.g. in Indonesia, the Philippines and Chile).

Regarding employment, it is important to note that mining work is inherently dangerous and injuries and fatalities occur in both LMICs as well as HICs. Risk to workers in and around the mine can never be completely eliminated, and are often worse in regions with weaker regulatory oversight (RMF 2021).

A brief analysis of meta studies on social impacts of mining result in similar impacts and conclusion that negative impacts are mostly felt at the local level, while economic benefits mostly occur at the national level (Mancini et al, 2018; Widana et al 2019). Additionally, researchers emphasize that the socio-economic outcomes of mining activities are highly context-specific and shaped by a combination of interrelated factors. These include the ownership structure and governance model of the mining company, the type and scale of mining operation, the nature of the extracted commodity, and the broader social, economic, and demographic characteristics of the affected region (Mancini et al. 2018).

**Figure 3.1**

## Common Social Impacts of Critical Raw Material (CRM) Mining




Source: PBL

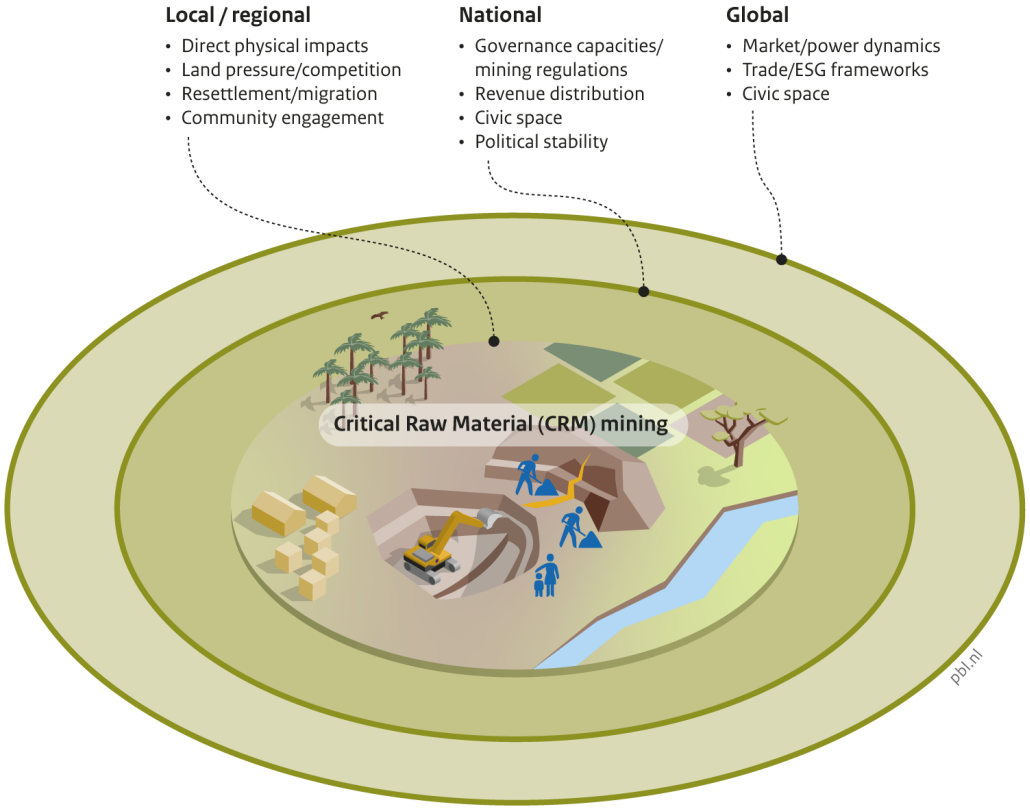
## 3.2 Key underlying factors

The local, regional and national context of metal extraction can vary substantially, making it very difficult to pinpoint precise root causes or drivers of certain social dynamics or impacts of mining operations. Despite this complexity, research in mining countries and regions does offer some insight into specific underlying factors that are seen across different cases.

Here, we discuss some of the factors influencing these social issues. Our analysis is based on the literature review in Chapter 2, focusing on context-specific factors that contribute to or mitigate negative impacts at the local (community level), regional, and national levels.

**Figure 3.2**

**Underlying factors of impact of Critical Raw Material (CRM) mining**




Source: PBL

### *Lack of community involvement*

Mining frequently occurs on or nearby land already used or inhabited. These pre-existing uses often clash with the profit-driven objectives of mining companies, creating fertile ground for conflict (Owen et al. 2022). Research points to a lack of ongoing consultation (Free Prior Informed Consent, FPIC) with, and informed consent by, local communities as an important factor in mining-related conflicts and violence (Bille Larsen et al. 2020; Oh et al. 2022). In many cases, mining companies fail to engage with affected people in an open and respectful way, according to the principles of FPIC. This can contribute to mistrust and resistance, as well as an increased risk of negative outcomes for local communities. When communities feel ignored or excluded, protests and conflicts are more likely to occur. For example, in Chile, disputes over land and environmental damage often arise because mining companies do not properly involve Indigenous groups in

decision-making (Akchurin 2020). Research has shown that companies will tend to engage with local communities more if their investors are varied and demand certain ESG standards (Wilhelm 2023b).

However, although international frameworks like FPIC encourage meaningful and continued consultation, they are not always incorporated well into policies around critical raw material (CRM) supply chains, or applied effectively. Consultation procedures can also be abused as a way to acquire a legal stamp of approval for a project, while there is no real FPIC to speak of (Billon & Middeldorp 2021). An example is the Battery Regulation, where FPIC is left out of the chapter on due diligence (Johnson & Khosravani 2024). In addition, FPIC procedures are not always properly facilitated or supported by national governments, which undermines their effectiveness.

In order for FPIC processes to have a safeguarding effect, specific preconditions need to be met (Billon & Middeldorp 2021). These include timely access for communities to information about mining plans, understanding their own rights, and the ability to speak out in order to protect their rights and interests, throughout the lifecycle of a project, and also after it has been concluded. In addition, developers and states need to actively recognise these rights and work within structures and protocols that allow communities to protect their rights (Owen et al. 2022).

