INTERGOVERNMENTAL FORUM on Mining, Minerals, Metals and Sustainable Development

What Makes Minerals and Metals "Critical"?

A practical guide for governments on building resilient supply chains

Secretariat hosted by

IISD

Secretariat funded by

Canada

Kingdom of the Netherlands

The International Institute for Sustainable Development (IISD) is an award-winning independent think tank working to accelerate solutions for a stable climate, sustainable resource management, and fair economies. Our work inspires better decisions and sparks meaningful action to help people and the planet thrive. We shine a light on what can be achieved when governments, businesses, non-profits, and communities come together. IISD's staff of more than 200 experts come from across the globe and from many disciplines. With offices in Winnipeg, Geneva, Ottawa, and Toronto, our work affects lives in nearly 100 countries.

IISD is a registered charitable organization in Canada and has 501(c)(3) status in the United States. IISD receives core operating support from the Province of Manitoba and project funding from governments inside and outside Canada, United Nations agencies, foundations, the private sector, and individuals.

IISD HEAD OFFICE

111 Lombard Avenue
Suite 325
Winnipeg, Manitoba
Canada R3B 0T4

IISD.org
@IISD_news

The Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF) supports its more than 80 member countries in advancing their sustainable development goals through effective laws, policies, and regulations for the mining sector. We help governments take action to develop inclusive and gender-equitable practices, optimize financial benefits, support livelihoods, and safeguard the environment. Our work covers the full mining life cycle, from exploration to mine closure, and projects of all sizes, from artisanal mining to large-scale operations. Guided by our members' needs, we provide in-country assessments, capacity building, technical training, publications, and events to advance best practices, peer learning, and engagement with industry and civil society. The International Institute for Sustainable Development has hosted the IGF Secretariat since October 2015. Core funding is provided by the governments of Canada and the Netherlands.

IGFMining.org
@IGFMining

What Makes Minerals and Metals "Critical"?
A practical guide for governments on building resilient supply chains

May 2024

Written by Isabelle Ramdoo, Grégoire Bellois, Murtiani Hendriwardani

Table of Contents

1.0 Introduction and Objectives

1.1 Introduction

Minerals and metals are the backbone of our modern society. These crucial elements are the building blocks that drive economic, social, and technological advancement. They serve as vital feedstocks for our food systems and are indispensable inputs for our industrial development.

Global trends and calls to action, such as the imperatives to address climate change, notably by moving away from a fossil-fuels-based economic model and the increasing digitalization of our society, will require a rapid adoption of a suite of technologies that are highly mineral intensive. As recent analysis suggests (see International Energy Agency [IEA], 2023b; Hund et al., 2019), these systemic changes in our industrial and societal models have led to an exponential rise in demand for minerals and metals. Increased demand from energy and digital transitions will be compounded by other recurrent development needs, such as basic access to energy from developing countries, rapid urbanization resulting from the demographic boom, and infrastructure needs, amongst others.[1] Forecasts—although probably largely underestimated—predict that the upward trend in demand is likely to continue at an accelerated pace.

However, these estimates indicate that the increasing demand for minerals and metals is unlikely to be met by a corresponding pace in the increase in mineral supply, at least in the short to medium term (IEA, 2023b).

It is, therefore, expected that the production of—and access to—minerals and metals that are essential to the manufacturing of digital, decarbonization, and energy transition technologies will be at the top of the political and economic agenda of many governments and influence strategic decisions and alliances at various levels, namely at bilateral, regional, and global levels. These will fundamentally reshape the markets for minerals and metals that are essential for the energy and digital transitions, indistinctly impacting all supply chain segments and actors, albeit in different ways.

[1] The British Geological Survey (2024) offers a comprehensive overview of where critical minerals are found in the typical household, as well as the everyday lives of families.

1.2 Objectives

This practical guide provides a series of questions for governments to consider when designing strategic policies and roadmaps regarding the minerals and metals they produce and/or need for resilient industrial supply chains.

There is no consensus on the terminology to designate minerals and metals that are essential feedstock in digital and energy transition technologies, and for which there are supply chain challenges. The aim of this practical guide is to support governments in defining what should be considered as "strategic" or "critical" based on a series of objective criteria, such as their mineral endowments, their national development objectives and priorities, their decarbonization and industrialization pathways, and their importance (and role) in global supply chains.

This practical guide provides a (non-exhaustive) set of questions and indicators that governments may use when conducting a thorough assessment of the risks associated with their minerals and metals. While the assessment is mainly aimed at identifying risks, the indicators provided in this practical guide can help governments identify strategic opportunities that can be leveraged to maximize the benefits from the rising demand for some minerals and metals.

2.0 Why and How Mineral "Criticality" Should Be Assessed

In the current literature, "criticality" assessments are mainly driven by downstream supply chain actors.[2] They are aimed at identifying and evaluating risks associated with the supply of minerals that are needed by countries that have a deficit in production and for specific industries or applications (Schrijvers et al., 2020; U.S. Department of Energy, 2023a). Motivations and perspectives may vary if the stakeholder is a company, a specific industry (such as renewable energy and digital technologies), a country, or a region (Schrijvers et al., 2020).[3]

2.1 Criticality Assessment Is Relevant for All Stakeholders

Minerals and metals are not equally distributed in the Earth's crust, which means that some minerals are highly concentrated in a handful of countries. This physical characteristic of mining is at the source of several potential risks and challenges that may, in turn, impact mineral value chains and their related supply chains. Risks differ across producing and destination countries and across different industries or sectors that require minerals and metals as inputs in their production (Schrijvers et al., 2020).

The rising demand related to the energy and digital transitions, the growing complexity of global supply chains, and the geopolitical tensions these dynamics have generated have exacerbated the risks. To manage the growing risks associated with access to, and production of, minerals, countries and industries who are most vulnerable to supply disruptions have undertaken risk assessments (also called "criticality assessments") to better identify sources of vulnerabilities and understand pinch points along mining production value chains, as well as related weaknesses in global supply chains (See European Commission, 2017; Nassar & Fortier, 2021; National Research Council, 2007).

[2] For detailed literature reviews on critical minerals see Achzet & Helbig, 2013; Hayes & McCullogh, 2018; Helbig et al., 2006; McCullough & Nassar, 2017; McNutty & Joewitt, 2021; Schrijvers et al., 2020; Takuma et al., 2020; Viebahn et al., 2015.

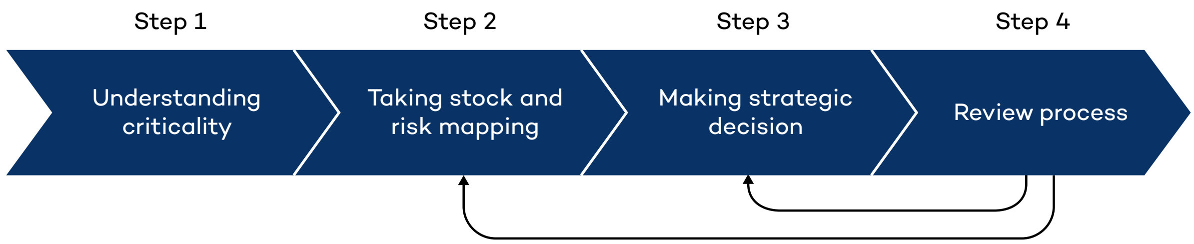
[3] For an extensive literature review on the notion of criticality and different definitions adopted by various countries, see Hilson, forthcoming.

At the same time, countries with a dominant position as producers of minerals and metals in high demand are increasingly taking a strong stance to position themselves as strategic partners (see Australian Government, 2023; Natural Resources Canada, 2022). Cognizant of their bargaining powers and of their geopolitical strengths, many have developed their own critical or strategic minerals policies (Ramdoo, forthcoming). Their objectives differ from those who are vulnerable to supply shocks and therefore want to strengthen their positions and protect their interests. Overall, arguments for a greater control over the supply of minerals vary from developing resilient domestic industrial capacities and supply chains to political positioning to become suppliers of choice. In some cases, strong nationalistic positions are a response to retaliate over measures taken by competing countries.

2.2 Key Steps to Define the Mineral Scope for Critical Minerals Policy Design

The following section provides a **four-step approach**, with a set of questions and key indicators aimed at providing policy-makers with a toolbox to conduct a criticality assessment and the identification of strategic assets.