### *Limited national governance capacities and political instability*

From the very beginning of a mining operation, through to long-term mine closure measures and rehabilitation, one of the strongest indicators of whether a mine will have a net positive or negative impact is the type and quality of the governance systems in place (Akchurin 2020; BHRRC 2024; Bille Larsen et al. 2021). Negative impacts in mining regions are often worsened by corruption and weak governance, as with poor transparency (RMF 2022). This can take many forms, for example, when national governments neglect to enforce regulations designed to protect communities and the environment, feel strong incentives to exploit natural resources due to economic pressures, fail to support environmental or social organisations that oppose mining activity, or even actively supress dissent.

In many LMICs or regions with weak or authoritarian governments, mining-related conflict is especially pervasive, such as in Mozambique. In some countries, authorities prioritise foreign investment over social and environmental safeguards, allowing repressive and harmful practices such as pollution to persist (RMF 2022), or by granting rights or licenses to mining companies without following procedures to protect the environment or ensure that mining will benefit local communities, as demonstrated in the case of nickel in Indonesia (BHRRC 2024). In the Democratic Republic of Congo (DRC), poor oversight and corruption have allowed unsafe mining conditions and human rights violations to continue (Amnesty International 2019). Similarly, in South Africa, laws mandate community consultation and development plans, but a lack of transparency means that many affected residents remain unaware of their rights and any potential benefits (Bench Marks Foundation 2022). A lack of effective and accessible grievance mechanisms often means that even if affected communities try to speak out about challenges they face, their complaints are not heard or given the necessary attention to ensure accountability and access to remedy (RMF 2022).

### *Direct physical impacts*

Due to the nature of mining, where large quantities of soil, rock, and sediment are extracted, transported, or displaced, significant physical and environmental impacts are almost inevitable. The extent of these effects depends on (geo)physical and practical factors such as the type of ore,

the extraction techniques that are necessary (or chosen), and the mine's proximity to stakeholder-sensitive areas (Boldy et al. 2021). Pollution of rivers, deforestation, and loss of farmland are common consequences of mining. For example, nickel mining in Indonesia has led to deforestation and water contamination, making it harder for farmers and fishers to earn a living (Lo et al. 2024). Mining can also contribute to conflicts over natural resources. In northern Chile, copper mining happens in areas where water is already scarce. The industry uses large amounts of water, leaving less for local farmers and communities, which creates tension (Garcia-Zaval et al. 2023). Conflict between mining operations and Indigenous Peoples is also increasing for this reason, as more and more mining takes place in or near Indigenous land (Owen et al. 2022; BHRRC 2024). Finally, environmental damage directly affects the health of local communities through, for example, air, soil, water, and noise pollution or mining disasters, such as tailings dams collapse (RMF 2021).

### *Unfulfilled promises for local economic development*

While mining can significantly contribute to economic growth at the national level, research has shown that mining operations often deepen economic inequality as benefits are unevenly distributed, exacerbating social tensions and hindering local development (Tiamgne et al. 2024). While mining companies and national governments profit significantly, communities near mine sites frequently see little improvement in living standards (Mancini and Sala 2018; Worlanyo & Jiangfeng 2021). This is especially the case concerning Indigenous communities (Horowitz 2024). The disparity is evident in countries like Guinee, where bauxite mining revenues primarily benefit international corporations while local communities struggle with inadequate infrastructure, limited social services, and scarce job opportunities.

Additionally, high economic dependency on the mining sector increases a region's vulnerability to commodity price volatility, often resulting in boom-bust cycles that can disrupt local development trajectories (Mancini et al. 2018). This dynamic is particularly pronounced in geographically remote resource towns, where structural constraints and limited connectivity reduce the potential for economic diversification and resilience (Tonts et al. 2012; Langton & Mazel 2015).

Similar patterns occur in South Africa and Chile, where promises of economic development have not alleviated poverty in mining regions (Human Rights Watch 2018). Lack of benefit sharing can create feelings of unfairness, especially when communities lose their land and resources to mining operations without receiving proper compensation (Bench Marks Foundation 2022; Akchurin 2020). While local communities face developmental challenges due to uneven benefit distribution, similar disparities occur on a global scale within the supply chains of critical raw materials.

### *Shrinking civic space and community rights*

Increasing restrictions on civic space in numerous countries pose a serious challenge to social justice in many sectors, limiting the ability of affected communities, workers, and environmental and human rights defenders to voice concerns, access information, and defend their rights (AIV, 2024; Bossuyt & Ronceray, 2020; Reisch 2023). Civil society organisations, local organisations, and the media play a critical role in holding companies and governments accountable, providing independent monitoring and reporting (Gianesello & Sabourin, 2024; Global Witness, 2023; Reisch 2023).

The shrinking of civic space globally has also intensified threats against those speaking out against mining projects, making mining one of the deadliest industries for defenders (RMF 2022). According to Global Witness, at least 196 land, environmental, and human rights defenders were killed in

2023, with many more facing legal harassment, physical violence, and smear campaigns (Global Witness 2024). Restrictions on media freedom and corporate secrecy further obscure the true extent of mining's harmful impacts. Underreporting of violence and environmental damage allows abuses to continue unchecked, creating and reinforcing an imbalance of power between extractive industries and affected communities (Global Witness 2024a).

A few major companies such as China Minmetals, Glencore, and Grupo Mexico are responsible for over half of all recorded allegations in the Business & Human Rights Resource Centre (BHRC) Transition Minerals Tracker, indicating that corporate policies and enforcement mechanisms play a crucial role in shaping mining outcomes (BHRC 2024). Governments and companies share the responsibility of safeguarding civic space to ensure open discourse, accountability, and fair decision-making (RMF 2022). However, it is still important to recognise the knowledge and leadership of defenders themselves, and to empower communities to help shape the future of mining governance (Bille Larsen et al. 2020; Le Billon & Middeldorp 2021).

### *The distribution of costs and benefits in global CRM supply chains*

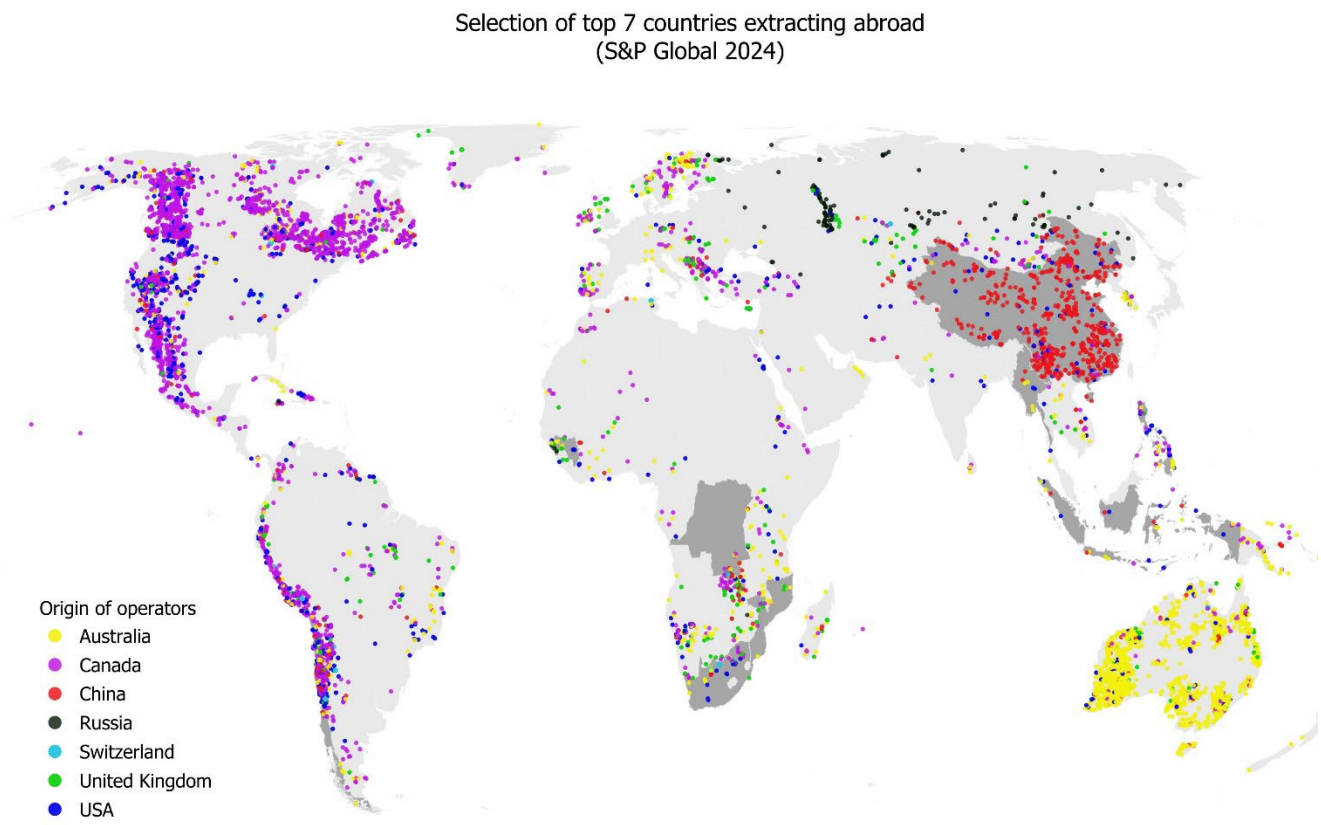
The distribution of benefits and burdens in global CRM supply chains is structurally imbalanced (Althouse et al. 2023). While many LMICs provide the raw materials essential for global industries, much of the economic value is captured elsewhere. According to a recent study, on average, low-income countries must export six tons of raw materials to earn what high-income countries gain from just one ton, and for the poorest net exporters, this figure rises to nearly thirteen tons (Rammelt & Ylla-Català 2025).

This occurs in two main ways. First, a large share of extraction is controlled by companies headquartered in high-income countries. According to the S&P Global database, 24% of registered mines are owned by Canadian firms, 15% by Australian, 7% by American, 7% by Chinese, and smaller shares by UK and Russian firms. Secondly, downstream value addition, through refining, processing, and manufacturing, predominantly occurs in countries with strong industrial capacity, such as China, Australia, and the United States, while the environmental and social costs are mostly found around the extraction sites (Chepeliev et al. 2025).

South Africa is a good example of this pattern (Creamer 2025). Although it holds around 37% of global manganese reserves and produced 7.2 million tonnes in 2023, only 2% of its ore is processed domestically. Most of the material is exported to China, where higher value is generated through industrial transformation and product development. Similar dynamics are observed for the other CRM. Local beneficiation is hindered by factors such as unreliable electricity supply, though recent policy efforts aim to address this through commodity-linked tariffs and other financial instruments.

Meanwhile, countries such as the DRC and Guinee continue to export raw materials while struggling to build domestic capacity for value addition. The result is that environmental and social costs, including pollution, displacement, and unsafe working conditions, are largely borne by communities in producing regions, while economic returns are concentrated elsewhere (Nakanwagi 2023).

**Figure 3.2.1**
Indication of external influence in CRM extraction in LMIC (Source: PBL and S&P Global)






### *Global governance mechanisms and power dynamics*

International policies around CRMs are shaped by three main components: economics, geopolitics, and technology (Cotula 2024a; Karkare 2024; Korteweg & Kranenburg 2024). These factors influence how countries manage, trade, and use these essential resources, often revealing differing priorities and challenges.