FIGURE 1. A four-step approach to identify indicators to assess criticality and define strategic interests



Source: Authors.

> A criticality assessment is a thorough assessment of risk to identify bottlenecks and pinch points in mineral value chains.
>
> The process of identifying "strategic assets" is aimed at gauging the importance of some minerals in meeting national development objectives and in leveraging the country's unique position in global supply chains.

To fully assess the criticality or the strategic importance of their minerals and metals, governments are advised to undertake a thorough assessment of risks and opportunities of the entire mineral supply chain.

The approach proposed in this section is a dynamic one. When there are changes in circumstances, whether at domestic, regional, or global levels, policy-makers need to take a step back and reassess their priorities accordingly. It is also advisable for policy-makers to review the criticality assessment regularly (on average every 3 years).

3.0 Step 1: Understanding criticality

3.1 Criticality Assessments

The first and perhaps most important step before making any policy choices is to have a holistic understanding of criticality from a technical, economic, and geopolitical perspective. This is crucial to properly identifying which minerals and metals are involved and, therefore, what types of measures would be needed to tackle the challenges. This step is key for producing and destination countries alike.

While the rationale for conducting a criticality assessment is well understood, there is, however, no universally agreed definition of what is “critical” or “strategic” or what minerals and metals should be considered as such. Methodologies and formulas to identify critical minerals vary across countries. Nonetheless, common challenges emerge across various methodologies, and these include economic importance, demand and supply risks related to the share of the mineral in a technology, and dominant suppliers.[4]

Box 1. Terminologies | Critical or strategic: Are these terms synonymous?

In the prevailing discourse, the term "critical minerals" has been commonly and widely used by advanced economies with significant industrial capabilities to manufacture energy and digital technological solutions, but with important deficits in domestic mineral production. For these countries, the terms "critical minerals" or “critical raw materials” refer to those elements that are needed for their key strategic industries but for which there are significant risks of supply disruption. Given their (over)reliance on external markets, their policies are aimed at the security of supply chains and at de-risking and diversifying sources of supply.

[4] See Hilson (forthcoming) for a review of methodologies used by various countries.

On the other hand, countries that produce or extract these minerals often prefer to refer to them as "strategic minerals" because these minerals are of crucial importance to their domestic economies and can potentially confer them a position of strength as suppliers of choice to destination countries. In some countries (in the United States, for example), the term "strategic" refers to minerals essential for the defence industry (National Research Council, 2007). In this case, both terminologies are used, and strategic minerals are a subset of critical minerals.

While there are significant overlaps in the scope of critical and strategic minerals, there are major differences in approach, which reflect national priorities, industrial competitiveness, and choice of global partners.

Other terms used include energy transition minerals, battery minerals, or green minerals. These refer to priorities related to specific objectives (such as "green" or energy transition) or target specific industries (such as batteries). Supply chain challenges are recognized as important policy drivers.

Acknowledging that terminologies differ across countries, this guiding document uses the term "critical minerals" due to its focus on the assessment of risks.

The outcomes of criticality assessment exercises generally lead to the design of critical minerals strategies and policies, often associated with a mineral scope, which are then used as levers for policy-makers and industrial players to make informed decisions regarding current and future investment plans, strategies to negotiate trade and global partnership agreements, and engagements in global policy agenda, among other things. See Appendix A for a comparative list of critical minerals as identified by Australia, Brazil, Canada, China, the European Commission, Japan, South Korea, the United Kingdom, and the United States.

3.2 Key Characteristics That Define Criticality

3.2.1 Demand and Supply Risks

Assessing risks associated with the demand of critical minerals involves examining factors such as industrial demand related to the energy and digital transitions, potential changes in technologies that may affect future demand, and broader mineral needs related to basic access to energy, infrastructure, construction and urbanization, and wider socio-economic development needs. Moreover, evaluating risks associated with supply, such as social and environmental risks, geopolitical tensions, and resource nationalism is crucial in defining criticality (Coulomb et al., 2015).

3.2.2 Production Volume

Minerals and metals may be considered critical because they are only produced in low volumes, while demand is high. Many significant mining projects face declining ore grades or depleting reserves.

Moreover, it is estimated that more than 60% of minerals and metals considered critical by the United States, European Union, Canada, and Australia[5] are not mined for themselves. They are minor metals, mainly extracted as co- or by-products of other major minerals and metals (Bellois & Ramdoo, 2023) and therefore are available in smaller volumes. They are considered to have higher levels of risk because their supply is generally inelastic in the short term because their production is highly dependent on the technical feasibility and/or economic sustainability of the host metal extraction processes.[6]

3.2.3 Uses and Applications

It is important to note, however, that the criticality of a mineral or a metal is not only a function of its physical availability—it depends on how demand will evolve. Changing demand is shaped by specific technologies (see Appendix B for a mapping of digital and energy transition technologies against critical minerals) and, importantly, by the pace of technological development. The latter may require different minerals, which may, in turn, impact the degree of criticality of minerals needed for the technologies in question.

3.2.4 Time Factors

Criticality is not static; it has a time dimension. Indicators of criticality evolve over time and are assessed differently in the short term and long term (Heffron, 2020). What is critical today might not be critical in a few years because new sources of production may emerge, including at the national level, substitution can be found, or technology may change, requiring different volumes of the mineral in question or different sets of minerals altogether. Time, therefore, is expected to affect the risk profile associated with mineral supply, reducing risk for some minerals and increasing risks for others.

Box 2. Criticality: Time matters

Technological evolution can be illustrated by the historic change of mobility vehicles at the beginning of the 20th century. In 1900, there were practically no motor vehicles. But the rapid deployment of the first cars meant that within a span of 20 years, horse-driven carriages were almost wiped out from large cities in the United States. This historic change drastically affected entire industries and their supply chains and—subsequently—the demand for minerals and metals (Amatucci, 2015).

Mineral intensity in various technologies can also evolve spectacularly. For instance, the move toward e-mobility significantly increases the demand for copper: with current technologies, a conventional internal combustion engine car requires, on average, 25 kg of copper, whereas for an equivalent size of vehicle, average copper requirements are 50 kg for a hybrid car and 75 kg for an electric vehicle (IEA, 2021).

[5] For example, about 75% of indium and 65% of germanium are by-products of lead-zinc-silver; almost 100% of gallium is associated with aluminum; and 50% of cobalt and palladium is co-produced with nickel.

[6] For a more comprehensive overview of how metals are produced and associated together, see Bellois & Ramdoo, 2023.

3.2.5 Stakeholders' Position in the Supply Chain

The understanding of the notion of criticality can vary depending on where stakeholders are positioned in the mineral supply chain at a point in time.

Midstream and downstream stakeholders and destination countries generally consider criticality from the security of supply and access to markets for minerals they do not produce or produce only in limited quantity. Criticality assessments from this perspective, will consider issues such as the degree of import dependency, economic importance for industrial use, risks of supply shortages, and geopolitical challenges, amongst others. To overcome this, many countries, including France (Messad, 2023), Saudi Arabia (El Yaakoubi, 2024), Laos PDR (Lapuekou, 2023), and the Philippines ("Philippines Seeks," 2023) are increasingly ramping up exploration efforts to find mineral deposits domestically.

For **upstream** stakeholders, such as mineral-producing countries and related domestic industries, criticality assessments involve a strategic consideration in addition to a risk perspective. From a risk management perspective, mineral-producing countries and domestic industries consider issues such as their degree of dependency on (and concentration of) export markets, the degree of fiscal revenue reliance, the risks related to changes in demand due to technological changes, availability of substitutes to replace the critical minerals, or policies from import-dependent countries to diversify away from their markets.

Box 3. Criticality assessment from mineral-producing countries—debunking a misconception

It is often (wrongly) perceived that criticality assessments are not necessary if countries are well endowed with minerals or are net exporters thereof.

In fact, risk assessments are equally, if not more important for mineral-producing countries for several reasons. First, economies are globally interdependent, and therefore measures taken to mitigate risks by destination countries will necessarily have ripple effects on producing countries. If not well understood, analyzed, and anticipated, risk mitigation strategies by destination countries may create new challenges and enhance vulnerabilities for producing countries. These unanticipated challenges will have repercussions on their mining sectors and on their future policy choices.

Moreover, many mineral-producing countries, particularly those with relatively undiversified economies and high dependencies on a limited number of mineral exports, are less resilient to external policy changes and shocks. They may, therefore, to be disproportionately impacted by policies aimed at managing risks in their partner countries.