From a simplistic economic perspective, many HICs and LMICs currently seem to have distinct goals. Global North countries tend to focus on securing CRMs to power advanced technologies like electric vehicles (EVs) and renewable energy systems (Karkare 2024). These strategies manifest in, for example, the European Critical Raw Materials Act. Meanwhile, many LMIC prioritise capturing more value from the materials they mine, working to move beyond simply exporting raw resources and toward building industries that process and add value (additional to their similar focus on an energy transition) (Jones, Nguyen-Tien and Elliott 2023). Examples include Indonesia's attempt for an export ban on nickel, the Africa Mining Vision, and Namibia's export restrictions on unprocessed minerals. HICs (with fewer reserves or less willingness to extract resources) rely on free trade agreements and bilateral deals to secure access and prevent such restrictions. Global trade policy (WTO rules) currently makes it difficult for 'resource-rich' LMICs to adopt protective policies that support domestic value addition (Sunayana Sasmal 2024).

Geopolitics adds another layer, as countries compete not just for resources but for control over global supply chains (Clingendael 2024). This competition is about more than just economic optimisation; it is about governments positioning themselves to maintain influence and economic power. For instance, China's export controls on gallium and germanium (2023) were not merely about economic optimisation but were widely interpreted as a response to Western trade and technology restrictions (Cotula 2024a). Likewise, the Minerals Security Partnership (MSP) represents a coordinated geopolitical effort by the US, EU, and allies to counterbalance China's dominance by securing supply chains through aligned partnerships, not just economic deals (Cotula 2024a).

Technological development is another central driver in the evolving governance of CRMs as countries accelerate efforts to transition away from fossil fuels. This shift is reflected in national and regional policies that prioritise research, innovation, and investment in clean energy and circular economy technologies (Cotula 2024a). Some examples include: in the United States, the Defense Production Act supports domestic production of key technologies such as EV batteries, solar panels, and heat pumps; the EU's Horizon Europe programme funds R&D in advanced CRM processing, material substitution, and clean mining. Similarly, the Netherlands' Circular Economy Action Plan promotes innovation in recycling and resource efficiency to reduce dependence on primary raw materials.

# 4. Lessons for the governance of sustainable supply chains

In Chapter 3, we concluded that critical raw material mining and its adverse impacts is heavily influenced by an interplay of factors from local to global level. This chapter identifies challenges and opportunities for governing sustainable CRM supply chains, from the perspective of downstream actors like the Netherlands and the EU. It provides additional insights regarding barriers and entry points for the governance of CRM supply chains, gathered from the literature review on mining's social impacts in Chapter 2. We discuss global, European, and Dutch mechanisms and policies related to social risks in mining and consider how they can improve responsible supply chain governance. By placing these insights within a broader policy context, this chapter sets the stage for future research into effective governance interventions.

## 4.1 The current global policy landscape

***Main approaches to governing CRM supply chains and addressing social impacts***

On national levels, public-private partnerships (PPPs) are gaining traction as governance models for the extraction and management of raw materials. These partnerships combine state oversight with private sector investment and technical expertise, aiming to balance economic growth with social and environmental objectives. In Chile, the National Lithium Strategy mandates that new lithium projects operate as joint ventures with a controlling interest held by the state, ensuring greater alignment with national development goals and community interests (IEA, 2023; Carry, 2025). Similar models are emerging in countries such as Indonesia, where state-owned enterprises play a central role in nickel extraction projects. Early evidence suggests that PPPs can increase transparency, improve benefit-sharing with local populations, and enhance environmental performance by embedding public accountability into project governance (OECD, 2023; SWP, 2025). While PPPs require careful institutional design to avoid inefficiencies or political interference, they offer a promising approach to ensuring that the exploitation of critical raw materials contributes to both national and local development objectives.

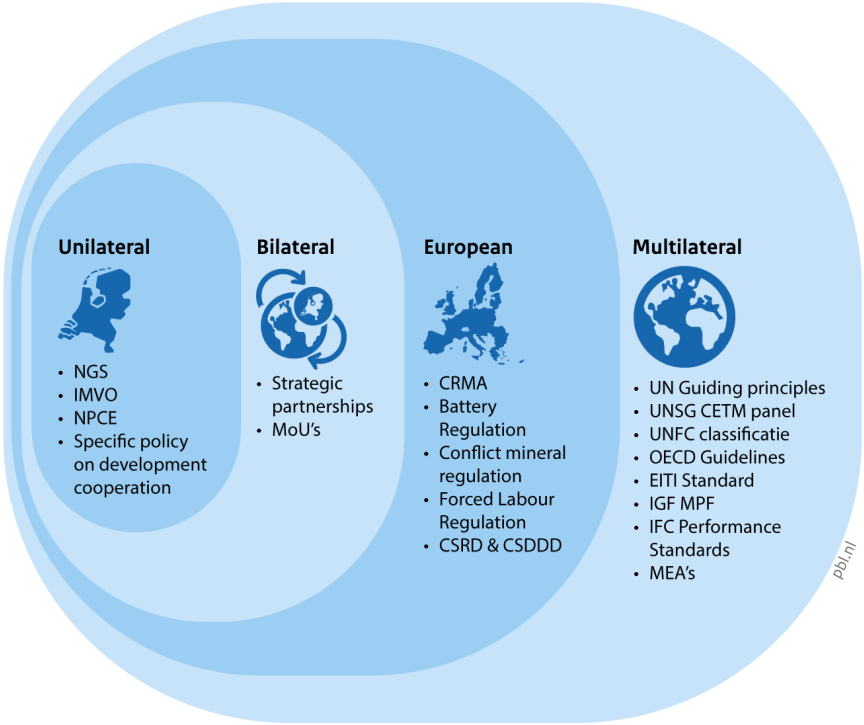
Second, in bilateral strategies the governance of supply chains happens through transactional agreements between states. These are often bilateral trade deals that reflect the strategic interests of the negotiating parties. Resource-rich countries may seek to capture more value locally, such as by requiring in-country processing, while resource-consuming countries aim to secure stable and affordable access to raw materials. An example is the Chile-EU CRM treaty, which links trade and climate goals by facilitating lithium exports for Europe’s green transition.

Thirdly, plurilateral strategies bring together small groups of like-minded countries to coordinate on CRM supply chains. These arrangements, such as the Mineral Security Partnership (MSP), which includes the US, EU, Australia, Japan, and others, focus on shared goals like supply security, transparency, and sustainability. They often operate through joint investment frameworks, knowledge-sharing, and soft standards. Other initiatives, like the Sustainable CRM Alliance, attempt to balance supply objectives with broader sustainability ambitions, although they typically prioritise government and industry interests over civil society participation (Cotula 2024a).

Lastly, global and multilateral efforts aim to make CRM governance more inclusive, systemic, and accountable. These efforts operate through international platforms such as the UN Panel on CRMs or climate negotiations at the COP level. They emphasise procedural rights and inclusion of Indigenous Peoples, workers, small-scale farmers, and other often-excluded actors. These forums provide space for raising global justice concerns, integrating social and environmental safeguards, and promoting human rights in the context of mineral supply chains.

**Figure 4.1**

**Social Governance within CRM supply chains**




Source: PBL

### *Challenges in addressing social impacts within CRM supply chains*

Although awareness of the social impacts of mining has grown, global governance remains limited in its ability to safeguard the rights and wellbeing of affected communities (Cotula 2024b). Over recent decades, international organisations have introduced various standards to influence the conduct of mining companies, including the OECD Guidelines for Multinational Enterprises and the UN Draft Norms on corporate responsibilities. However, most have either been abandoned or converted into voluntary frameworks. Soft-law instruments such as the UN Global Compact and the UN Guiding Principles on Business and Human Rights rely on voluntary engagement and national implementation, which often proves weak, particularly in countries where governments hesitate to impose strong protections out of concern for deterring investment (Cotula 2024b).

A review by Mancini et al. (2018) found that global frameworks such as the SDGs, GRI, EU impact assessments and quantitative Social Life Cycle Assessment databases each capture certain dimensions of social impact but fail to provide a complete picture. Localised issues such as land use conflicts, unstable employment, and demographic shifts are frequently overlooked, and positive effects such as income growth or education access are rarely measured in a meaningful way. In practice, much of the responsibility for mitigating harm falls to corporate social responsibility (CSR) programmes (Mancini et al. 2018).

Governance for sustainable supply chains of CRMs now relies on a mix of corporate self-regulation, civil society efforts, and multistakeholder partnerships, forming a complex transnational regulatory system (Elbra 2024). As long as the regulation of multinational corporations remains voluntary and market-driven, the system will continue to favour corporate profits over the rights and well-being of local communities (Elbra 2024). A more effective governance system would need to include binding social safeguards, clear accountability mechanisms, and a stronger role for civil society, Indigenous Peoples, and workers (Cotula 2023; Elbra 2024).

Finally, current efforts to make supply chains more sustainable often focus on reducing visible risks, like human rights abuses or environmental damage. However, these are symptoms of deeper structural inequalities in how materials are traded globally. Ecological unequal exchange refers to the way raw materials and environmental costs flow disproportionately from poorer, resource-rich countries to wealthier consumer countries (Rammelt & Ylla-Català 2025). While low-income countries often bear the environmental harm and social disruption of extraction, high-income countries benefit from the materials without facing these costs. Integrating measures of these unequal flows into policies like the EU's CSDDD and the Battery Regulation would move beyond risk management to address the root causes of injustice. Recognising and correcting these imbalances is key to building supply chains that are not only resilient but also fair and sustainable (Rammelt & Ylla-Català 2025).

## 4.2 EU level governance

While the social impacts of CRM extraction are still only partially understood (Maus & Werner 2024), they are increasingly acknowledged in EU policy frameworks. This section assesses how EU legislation addresses these impacts, using a structured lens: how social issues are framed in multiple policy developments and what limitations exist in light of the findings from earlier chapters. It focuses on key EU instruments, including the Critical Raw Materials Act, the Battery Regulation, and due dilligence directives (CSRD and CSDDD).

### *The Critical Raw Material Act*

The EU's Critical Raw Materials Act (CRMA) aims to reduce dependency on dominant suppliers by diversifying supply chains and increasing domestic extraction, processing, and recycling. It positions itself as a cornerstone of the EU's industrial policy for green and digital transitions.

The importance of the circular economy as a strategy for reducing our impact is acknowledged. However, by 2023, waste recycling in the EU met only 7.3% of CRM demand, with most CRMs having end-of-life recycling input rates below 5% (van Gaalen & Slootweg 2025).

Social and environmental risks are acknowledged in the regulation, and companies are encouraged to follow due diligence principles in line with the Corporate Sustainability Due Diligence Directive (CSDDD).

However, the CRMA does not impose mandatory due diligence requirements. Instead, it relies on sustainability criteria that encourage higher environmental and labour standards both inside and outside the EU. These criteria are largely voluntary and lack strong enforcement mechanisms. The regulation supports partnerships with resource-rich countries and promotes responsible mining, but does not include concrete tools to ensure social justice or improve local development outcomes. As discussed earlier in this report, these gaps may lead to unintended consequences in

LMICs, where the regulation's implementation could reinforce inequalities or sideline community needs (Berthet et al. 2024).

### *Strategic partnerships*

The CRMA emphasises the need for strategic and equal partnerships. The European Union has established several strategic partnerships focused on critical raw materials (CRMs) with resource-rich countries, including Canada, Ukraine, Namibia, the Democratic Republic of the Congo (DRC), Kazakhstan, Argentina, Chile, Zambia, and Rwanda. These partnerships, often formalized through Memoranda of Understanding (MoUs), aim to secure the EU's supply of essential minerals while promoting sustainable and responsible sourcing practices. While these agreements are designed to be mutually beneficial, concerns have been raised regarding their equity and effectiveness. The partnership with Zambia includes commitments to develop local capacity, but progress has been limited (SWP, 2024). Similarly, the agreement with Rwanda has raised ethical concerns due to the country's alleged involvement in conflicts in the DRC (The Guardian, 2025). These examples show that ensuring truly equitable and sustainable partnerships remains a challenge for the EU.