Finally, the current mineral boom represents a narrow window of opportunity for producing countries to leverage their geopolitical strengths to become suppliers of choice. While the demand for critical minerals is likely to continue to grow, the risks associated with supply shortages or disruptions may eventually be managed and addressed. The focus on their "critical" nature will wane, therefore lowering the bargaining power of producing countries. In that regard, criticality assessment can be a useful compass to provide strategic insights into how markets are evolving.

Mineral-producing countries have a strategic role to play as key suppliers to countries and industries that are further downstream. Arguably, mineral-producing countries can leverage their mineral resources as a source of bargaining power to develop their own industrial and value-addition capacities, notably through investments and partnerships.

A global consultation conducted in 2023 by the IGF (see IGF, forthcoming) revealed that a significant number of developing countries already have or are in the process of adopting a critical mineral strategy (60%) and/or a critical mineral list (80%). The primary drivers behind formulating and executing critical mineral strategies were (a) increased domestic value addition (27%), (b) increased fiscal revenues (26%), and (c) strategic positioning in global supply chains (21%). The survey underscored the perception among producing countries that critical minerals are regarded as a strategic concern.

Despite the increasing move to adopt critical mineral policies and lists, very few producing countries, however, have conducted in-depth criticality assessments to gauge the levels of risks to be managed and to identify opportunities that can be leveraged from a supplier's perspective. The few exceptions include Australia and Canada, which are both major producers and industrial actors and have positioned themselves as partners of choice with key midstream and downstream stakeholders.

4.0 Step 2: Taking stock

Understanding criticality	Taking stock and risk mapping	Making strategic decision	Review process

For policy-makers in mineral-producing countries, having a strategic vision for their mining industry is important, irrespective of whether they are planning to identify or classify certain minerals as strategic or critical. In that context, it is crucial to conduct criticality assessments to inform the country's long-term strategic objectives.

The exercise will allow countries to identify opportunities to leverage the benefits from minerals in high demand, for various reasons. It will provide countries with evidence to make informed decisions to adjust their mining policies and strategies, and design measures to address bottlenecks that may prevent the implementation of domestic industrial policies and global commitments with key buyers and trading partners.

As a foundation for strategic decision making, the second step, therefore, is to **take stock** of various factors that impact the demand and supply of minerals. This includes a deep understanding of the availability and accessibility of mineral resources, of their industrial uses (domestic and global), of trends in global markets, and of geopolitical dynamics surrounding these minerals. The knowledge generated should allow countries to identify associated risks. The main outcome of the stocktaking and risk mapping exercise is a comprehensive list of minerals and metals, which will then inform the strategic decision (Step 3) to select a mineral narrow scope on which the country might want to focus more attention.

4.1 Key Questions to Guide the Criticality Assessment

To conduct the stocktaking exercise, governments need to gather as much data and information as possible, from multiple sources, to get a deeper understanding of their mineral resources, their use and applications and global trends driving the demand for their resources. Information gathered should be disclosed to ensure transparency and accountability.

Based on the information gathered, governments should define a preliminary set of minerals that they may want to further investigate and monitor more closely.

Box 4. The importance of conducting the assessment despite possible data gaps

This section provides a comprehensive checklist of questions. While the exercise may seem complex and time consuming, the objective is to gather as much information as possible on various aspects of mining activities, across the life cycle of mining projects to be able to conduct an informed risk assessment.

We acknowledge, however, that data and information may not always be available, up to date, or complete. Also, some countries may not have systems in place to collect and process the information gathered or may not have historical data in a format that can be easily used or made available. Other countries may have smaller or nascent mining sectors and, therefore, may not have sufficient historical data to inform longer-term policies. In that case, we encourage countries to collect the basic information they may have and work toward improving their database, to ensure they can improve their analysis in the future.

Despite these challenges, governments should nonetheless attempt to conduct the stocktaking exercise to the best of their ability and improve on the assessment as data gaps are filled.

This section is organized into five subcategories:

- **Geological considerations**: Identifying the sources and geographical location of mineral production, notably by mapping the geological ore bodies and occurrences for major and minor minerals, in terms of resources, reserves, and production at the domestic level and assessing global supplies and potentials.
- **Economic, market, and fiscal considerations**: Assessing actual and forecasted industrial needs, by mineral, by sector and by application.[7] The analysis should take a holistic approach across the value chain and supply chain, to identify potential bottlenecks and weaknesses at all levels. It should also consider how demand can affect by- and co-products differently (see Bellois & Ramdoo, 2023), and whether the current fiscal regime is fit for purpose.
- **Social and environmental considerations**: Assessing the impacts of current (and future) mining activities on the social fabric and on the environment. These should inform the subsequent question of what policies to prioritize based on the strategic mineral list.
- **Geopolitical considerations**: With a focus on global trade tensions, identifying pinch points in the global supply chains and other countries' critical minerals assessments and de-risking strategies.
- **Governance, legal and regulatory issues**: Assessing national policy frameworks and instruments that may impact mineral production and trade, global standards (such as responsible sourcing obligations), industry standards and requirements (such as environmental, social, and governance [ESG] reporting requirements), that may have an impact on demand and supply of minerals and on specific countries/ regions.

[7] This should include current and estimated future domestic and global demand; potential changes in demand due to changes in technologies, substitutions, or availability of new sources of supplies; potential changes in domestic or global supply; key market considerations, such as price volatility, levels of investments, government incentives, and trade restrictions.

Each subsection highlights the main questions that are relevant to the stocktaking and the risk-mapping exercise. Appendices C–G, organized according the five subsections mentioned above, provide a comprehensive checklist of information and data that are relevant to inform the exercise. The appendices also provide a set of performance indicators that can be used to measure risks that may impact the design and implementation of the strategic policies that governments may consider adopting.

4.1.1 Geological Considerations

Information gathered under this section allows governments to determine the importance of their mining potential by type of minerals and, hence, gauge the potential strength in the upstream part of the mineral value chain. It is important to make sure the potential for co-production and by-production is well documented, as a significant number of minerals and metals needed for the energy transition and digital technologies are minor elements whose production is dependent on the extraction of major metals.

Box 5. What minerals are available in my country?

i This question is aimed at conducting a detailed assessment of domestic mineral production capacity. Geological consideration informs how deposits can be exploited, which in turn allows for a better understanding of the potential future risks.

Information gathered should include detailed geological information on mineral occurrences, estimated resources and reserves with details about their subnational locations. Geological data should be classified by types of minerals.

Geological information should include the quality of ore bodies, associated elements in the ore bodies (whether in commercially exploitable quantity or not), and minerals associated with problematic elements (such as radioactive elements).

Data should be sourced from existing national geological surveys’ library, exploration, and mining companies, as well as planned state-funded information acquisitions at the regional level.

Governments should map out the location of resources that may overlap with biodiversity hotspots and conservation areas, water bodies, or land of Indigenous Peoples etc.

Appendix C provides a checklist of information that is needed to get a good understanding of the mining potential of a country and provides a set of indicators to conduct the assessments.

Possible risk factors to consider:

- depletion time of reserves
- risk of temporary scarcity, due to technical feasibility, political issues (sanctions), or geopolitical issues
- levels of risk in country, including political risks, risks of corruption, and risk of conflict that may impact decisions to invest

4.1.2 Production, Macroeconomic, and Market Considerations

In addition to maintaining updated geological knowledge, it is necessary to keep track of actual and historical production data by value and volume. Data on mining operations and mining projects, disaggregated by project advancement stage,[8] should also be gathered. This will allow governments to have a deeper understanding of the country’s position (current and future) in the upstream mineral value chain, compared to other producing countries, and to assess the associated risks. The analysis is needed to develop strategic plans on the use of mineral resources domestically and determine what is needed to develop downstream capabilities.

Box 6. How much do I produce and how will my production capacity evolve?

i

Information gathered on domestic production will help identify a preliminary list of minerals for further investigation. Information should cover all size of mining activities and all minerals identified in the previous section. It should consider all minerals associated together as co-products and by-products. It should also include minerals that can be recovered from waste and tailings storage facilities as well as from scraps and recycling. The analysis should be done in comparison to other global producers.

Information should include mineral production by size of mining activities and by types of commodities (in volume and in value). Governments need to estimate the importance of each mineral produced in comparison to total mining in-country and globally.

All potential sources of supply should be considered, including production from artisanal mining, from small-scale and mid-sized mining activities, from reprocessing of waste rocks or tailings, and from recycling of end-product wastes.

Measuring the importance of the mining production in the national economy and on the global scene is key to informing national development programs and diversification strategies. Particular attention should be given to minerals that contribute significantly to the national income (in terms of fiscal or export revenues) and governments may want to further investigate how strategic they may be for the country.

Appendix D provides more details on types of information that governments may want to collect to inform their policy documents and includes a set of indicators to conduct the assessments.

Possible risk factors to consider:

- price volatility
- regulatory bottlenecks that can impact the permitting process
- challenges in accessing investment to finance mining projects
- (non-transparent or absence of) pricing of minerals (including for minor elements)
- risks of substitutability
- technological change
- accessibility to and from mine site
- risks associated with informality or illegal mining
- stockpiling strategies being developed by import-dependent countries

8 Mining project advancement stage include exploration, feasibility, development, construction, and production phases, as well as closure.

Box 7. How important is the mining sector to my country?

Information gathered about the domestic mining sector will help provide a macroeconomic overview of how the mining sector contributes to the income of the nation, either through fiscal revenues, export revenues, investments, and/or employment.

Information should include the following:

Economic contribution of the mining sector to national income, investment, fiscal revenues, export revenues, and employment. This will help governments assess how dependent their country is on the mining industry and take the necessary measures to manage associated risks and vulnerabilities.

Data on **domestic and foreign investment** flows into exploration and production and across mining value chains (and associated supply chains for specific minerals) are important for assessing the strategic interests of global mining actors. Data should include private investment, public investments (including through state-owned entities) and state-backed investments.

Data on public resources invested in research and development (R&D) and innovation, which are key to supply chain development. To stimulate private sector investment in innovation, governments need to strengthen intellectual property rights regulations and institutional capacity, notably to protect innovation and industrial designs.

Detailed information on producing companies (as well as refining and smelting companies), whether domestic or foreign, is necessary to assess in-country capacity to beneficiate mineral production. Historical data on exploration budgets, the number and types of companies involved, and the types of transactions conducted (such as mergers and acquisitions or joint ventures, etc.) must be tracked and analyzed. Importantly, the ownership structures of foreign mining companies should be understood because they may have geopolitical implications.

Detailed information on trade flows and trade measures in place is essential for evaluating the importance of specific markets, identifying key partners, and assessing the level of dependency (import and export), which may be a source of risk and vulnerability, both for the producing country and the importing partner country. The existence of trade measures on specific minerals also signals some level of strategic importance and these should be examined in detail, particularly in terms of their implications on the domestic economy or the foreign market.

Appendix D provides more details on the types of information that governments may want to collect to inform their policy documents and includes a set of indicators to conduct the assessments.

Risk factors to consider:

- degree of mineral trade dependency (imports and exports)
- impact of trade barriers on country's competitiveness
- impact of trade barriers on fiscal revenues
- impact of trade barriers on production costs
- impact of third countries' trade barriers on domestic value chains
- investment risks related to price volatility, fiscal policies, trade barriers

4.1.3 Industrial Development Considerations

Data gathered in this section provides the basis to assess existing and potential industrial capabilities based on domestic mineral production when available, as well as an indication of the country's reliance on external sourcing when there is a gap in domestic supply.

This analysis allows governments to properly design risk mitigation and management policies and address domestic and external risks in a timely manner. For instance, countries that are highly dependent on mining face higher risks if there are significant changes in global demand, in technologies requiring the minerals they export, or in any other aspect affecting investment decisions.

Gathering a holistic picture of the mining landscape from an industrial perspective is relevant for strategic thinking about ownership of key mining assets. Even if countries do not yet have significant industrial production capabilities, based on their endowments, it is important nonetheless to assess potential future use against mineral production and accessibility.

Box 8. Which minerals are essential to my country's strategic objectives?

i Information gathered in this section is crucial for assessing current industrial capacities and the extent and degree of self-sufficiency (or of reliance on external sources), which is a necessary preliminary analysis when defining criticality.

Information should include industrial policies and roadmaps, with a focus on how the mineral sector will contribute to industrial activities. These plans should include priority sectors that have been identified that will require domestic mining production feedstocks and the level of domestic demand (current and forecasted) anticipated for an agreed period.

Information should also include an assessment of the current domestic demand for minerals and metals needed to fulfill the needs of the current industrial sector. Consideration should be given to longer-term development plans, including longer-term industrial trajectories.

Data analysis should include existing downstream capabilities as well as future plans to scale up value-added industries for locally mined products.

Historical information about plans that may not have succeeded must be collected, and reasons for failures need to be examined. Any plans to build new facilities should be identified.

Appendix D provides more details on the types of information that governments may want to collect to inform their policy documents and includes a set of indicators to conduct the assessments.

Risks factor to consider:

- technological changes that may impact on mineral intensity or mineral needs
- geopolitical risks related to sourcing of inputs not produced domestically
- bottlenecks that may negatively affect investment plans and downstream industrial plans
- level of dependence on parts of the supply chains not present in the country

Recent years have highlighted vulnerabilities in mineral supply chains, resulting from several often interdependent factors. Geopolitical tensions over access to mineral feedstocks, pinch points in supply chains, and strategic needs have all contributed to the design, implementation, and financing of critical mineral strategies. Led initially by advanced economies, an increasing number of emerging economies that want to position themselves across various parts of global supply chains for energy and digital technologies have announced similar strategies. More recently, mineral-producing countries have joined the bandwagon.

Box 9. Is my domestic production sufficient to meet my industrial needs?

i

Information gathered about mineral production in relation to industrial needs will help inform a preliminary identification of which minerals are available domestically and therefore could be considered as "strategic" for various reasons and which ones are not sufficiently available (or not available at all), and therefore could be considered as "critical."

Information should include the analysis of mineral feedstocks produced locally and needed by domestic industries. The data should assess the production and trade deficits by mineral. For minerals available locally, it is important to assess whether those minerals are likely to be sufficiently available over time both for domestic needs and to meet international demand.

As countries seek to build their capabilities for local value chains, they may need to import mineral feedstocks. Governments, therefore, need to have a good understanding of their levels of dependency on minerals and metals that are not available locally (or available in insufficient amounts) to be able to assess, anticipate and manage any risks associated with the security of supply. Methodologies used by the EU (European Commission, 2023b), the United States (Nassar & Fortier, 2021), the United Kingdom (BGS, 2022), Australia (Australian Government, 2023), or Canada (Natural Resources Canada, 2022) provide good examples for conducting such assessments.

Appendix D provides more details on types of information that governments may want to collect to inform their policy documents and includes a set of indicators to conduct the assessments.

Risk factors to consider:

- level of dependency on imports
- level of concentration of minerals production not produced in country
- geopolitical risks associated with the supply of minerals not produced in country
- regulatory frameworks in third countries
- conflicts such as those linked to war or political stability

4.1.4 Fiscal Considerations

In the context of the surging demand for critical minerals, the following questions will help examine whether—and to what extent—current fiscal approaches and policies are fit for purpose to ensure that mineral-rich countries collect an appropriate share of the financial benefits arising from the extraction of their critical minerals. The information can also inform whether (or not) and what types of fiscal policies and incentives can be implemented to support the development of midstream and downstream supply chains.

Box 10. Are my fiscal policies fit for purpose for appropriate collection of financial benefits and incentivization of local industrial development?

i Information gathered in this section should help assess whether existing set of fiscal instruments and administrative practices are fit for purpose when considering critical minerals extraction and beneficiation.

While the fundamentals of fiscal policies are likely to remain largely the same, governments may want to reflect on whether the rising demand for critical minerals requires a recalibration of existing financial benefit-sharing systems and instruments, and if so, what types of instruments would be relevant in that context.

Governments are recommended to examine current practices regarding pricing and valuation, with regard to specific minerals or to mine wastes and tailings that may contain commercially exploitable concentrations of critical minerals. Current fiscal regimes will need to be assessed on that basis.

To optimize financial benefits that may be derived from higher demand for some critical minerals, governments may want to give higher consideration to issues such as ringfencing, tax incentives, state participation, ownership of mining rights by large end users in the value chain, and administrative capacity for tax administration, amongst others.