Aligning more closely with public-private partnership (PPP) models can strengthen this approach by supporting local value creation, community benefits, and higher environmental and social standards (OECD, 2023; IEA, 2023). Integrating PPP principles into the CRMA, investment agreements, and the Global Gateway strategy would move the EU beyond traditional trade-focused models toward more balanced cooperation (European Commission, 2023; SWP, 2025).

### *The Battery Regulation*

Batteries, especially those for EV's, are currently by far the most important driver for the increasing demand of CRM discussed in this report (IEA 2024b). The Battery Regulation is the most advanced EU instrument linking CRM use to environmental and social responsibility. It introduces strict lifecycle standards for battery production, including carbon footprint thresholds, collection and recycling targets, and material recovery requirements. These standards will gradually increase from 2025 onwards. From 2027, all portable batteries must be replaceable, and by 2031, minimum percentages of cobalt, lithium, and nickel must be sourced from secondary materials.

The regulation mandates due diligence and risk assessments on human rights and community impacts, following OECD and UN frameworks. Companies must adopt a due diligence policy and demonstrate compliance, or face market access restrictions. This 'no compliance, no market' approach offers stronger enforcement compared to the CRMA (Melin et al. 2021).

Despite this progress, the regulation leaves critical gaps. The regulations have faced criticism for permitting mining companies to outsource due diligence to private auditors and for exempting aerospace and defence contractors (Johnson & Khosravani 2024). Additionally, it does not contain provisions to support local economic development or tackle inequality in the value chain, where most profits remain with downstream actors in Europe (Johnson & Khosravani 2024). Nor does it directly address toxic emissions or the protection of Indigenous rights (Rouhana et al. 2024). As such, while the Battery Regulation defines and manages risk more explicitly than the CRMA, it does not take into account all social impacts as identified in Chapter 2, such as economic and health issues (Melin et al. 2021; Dunlap & Laratte 2022).

### *The conflict minerals regulation*

The EU Conflict Minerals Regulation (CMR) was introduced to reduce the impact on conflict of trade in tin, tantalum, tungsten and gold. The Regulation builds on the OECD Guidance for responsible mineral sourcing from high-risk areas, but innovates by making this previously voluntary framework mandatory for EU importers.

Recent evaluations by IPIS (2024) and PAX (2023) show that the regulation has had little meaningful impact in mineral-producing countries (de Brier & Walschot 2024; PAX 2023). Member States' Competent Authorities (MSCAs), which are responsible for ensuring the "effective and uniform" implementation of the Regulation lack the expertise and capacity to enforce it consistently, and interpret the rules differently, leading to uneven implementation. Many EU 3TG importers still fail to meet the Regulation: their reporting is sub-standard, traceability systems incomplete, and key data undisclosed. Because they rely on non-EU smelters and refiners that seldom reveal mineral origins, importers rarely know the mine source, so the EU's due-diligence duties seldom reach upstream producers.

PAX and IPIS recommend stronger engagement with stakeholders in producing countries, as many, such as in the DRC, are unaware of the Regulation. Training EU delegations could enhance local collaboration. Supporting and formalizing ASM would reduce risks and promote responsible sourcing. They also call for mandatory EU-wide transparency rules, as current disclosure practices are inconsistent. Finally, they highlight a key gap: trading and transit countries like Rwanda and the UAE are not classified as high-risk, despite their role in smuggling (from high risk countries), undermining supply chain oversight.

### *EU sustainability regulation*

The EU's Corporate Sustainability Reporting Directive (CSRD) and Corporate Sustainability Due Diligence Directive (CSDDD) represent a broader shift toward binding corporate responsibility in global supply chains. The CSRD, which replaces the Non-Financial Reporting Directive, requires around 60,000 companies to report on their environmental, social, and governance (ESG) impacts. The directive aims to reduce systemic sustainability risks and improve investor information, but implementation delays have occurred in several member states, including the Netherlands.

The CSDDD complements the CSRD by requiring large companies to identify, prevent, and mitigate human rights and environmental risks in their operations and supply chains. It also mandates the adoption of climate transition plans. However, the scope is limited; in the Netherlands, fewer than 500 companies fall under the directive. Non-EU companies operating in the EU are also covered, but only above certain thresholds.

Political uncertainty currently threatens the effectiveness of both directives. In 2024, the European Commission proposed an 'Omnibus package' to streamline sustainability rules in response to competitiveness concerns. This follows recommendations from the Draghi report on industrial policy and reflects growing industry pressure. Civil society actors warn that this trend may dilute the effectiveness of the EU's sustainability agenda, even though research shows compliance costs are modest relative to corporate profits (Kersten et al. 2024).

Recent research (Muñoz 2025) identifies three key uncertainties that will shape the success of EU regulations. First, companies must choose how to prioritise among many social and environmental risks. Effective oversight will require well-resourced national authorities. Secondly, stricter due diligence rules may increase tensions between companies and affected stakeholders, unless they

are framed as tools for collaboration. Finally, real transformation will depend on whether companies integrate due diligence into their core business models, moving beyond mere compliance. This will likely require more positive incentives, not just legal pressure.

Several strategic entry points emerge for the EU to strengthen governance of socially responsible CRM supply chains. These include expanding the scope of binding obligations, linking social risks to industrial policy incentives, and supporting local value addition in producing countries (Berthet et al. 2024; IEA 2024b).

## 4.3 Governance in the Netherlands

The Netherlands is a significant consumer of critical and strategic raw materials, although it does not import large quantities of raw materials directly (except aluminium). Its impact and also its leverage are largely indirect, expressed through investment flows, technology, consumption, and its role within the EU. As earlier chapters show, failing to address social issues in CRM extraction is an issue which can lead to local unrest and trade instability, which ultimately threaten supply security. This section shortly analyses how social issues are framed in different Dutch policy measures. A critical reflection is not included since a research base for this is still lacking. Instead, in 4.4 entry points for governance are summarized.