To support the development of local industrial capabilities and foster R&D and innovation, governments may want to assess what types of incentives would be required to stimulate investments in supply chains. Incentives could take the form of fiscal instruments or non-fiscal instruments, such as concessional access to finance for local firms, duty-free imports of inputs and equipment, or the creation of special economic zones.

Appendix D provides more details on types of information that governments may want to collect to inform their policy documents and includes a set of indicators to conduct the assessments.

Risk factors to consider:

- undervalued minerals production affects government revenues
- underpriced or lack of transparency in pricing mechanisms affects government revenues
- risks of tax base erosion and profit shifting
- missed opportunity to leverage the benefits of rising demand
- corruption
- market distortions resulting from incentives

4.1.5 Social and Environmental Considerations

Companies that fail to consult and engage with mining-affected communities will face a backlash that can hold back mining projects. Acquiring and maintaining the so-called "social licence to operate" should, therefore, be a key aspect of criticality assessments and of mineral strategy to secure mineral production.

In several countries, the mining sector already faces growing opposition from local and international communities. These are linked to various environmental challenges and social issues, such as human rights abuses and gender-based violence. Expansion of mining activities can exacerbate existing or increase potential conflicts over access to water and land use with local communities. There are real concerns that measures to fast-track mineral development projects may be conducted at the expense of appropriate consultations, further antagonizing relationships with local communities.

Box 11. What key social issues do I need to consider to constructively engage with mining-affected communities and ensure benefits for society at large?

i The information gathered in this section provides an overview of the social landscape and issues relevant to securing the mining social licence to operate. It seeks to understand whether there is a platform to consult and consider local communities. This is necessary to manage the relationship with Indigenous communities, ensure local community development, and build resilience.

Information should include detailed and historical databases and geographical maps of mining projects that coexist with local communities. Particular attention should be paid to potential overlaps between mining projects and community-owned land, including Indigenous and ancestral land, where applicable.

To the extent possible, governments should ensure they maintain a repository of voluntary actions and community development agreement plans as well as projects executed under those plans to ensure continuous knowledge management. They must ensure that they keep track of conflicts with communities over time, as ownership of companies changes hands.

When relevant, implementation of local content policies, such as requirements and opportunities for local employment, skills development, business opportunities, and shared infrastructure, need to be monitored and assessed (disaggregated by gender where possible). This would allow governments to better plan and update their local content policies, assess the extent to which communities' demands align with companies' policies, and compare training opportunities and quality across different locations.

Appendix E provides more details on the types of information that governments may want to collect to inform their policy documents and includes a set of indicators for conducting the assessments.

Risks factors to consider:

- historical tensions and conflicts with local communities in direct relation or not with mining activities
- tensions with communities over land rights and traditional lands
- tensions with communities over the perceived inequitable split of revenues by the central government
- tensions with communities over lack of local employment opportunities in the mining operation
- human rights abuses and gender-based violence

Likewise, should there be significant environmental risks, producing countries will not be able to develop or expand mining projects without (or against) the consent of their population, particularly of communities that live close to mine sites.

Mining is the industrial sector that generates the largest volume of wastes. It is a highly energy- and water-intensive activity, usually associated with negative externalities, such as deforestation and water, air, and noise pollution. As any impact on the environment affects local communities, environmental conflicts can exacerbate unresolved tensions that will result in social conflicts, posing risks to mining projects.

Box 12. What environmental issues are critical for the sustainability of my mining sector?

i It is critical to make sure that sufficient and appropriate safeguards are in place to avoid creating or exacerbating environmental challenges. Information gathered in this section will help governments monitor the sustainability of the mining sector from an environmental perspective.

Assessing the impacts of mining activities on the environment, as well as the interconnected effect of climate change on mining activities, would enable governments to put in place the necessary safeguards to address the environmental impacts of mining activities. Data gathered should include historical accounts of the impacts of mining activities on the environment, water quality, availability, use and access to water rights, the impact of mining on air quality, and potential overlaps between mining activities and nature and biodiversity, amongst others.

It is necessary to assess the extent to which climate change that induces new environmental conditions (e.g., more frequent and more intense climatic events), is expected to impact mining operations and surrounding communities. This makes it possible to implement appropriate mitigation measures to build resilient mining communities, operations, and supply chains.

Appendix E provides more details on types of information that governments may want to collect to inform their policy documents and includes a set of indicators to conduct the assessments.

Risk factors to consider:

- externalities such as water, soil, and air pollution
- tensions with other stakeholders over water rights
- nature and biodiversity sensitivity
- environmental risks associated with technologies used to process ore grades.[9]

[9] For example, the high-pressure acid leach technology used in Indonesia, although necessary from an economic standpoint to process low-grade laterite ore, might appear as an environmental ticking bomb that could ultimately disrupt nickel supply.

4.1.6 Geopolitical Considerations

Analysis of the information regarding the types of policies and strategies being deployed elsewhere (e.g., industrial policies to develop local capabilities, trade policies to secure access to minerals, and political alliances among groups of third partners) will provide a better understanding of how they can or will have impacts on producing countries.

Box 13. Which minerals are considered critical by my main trading partners, and what are the key industrial uses in those markets?

i Information on criteria used by destination countries to define criticality will provide a good understanding of challenges linked to different aspects of supply chains and the associated geostrategic implications.

Global policies will significantly impact demand and supply of critical minerals and will reshuffle supply chains. Governments, therefore, need to assess the implications of global strategies on critical minerals for the mining sector at the national level.

Information gathered must cover the following issues:

Understanding criticality as defined by main trading partners, assessing the mineral scope associated with those definitions, the industries and technologies for which they are relevant, and measures taken by partner countries to manage and mitigate risks. This also includes specific policies from destination countries to limit sourcing of critical minerals from a unique supplying country.[10]

The role of the country in global supply chains, i.e., what is the share of the country's exports of critical minerals to partner countries that have critical minerals strategies and in global demand, more generally. Governments also need to get data on other sources of supplies to assess their bargaining power.

Understanding global needs, i.e., having a good understanding of the major technologies that require such critical minerals is essential. It can guide policies to find alternative markets to avoid asset stranding in case measures taken by destination countries to address risks associated with criticality lead to mineral substitution in technologies.

Appendix F provides more details on the types of information that governments may want to collect to inform their policy documents and includes a set of indicators to conduct the assessments.

Risk factors to consider:

- pressure from international partners to sign bilateral agreements and memoranda of understandings (MOUs), in particular, if countries do not have a clear domestic strategy in place
- de-risking policies in partner countries to mitigate risks may have unintended consequences for producing countries
- search for alternative sources can affect producing countries
- orientations in R&D to de-risk supply chain vulnerabilities may accelerate technological changes, with different mineral feedstock needs

[10] The EU Critical Raw Material Act (CRMA) last disclosed in 2023 sets benchmarks to diversify EU supply by 2030: no more than 65% of the Union's annual consumption of each strategic raw material at any relevant stage of processing should be sourced from a single third country.

4.1.7 Governance, Legal, and Regulatory Considerations

As countries design or review their policies to consider the rising demand for minerals and metals, it is important to have a good overview of the status of current regulatory frameworks and how they might evolve over time. Governments need to ensure coherence and consistency, in particular with regard to future development plans. Domestic regulations give important signals to foreign partners (investors, trading partners, etc.) and therefore must be in line with national development ambitions while remaining consistent with their international commitments.

Most countries have legal obligations at the international level through agreements signed over the years with investors and/or with trading partners. As development ambitions evolve, domestic measures may not always be compatible with bilateral and multilateral agreements already in place. Governments may, therefore, have to design other types of measures (with similar effects) or engage their partners to avoid legal disputes.

Furthermore, there could also be several industry-to-industry agreements in place, such as offtakes or long-term supply contracts, or even deals such as infrastructure financed by external partners in exchange for natural resources. Through these deals, mining companies or governments may have already committed a large share of mineral production to international buyers or to trading partners. Governments should track and monitor these agreements and assess their implications, namely for the availability of mineral resources for domestic uses and for other issues, such as revenue collection.

Box 14. What policies, legislation, and regulations have an impact on my mining sector?

i This question is aimed at taking stock of policies and obligations at various levels—national, regional, and international.

Governments need to map out all existing domestic policies,[11] measures, and instruments that can impact the mining sector, covering the entire life cycle of the mine. Gaps must be identified so that plans to explore and produce minerals and to process or reprocess tailings are not held back by regulatory bottlenecks and that there is no trade-off regarding sustainable mining practices.

It is recommended that governments gather information regarding ESG policies and performance indicators from mining companies to ensure a level playing field in terms of responsible mining practices from all industrial actors, including state-owned companies, operating in their territories.

With regard to international agreements and partnerships, it is necessary to keep track of all bilateral and international agreements that could be relevant for critical minerals. These include, for example, trade and investment agreements, MOUs and strategic partnership agreements, and scientific and technical cooperation or infrastructure for resource deals. The impacts of those agreements for the mining sector and on national or regional development goals must be regularly assessed.

[11] Examples of policies include mining codes, environmental regulations, mining contracts, local content policies, beneficiation strategies, and regulations that already identify specific types of minerals for specific purposes.

Where possible, governments need to take stock of other types of agreements, such as long-term supply contracts and offtake agreements that mining companies may have signed with trading partners or with supply chain actors. The nature and time frame of these deals need to be understood as they may impact the ability of local industries to access critical minerals when required for domestic manufacturing industries.

Governments are advised to regularly assess the effectiveness of domestic regulatory measures and other forms of incentives aimed at supporting industrial development. Data will allow governments to adjust measures and dedicate financial resources to accompany the strategic sector. Developing countries may face financial constraints in supplying domestic industries. In that case, engaging with financial institutions is key.

Appendix G provides more details on the types of information that governments may want to collect to inform their policy documents and includes a set of indicators to conduct the assessments.

Risk factors to consider:

- Regulatory bottlenecks impact the ability to start mining operations.
- Pressure to mine more may have unintended negative consequences due to gaps in regulations.
- Trade and investment agreements limit the policy space of governments to meet development goals.
- Restrictive domestic trade and investment instruments affect global supply chains.
- Industry-to-industry agreements limit the ability of local industries to access critical minerals.

Governments need to make sure that regulatory frameworks are in line with good governance practices at the global level. Global frameworks exist to address corruption, human rights abuses, and transparency and accountability, among other aspects of the mining sector. At the same time, mining companies are also engaged in voluntary sustainability standards.

Box 15. What global governance frameworks are applicable to my mining sector?

i This question is aimed at understanding how global sustainability governance frameworks affect mining activities and whether global processes are owned and implemented at the national level.

Sustainability initiatives in the mining sector, including voluntary standards, play a key role in advancing good practices and in informing governments, consumers, and investors about how minerals are sourced. They are meant to be part of the solution to mitigate impacts on local communities, society, and the environment. The rise in demand for critical minerals is likely to lead to more mining activities. Governments need to actively promote and enable responsible mining practices in all sizes of mining operations to minimize the potential negative impacts and avoid unintended consequences for local communities and the environment associated with increased activities.

In countries where challenges associated with risks of conflicts exist, governments need to actively engage in global discussions related to conflict minerals, given that some critical minerals may be mined together with conflict minerals.

Appendix G provides more details on the types of information that governments may want to collect to inform their policy documents and includes a set of indicators for conducting the assessments.

Risk factors to consider:

- local mining actors like artisanal and small-scale mining (ASM) excluded from supply chains
- the lack of coherence between discussions around conflict minerals and critical minerals
- lack of implementation of global frameworks because producing countries are not actively involved in global discussions.

Some critical minerals are mined in regions where governance challenges have been observed, such as regions prone to conflicts or human rights violations. For instance, tin, tantalum, and tungsten (3Ts) are considered as potential "conflict minerals" when they are mined from conflict-affected or high-risk areas (CAHRAs). The sourcing of the 3Ts is regulated by law at the global level by importing countries, industrial sectors, or stock markets if mined in CAHRAs (Organisation for Economic Co-operation and Development [OECD], 2016).

However, the 3Ts are also considered critical minerals by several countries, as Appendix H highlights. This raises the question of the extent to which criticality assessments consider risks related to conflict and what safeguards are in place to ensure that the heightened attention given to supplying more critical minerals (that are also conflict minerals) does not unintentionally fuel more conflicts in already-fragile jurisdictions.

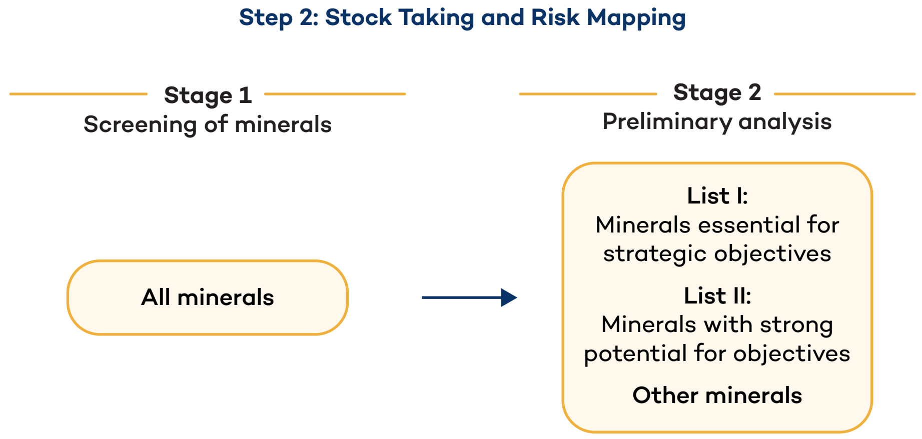
Governments need to make sure to monitor the evolution of conflict and critical minerals regulations concurrently, given that there does not seem to be a clear connection across those policy instruments.

In cases where critical minerals are mined as by-products of conflict minerals, producing countries must anticipate how responsible sourcing policies may evolve so they are able to take the necessary measures to address potential weaknesses in their mineral supply chains.

4.2 Summary of Outcome Expected From Step 2

Based on this stocktaking exercise, governments should outline a preliminary comprehensive list of the minerals and metals to be considered for further investigations. Strategic decisions, policies, and implementation measures can then be considered in the following Step 3.

FIGURE 2. A two-stage approach to knowing your resources and assessing their associated risks



Source: Authors, based on Viebahn et al., 2015.

5.0 Step 3: Strategic considerations

Once Steps 1 and 2 are completed, governments need to decide what types of policies, tools, and instruments are most suitable for attaining their objectives. This section highlights three complementary strategic orientations that governments need to consider **before** designing the critical minerals policies and associated lists.

5.1 National Priorities

Based on the assessments made in Step 2, governments must clarify the role that their mining sector plays, or is expected to play, in national development plans. Minerals that have been identified from Step 2 must be classified according to a nationally agreed taxonomy, based on domestic needs, industrial trajectories, and global demands.

To guide policy implementation and engagement with industry stakeholders and global partners, governments need to outline national priorities clearly. The definition of these priorities should be informed by other national policies and by consultations with national stakeholders, such as other government departments, industry actors, and representatives of local communities. National policies should also consider regional initiatives and commitments made at the global level to support resilient supply chains, notably for the energy and digital transitions.

Key drivers of a critical minerals strategy

- beneficiation and value addition in the mining sector
- development of domestic and regional critical minerals supply chains
- securing higher revenues from critical minerals
- strategic positioning as suppliers of choice
- strategic positioning as investors of choice

- ensuring a more socially responsible and inclusive mining sector
- application of circularity principles, including recycling, to produce critical minerals from existing sources
- partnerships with supply chain actors (such as original equipment manufacturers; specific technology companies etc.)
- managing geopolitical tensions while balancing response to global demands and growing risks of trade wars

Potential scope of a critical mineral strategy

- new regulatory instruments specifically focused on those minerals (including contracts and environmental laws)
- different forms of state participation, such as joint ventures with mining companies, or creation of state-owned companies
- revision of fiscal policies and other financial benefit-sharing mechanisms
- provision of incentives to local supply chain industries
- domestic regulations and trade measures to limit exports of unprocessed minerals
- greater role for the artisanal and small-scale mining sector in critical minerals
- reprocessing of tailings and mining wastes
- national joint ventures, bilateral agreements with other producing and value-chain countries, partnerships with industry players, and regional cooperation

Potential risks to consider

- lack of geological data
- insufficient industrial capabilities and related skills
- lack of access to finance to stimulate and advance industrial development
- insufficient access to infrastructure and high cost of energy
- price volatility and market uncertainty for some metals, especially minor ones
- change in technologies that may influence demand for some critical minerals
- lack of applicable legal and regulatory framework, alongside environmental and social concerns
- social tensions and lack of trust from local communities
- lack of a coherent vision and objectives, information asymmetry, and capacity constraints

5.2 Regional Initiatives

Alongside their national priority orientations, governments need to work collaboratively with their neighbours to build on each other's strengths and comparative advantages. In many cases, domestic markets are small and nascent, and for industrial activities to become competitive and thrive, economies of scale and larger markets need to be secured. Regional initiatives must, therefore, be encouraged and supported. They will also act as a cooperation tool to mitigate regional concurrence and a race to the bottom.