### *Circular Economy*

Firstly, a key strategy a consuming country can do to reduce impact is by reducing consumption of CRM (UNEP 2024b). Both in the NGS and the National Programme on the Circular Economy (NPCE) this is acknowledged as an important strategy. According to Hanemaaijer et al. (2025), recycling is still the dominant strategy for circularity, but especially for CRMs, this is inadequate. High-quality recycling remains underdeveloped, and the availability of recycled material is not expected to meet the projected demand anywhere soon for multiple CRM. More concrete strategies for recycling, lifetime extension, reuse, sharing, and overall demand reduction are needed to truly limit the dependency on CRM (Hanemaaijer et al. 2025). Especially for strategies on consumption reduction, it is important that this is broadened towards sectors and governmental departments influencing this demand, such as climate and energy, trade defence, medical and digitalisation departments.

### *The Dutch Raw Materials Strategy (NGS)*

The NGS largely aligns with the European CRMA. In several parts of the document, it is clear that social aspects, such as human rights, gender equality, and the working conditions in supply chains, are considered an integral part of the strategy. For example, the document explains that the Dutch government insists that any international partnership or project must account for the impact on people as well as on the environment. This is reflected in measures such as involving not only companies but also unions, local communities, and NGOs in discussions and decision-making. One section highlights that in sectors like renewable energy, diverse stakeholders (including workers' organisations and societal groups) work together to map, address, and prevent human rights and environmental risks in the supply chain.

On a multilateral level, the Netherlands supports international standards and forums that encourage responsible practices globally, for example, through participation in the Extractives Industries Transparency Initiative and the Women's Rights and Mining network. These initiatives are aimed at change by promoting transparency, capacity building, and the integration of social criteria into broader trade and environmental policies. They also support the incorporation of social criteria into EU regulatory frameworks, such as the CSDDD and the EU Anti-forced Labour

Regulation, ensuring that companies in the CRM supply chain remain accountable on a broader scale (EZK et al. 2022).

In addition to EU partnerships, the NGS (and policy updates) mentions efforts to develop bilateral strategic partnerships. For instance, partnerships with countries in Latin America and Africa are being explored to further diversify supply sources and reduce dependency (EZK et al. 2023). These initiatives are aimed at ensuring a balanced relationship where the benefits and responsibilities are shared.

In the NGS, the role of new collaborative platforms like the Critical Raw Materials Club is highlighted as well. This club is set up to foster reciprocal and inclusive relationships between the EU (and its Member States) and third countries. By doing so, it contributes to improving supply security and advancing the sustainability of critical raw material value chains.

### *The Dutch battery strategy*

Batteries, especially lithium-ion batteries in EV's, are the most important commodities driving the Dutch demand and dependency on CRM (primarily manganese, graphite, cobalt, nickel and copper) (IEA 2024).

The battery strategy, initiated in 2020, focuses on managing the increasing use of batteries driven by the energy transition and the electrification of mobility. It aims to ensure that this growth is safe, responsible, and sustainable, emphasising five key pillars: raw materials, circularity, safety, economic perspectives, and energy systems. The battery regulation mainly aims to stimulate a circular economy for batteries by extending their lifespan, improving recycling, and reducing the need for primary raw materials rather than directly reducing the consumption of batteries themselves. Additionally, the strategy acknowledges the upstream impacts of resource extraction by promoting responsible sourcing through due diligence (IenW 2024). For the approach to address impacts of CRMs, the strategy refers to the NGS.

### *Forced labour ban*

The Netherlands will implement the EU Forced Labour Regulation on 14 December 2027, banning the sale and export of products made with forced labour. The regulation targets high-risk product categories, including metals such as iron, steel, aluminium, copper, zinc, nickel, and tin. These risks are particularly relevant for imports from countries like China, Brazil, and Indonesia, where forced labour is widespread, especially in manufacturing and metal production. The ban may lead to improved supply chain transparency and human rights practices, but could also cause disruptions in supply chains and pose challenges for companies relying on high-risk materials or sourcing regions (BZ 2025).

## 4.4 Entry points for enabling sustainability in supply chains

Despite limited direct regulatory powers, the Netherlands can strengthen its impact in several ways.

Multilaterally, it can continue to shape EU CRM governance through its knowledge base and policy leadership. The Ministry of Foreign Affairs has been recognised as influential in EU processes, often 'punching above its weight' due to its expertise and constructive engagement (IOB 2024). One of the factors contributing to this influence is a strong contribution based on substantive knowledge and experience. The Dutch government can continue to invest in research and knowledge sharing on the topic of CRMs, to support EU policy processes that affect how the EU will move forward to

both ensure supply chain stability (currently a focus of the Dutch National Material Observatory) as well as sustainability in mining of CRMS (IOB 2024).

Bilateral partnerships offer opportunities to co-develop socially responsible sourcing frameworks. These should include stakeholder dialogue, community participation, aligning with PPP structures, and benefit-sharing mechanisms. Dutch support for civil society organisations in mining regions can also amplify local voices and promote more stable, equitable outcomes.

At the market level, the Netherlands can further incentivise corporate transparency and grievance mechanisms through instruments such as the IMVO covenants ('Internationaal Maatschappelijk Verantwoord Ondernemen', or international corporate social responsibility). Even though voluntary in nature, these frameworks can push companies toward more responsible practices, especially when tied to public procurement or export support.

Unilateral measures can further reduce CRM demand through circular economy policies. These include not only improving recycling and reuse, but also fundamentally reducing material consumption by integrating CRM considerations and CE strategies into climate, construction, digitalisation, and defence policies. Smarter design and product lifespans should be prioritised to manage those CRMs that already circulating in the economy more effectively.