Such regional initiatives, if harnessed, can support the development of resilient regional value and supply chains to feed into priority sectors, such as e-mobility, renewable energy solutions, or other electronic industries that are significant consumers of critical minerals.

Some elements to consider when designing regional initiatives:

- the importance of having coherent discussions on national critical minerals plans and lists
- identification of priority regional value and supply chains, with clear roles defined for each regional partner
- fiscal regime harmonization to avoid a race to the bottom
- coordination and knowledge sharing across countries
- regional investment mechanisms to facilitate investment across countries
- trade agreements, with rules of origin that facilitate supply chain development
- regional industrial policies, where standards are harmonized and technical barriers to trade eliminated
- trade facilitation protocols that have removed cross-border trade challenges influencing movement of goods and services across countries
- coordinated shared regional infrastructure to facilitate cross-border transportation

Bilateral initiatives across neighbouring countries are also important levers. An interesting example is Zambia and the Democratic Republic of Congo (DRC), who signed an agreement in 2022 to set up a special economic zone for the joint development of electric battery manufacturing capacity, notably using both countries' mineral wealth. The DRC is the world's largest cobalt producer, Zambia is also a producer, and both countries have copper reserves. In addition to cobalt, lithium, nickel, and manganese are also required for the production of basic batteries. While the DRC has these resources, they are currently not being mined, at least not at significant levels.

Discussions are ongoing with other regional partners, such as Gabon, Madagascar, and Zimbabwe. A recent study by Bloomberg NEF (2021) estimated that building a battery precursor manufacturing plant in the DRC could cost only a third of an equivalent plant in China or the United States. Compared to Poland, for example, the cost is just under two-thirds. Operating costs are similar and, as they are mostly driven by commodity prices (85%), integrated operations that have access to cobalt at cost would be the most competitive. Should the operation need to buy on the spot market, operating costs will be affected by labour costs and are expected to be higher than in Poland, but still cheaper than China and the United States (BloombergNEF, 2021).

5.3 Global Responsibilities

While producing countries have a duty to optimize the benefits from their mineral resources, including by adding more value at the national and regional levels, they also play a key role in supplying global markets. In recent months, several destination countries have entered negotiations to sign bilateral agreements and MOUs to secure access to critical minerals.

Producing countries need to ensure that the terms of these agreements and MOUs are fair and that benefits are mutually shared.

As countries commit to achieving net-zero emissions and digital technologies become more prominent, the demand for critical minerals and metals will surge. Midstream and downstream industrial sectors and the countries that host them are particularly concerned around supply shortages and/or disruptions. These challenges may affect the competitiveness of industries and plans to build larger industrial capacities in the cutting-edge technologies needed to embrace the energy and digital transition.

Given the complexity of global supply chains, no countries will be able on its own to provide every technological solution for the energy transition and attendant digital technologies. In that regard, global partnerships are crucial. Countries thus need to have clear objectives defined regarding the scope of global partnerships to ensure they are able to position themselves in global supply chains as suppliers of choice while benefiting fairly from the critical mineral demand windfall. This would help buyers diversify their sources of supply away from potential chokepoints, and thus address political risks associated with market over-concentration.

Furthermore, there is a strong case to be made to attract investors to new industrial locations, closer to critical minerals production centres and stimulate the development of value-added activities to expand options. Having other industrial hubs for key parts of supply chains is a de-risking strategy, for both producing and destination countries.

Commitments to lower greenhouse gas emissions also require that developing countries produce their own energy transition solutions. Many countries need to secure access to basic energy and transportation, and, as their population and economies grow, they will need to substantially scale up their energy production. Building low-greenhouse gas-emission energy capabilities is key to securing energy access. Being part of global supply chains is part of the learning curve to develop industrial capabilities domestically or at the regional level.

6.0 Step 4: Review

Understanding criticality → Taking stock and risk mapping → Making strategic decision → **Review process**

Designing a policy is not an end in itself. It must be administered and enforced, and progress must be measured against realistic benchmarks, preferably in the form of goals to be achieved. In the case of critical minerals, risks associated with criticality are a factor of time, which may impact the mineral scope attached with the policy. The objective of the review process is to evaluate whether the initial assessment is still valid after a period of time and whether the administrative and enforcement tools efficiently delivered on the stated objectives. The exercise allows governments to revise the strategy to reflect new realities and changes in circumstances and adjust the tools in place (critical minerals strategy or critical minerals list) to meet the overall objectives in a changing landscape.

Key elements of the review process are

- clear objectives outlined when designing the critical and/or strategic minerals policy
- measurable targets agreed against the policy objectives that can be assessed on an annual basis
- a list of minerals considered as “critical” and or “strategic,” with indicators and benchmarks that allow periodic reviews
- strong systems for collecting data on various elements that inform the policy design and the list of critical and/ or strategic minerals
- a multistakeholder committee in place, with a mandate for a specific period of time, tasked to review the list against the goals that governments have identified
- a time frame set to revisit the policy objectives and the targets, with the aim of making recommendations to adjust the policy objectives and the mineral scope accordingly.

Common reporting frameworks allow governments to

- gather and aggregate data on various aspects of the mining value chain and on the regulatory, geological, geopolitical, economic, social, and environmental considerations
- obtain a holistic picture of the sector's progress toward building resilient supply chains
- design realistic critical minerals policies and strengthen domestic capabilities, skills, and technological knowledge to achieve mid- to longer-term development objectives.

7.0 Next Steps

Once the four steps are completed, governments will have identified the minerals that are essential for their country's strategic objectives. The next step is to design **a critical minerals strategy accompanied by a roadmap** and related policy instruments, incentives, and mechanisms to leverage the potential opportunities from their critical minerals' endowment, while properly and effectively managing risks identified in the assessment conducted under Steps 1 and 2.

The critical minerals strategy and the roadmap need to provide the strategic direction, priorities, and timelines with regard to a set of well-defined objectives. The critical minerals strategy and the roadmap should include the following key elements:

- **clear goals and objectives**: The roadmap should articulate the overarching goals and objectives of governments regarding their development pathways. Goals must be specific, measurable, achievable, relevant, and time bound.
- **identified short-, medium-, and long-term priorities**: The roadmap must clearly outline the key initiatives and activities that need to be undertaken to achieve the stated goals. These initiatives should be prioritized based on factors such as mineral resource availability, strategic importance for industrial development, and market demand, amongst others. Timelines must also be identified.
- **risks and constraints**: Governments must identify any constraints that may impact the implementation of the roadmap. This could include domestic factors such as industrial capabilities, technical skills, environmental and social acceptance, financial resource limitations, regulatory requirements, or external risks, such as potential geopolitical shifts and changes, as well as differing or potentially contentious critical mineral policies of partners.
- **availability of resources**: The roadmap should provide a clear indication of financial, human, and technical resources required to implement the strategy.
- **geological data transparency**: National geological surveys should collect and publish more systematic geological information from exploration and from producing companies.
- **flexibility and adaptability**: While the roadmap provides the milestones to implement the critical minerals strategy, it should also allow for flexibility and adaptability, as

circumstances may change, and new opportunities or challenges may arise, requiring adjustments to be made.

- **implementation and measuring performance**: The roadmap should include key performance indicators to measure the progress, successes, and failures of the policies outlined. Tracking performance and evaluating the effectiveness of policies is an important element for the periodic review of the list of critical minerals and of the associated strategy overtime.
- Finally, countries should make a plan to **review the assessments on a regular basis** to ensure they remain relevant over time.

8.0 Conclusion

The assessment of what makes mineral and metals critical is a multifaceted process that requires comprehensive understanding, strategic planning, and proactive engagement. The spotlight on critical minerals is driven by the significant risks associated with potential supply bottlenecks or disruptions, compelling key industries and countries to minimize these risks through various measures, such as diversifying supply sources and investing in research and development for substitutes.