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# Appendix: Impact framework used in case studies

### *Six typical areas of social impacts of mining*

Several studies have tried to address the issue of how adverse impacts related to natural resources are connected to their causes (Camara et al. 2021). O'Brochta (2019) has suggested that contextual aspects, which are frequently overlooked, are key in understanding impacts. He has argued that researchers should focus more on studying the specific factors behind these impacts rather than just looking for general patterns. In order to more effectively take contextualities into account, we chose a case study approach in this report. Impacts related to the mining of metals can be categorised into six main areas, as identified in a large systemic review on the topic by Mancini & Sala (2018). We used these impact categorised as a guiding framework to assess the overall social impacts per metal and region.

The six categories are:

*Economy, income, and security*

Mining can stimulate local economies by increasing income and business opportunities across multiple sectors. However, it can also lead to income inequality, with unfair distribution of mining profits and corruption, which can spark social unrest. Conflicts may arise between mining companies, illegal miners, and anti-mining activists. In some cases, mining can exacerbate poverty when local populations lose traditional livelihoods, and when governments fail to reinvest mining revenues effectively.

*Employment and education*

Mining often creates jobs directly in the industry and indirectly in other sectors. Many studies highlight the positive effects of job creation at both local and national levels, as well as the educational opportunities and skill development provided by mining companies. However, negative outcomes include the exploitation of child, forced, and compulsory labour, along with poor working conditions, low wages, health hazards, and restrictions on trade union activities. Mechanisation in mining can also lead to increased unemployment.

*Land use and territorial aspects*

Mining projects can create land competition, leading to displacement, land expropriation, and resettlement of local communities. This reduces access to land for rural populations, negatively impacting their livelihoods and generating food insecurity. Already complex or contested arrangements of land rights, for instance land rights by traditional leaders, can come under additional pressure. Post-mining land restoration and rehabilitation also directly affect livelihoods and socio-economic opportunities in mining regions. However, in some cases, mining companies contribute to local development by improving infrastructure, such as roads, power, and water supplies, which in turn enhance access to health and education services.

*Demography and gender*

Mines can exist for long periods where work is done by the same community for generations, but new mines in remote areas attract workers from other regions, resulting in migration, new cities and demographic shifts. This can lead to gender imbalances as the workforce is predominantly male, which, in many cases has led to disruption of social cohesion and to increased issues such as alcoholism, drug addiction, and prostitution. This differs per metal and region; in some mining areas women are involved in the lowest and riskiest jobs, while in others women are barely involved in mining itself but bear the brunt of the impacts of the mine as important caregivers in households, while insufficiently compensated.

*Environment, health, and safety*

Mining can negatively impact local communities through environmental degradation, such as water contamination, which affects livelihoods like fishing. Health issues may arise from exposure to toxic substances, and physical harm may occur from accidents or damage to property due to mining activities. Water scarcity and competition for water resources are recurring problems in mining areas.

*Human rights*

Human rights violations can occur in various forms, including the marginalisation of vulnerable groups, exclusion of stakeholders, and failure to respect Indigenous populations. Other impacts may include the abuse of cultural and aesthetic resources.

### *Overview of impacts found in case studies*

1. Human Rights and Conflict (at least 10 impacts)
    - Violations of consultation rights (Chile, South Africa, Philippines, DRC)
    - Forced displacement and resettlement (Indonesia, Guinee, Mozambique, DRC)
    - Violent repression of protest (Guinee, Philippines)
    - Child labor (DRC)
    - Abuse of subcontracted workers and lack of compensation (Chile, Indonesia, DRC)
    - Corruption and lack of transparency (DRC, South Africa)
    - Criminal control over mining (DRC)
    - Overlap with protected or Indigenous lands (Philippines, Myanmar)
    - Political instability and violence (Mozambique, DRC)
2. Environment, Health, and Safety (at least 11 impacts)
    - Water scarcity and pollution (Chile, South Africa, Indonesia, Guinee, Mozambique)
    - Air pollution and dust exposure (Chile, Guinee, Mozambique, China)
    - Toxic waste and tailings (Guinee, China, Myanmar)
    - Respiratory diseases and silicosis (Chile, South Africa, Mozambique, China)
    - Exposure to heavy metals and radioactivity (DRC, Myanmar, China)
    - Health risks from unsafe working conditions (Chile, DRC, Indonesia)
    - Mining-related accidents and fatalities (Chile, DRC, Indonesia)
    - Deforestation and biodiversity loss (Indonesia, Myanmar)
    - Climate-related disruptions (South Africa)
3. Employment and Education (at least 6 impacts)
    - High wages in mining (Chile, South Africa)
    - Limited local employment due to skill mismatch (Indonesia, Guinee)
    - Health risks for mine workers (Chile, South Africa, China)
    - Mental health impacts from shift work, noise, relocation (Chile)

- Gender barriers to employment (South Africa, Guinee)
- Education access and literacy challenges (Mozambique, South Africa)

4. Economy, Income, and Security (at least 6 impacts)
   - Unequal benefit distribution (Guinee, Indonesia, Mozambique)
   - Local unemployment despite mining growth (Guinee)
   - External hiring and job insecurity (Guinee, Indonesia)
   - Export reliance with limited value addition (South Africa, Mozambique)
   - Exposure to global price fluctuations (DRC)
   - Revenue capture by foreign companies (Guinee, DRC, Mozambique)
5. Land Use and Territorial Aspects (at least 5 impacts)
   - Loss of farmland and livelihood spaces (Indonesia, Guinee, Mozambique)
   - Inaccessible or degraded land (all)
   - Disputes over compensation and land valuation (Indonesia, Guinee)
   - Mining on Indigenous or communal land (Philippines, Myanmar)
   - Tenurial conflict and land grabbing (Indonesia)
6. Demography and Gender (at least 4 impacts)
   - Gendered impacts of land loss and caregiving burdens (South Africa, Guinee)
   - Male-dominated compensation structures (Guinee)
   - Migration and demographic change (Indonesia, Mozambique)
   - Mixed effects of in-migration on community cohesion (Indonesia)
7. Socio-environmental Conflict (at least 2 impacts)
   - Protest and community resistance due to unmet promises or damage (Chile, Guinee, Mozambique)
   - Links between environmental damage and violence (Philippines, Guinee)