The importance of this assessment cannot be overstated, as critical minerals are essential components of numerous industries, including those driving the energy and digital transitions. As such, the assessment process outlined in this guiding document provides a valuable framework for stakeholders to assess the criticality of minerals and metals within national, regional, and global contexts. By addressing geological, production, economic, fiscal, market, social, environmental, geopolitical, governance, legal, and regulatory factors, stakeholders can gain insights into the risks and opportunities associated with critical minerals.

However, while the current focus on de-risking and diversifying supply chains presents a window of opportunity for producing countries, it is essential to recognize that this window may be short-lived. As solutions are developed to mitigate supply risks, the spotlight on critical minerals may fade, highlighting the importance for producing countries to act swiftly and strategically. Failure to capitalize on this opportunity may result in missed opportunities for attracting investors, accessing finance, and fostering industrial growth.

Producing countries must, therefore, seize the moment to position themselves as suppliers of choice across the value chain and adopt a proactive approach to maximize the benefits of their mineral resources. This involves not only scaling up the production of minerals but also participating in joint ventures, investing in complementary assets, and establishing partnerships to enhance their competitiveness in the global market. With a sound understanding of the dynamics of their mining sector and with enhanced efforts to innovate, collaborate, and engage in strategic investments, producing countries can strengthen their position as key players in the critical minerals market and contribute to sustainable economic development at both national and global levels.

References

Achzet B., & Helbig, C. (2013). How to evaluate raw material supply risks—An overview. *Resources Policy, 38*(4), 435–447. https://opus.bibliothek.uni-augsburg.de/opus4/frontdoor/deliver/index/docId/44156/file/Postprint_AchzetHelbig2013-SupplyRisks+(1).pdf

Amatucci, M. (2015). The world that chose the machine: An evolutionary view of the technological race in the history of the automobile. *International Journal of Automotive Technology and Management, 15*(1). https://www.researchgate.net/publication/272086064_The_world_that_chose_the_machine_an_evolutionary_view_of_the_technological_race_in_the_history_of_the_automobile

Australian Government. (2023). *Critical minerals strategy 2023–2030.* Department of Industry, Science and Resources. https://www.industry.gov.au/sites/default/files/2023-06/critical-minerals-strategy-2023-2030.pdf

Bellois, G., & Ramdoo, I. (2023). *Searching for critical minerals? How metals are produced and associated together.* Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development. https://www.iisd.org/publications/report/searching-critical-minerals-how-metals-produced-together

Boer L., Pescatori, A., & Stuermer, M. (2021). *Energy transition metals* (IMF working paper WP/21/243. International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2021/10/12/Energy-Transition-Metals-465899

BloombergNEF. (2021, November). *The cost of producing battery precursors in the DRC.* https://assets.bbhub.io/professional/sites/24/BNEF-The-Cost-of-Producing-Battery-Precursors-in-the-DRC_FINAL.pdf

BloombergNEF. (2023). *Transition metals become $10 trillion opportunity as demand rises and supply continues to lag.* https://assets.bbhub.io/professional/sites/24/BNEF-The-Cost-of-Producing-Battery-Precursors-in-the-DRC_FINAL.pdf

British Geological Survey. (2022). *UK criticality assessment of technology critical minerals and metals.* https://www.bgs.ac.uk/download/uk-criticality-assessment-of-technology-critical-minerals-and-metals/

British Geological Survey. (2024). *Critical minerals – teaching resources.* https://www.bgs.ac.uk/discovering-geology/maps-and-resources/critical-raw-materials-resources/

Coulomb, R., Dietz, S., Godunova, M., & Nielsen, T. B. (2015). *Critical minerals today and in 2030: An analysis of OECD countries.* ESRC Centre for Climate Change Economics and Policy, London School of Economics and Political Science. https://www.lse.ac.uk/granthaminstitute/publication/critical-minerals-today-and-in-2030-an-analysis-of-oecd-countries/

Department of Industry, Science and Resources. (2023). *Updates to Australia's critical minerals list.* Australian Government. https://www.industry.gov.au/news/updates-australias-critical-minerals-list

Dewulf, J., Blengini, G. A., Pennington, D., Nuss, P., & Nassar, N. T. (2016). Criticality on the international scene. Quo vadis? *Resources Policy 50,* 169–176. https://www.researchgate.net/publication/309134740_Criticality_on_the_international_scene_Quo_vadis

El Yaakoubi, A. (2024, January 10). *Saudi Arabia earmarks $182 mln for minerals exploration in mining push*. Reuters. https://www.reuters.com/markets/commodities/saudi-arabia-allocates-182-mln-mineral-exploration-incentives-mining-minister-2024-01-10/

European Commission. (2017). *Methodology for establishing the EU list of critical raw materials: Guidelines*. https://op.europa.eu/en/publication-detail/-/publication/2d43b7e2-66ac-11e7-b2f2-01aa75ed71a1

European Commission. (2023a). *Study on the critical raw materials for the EU 2023: Final report*. https://single-market-economy.ec.europa.eu/publications/study-critical-raw-materials-eu-2023-final-report_en

European Commission. (2023b). *Proposal for a regulation of the European Parliament and of the Council establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020. COM (2023) 160 Final*. https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023PC0160

European Council. (2024). *An EU critical raw materials act for the future of EU supply chains*. https://www.consilium.europa.eu/en/infographics/critical-raw-materials/

Government of Canada. (2022a). *Canada's critical minerals strategy*. https://www.canada.ca/en/campaign/critical-minerals-in-canada/canadian-critical-minerals-strategy.html

Government of Canada. (2022b). *Canada's critical minerals strategy: Discussion paper*. https://www.canada.ca/content/dam/nrcan-rncan/documents/critical-minerals-discussion-paper-eng-2.pdf

Hayes M. S., & McCullough, E. A. (2018). Critical minerals: A review of elemental trends in comprehensive criticality studies. *Resources Policy, 59*. https://doi.org/10.1016/j.resourpol.2018.06.015

Heffron, R. J. (2020). The role of justice in developing critical minerals. *The Extractive Industries and Society 7*(3). https://doi.org/10.1016/j.exis.2020.06.018

Helbig C., Wietschel, L., Thorenz, A., & Tuma, A. (2006). How to evaluate raw material vulnerability – An overview. *Resources Policy, 48*, 13–24. https://doi.org/10.1016/j.resourpol.2016.02.003

Hilson, G. (forthcoming). *Defining criticality of mineral resources: A review of literature*. Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development

Hönke, J., & Skende, L. (2022). *Cobalt as 'conflict mineral'? On the opportunities and limits of new supply chain laws*. InfraGlob. https://infraglob.eu/2022/12/20/cobalt-as-conflict-mineral-on-the-opportunities-and-limits-of-new-supply-chain-laws/

Hund, K., La Porta, D., Fabregas, T. P., Laing, T., & Drexhage, J. (2019). *Minerals for climate action: The mineral intensity of the clean energy transition*. World Bank. https://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf

Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development. (forthcoming). *Critical minerals: National priorities, regional initiatives and global responsibilities. Summary outcomes of national consultations conducted by the IGF Secretariat in October and November 2023.*

International Energy Agency. (2021). *The role of critical minerals in clean energy transitions.* https://www.iea.org/topics/critical-minerals

International Energy Agency. (2022). *Critical minerals list.* https://www.iea.org/policies/16070-critical-minerals-list

International Energy Agency. (2023a). *Critical mineral list in Korea.* https://www.iea.org/policies/17943-critical-mineral-list-in-korea

International Energy Agency. (2023b). *The role of critical minerals in clean energy transitions – Analysis*. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf

International Round Table on Materials Criticality. (2020). *Material criticality: An overview for decision-makers* [Brochure]. https://irtc.info/2020/05/15/material-criticality-an-overview-for-decision-makers/

Kowalski, P. and C. Legendre (2023). *Raw materials critical for the green transition: Production, international trade and export restrictions*, OECD Trade Policy Papers, No. 269, OECD Publishing. https://doi.org/10.1787/c6bb598b-en.

Lapuekou, C. (2023, November 10). Laos sets targets in 5-year energy, mines development plan. *Laotian Times*. https://laotiantimes.com/2023/11/10/laos-sets-targets-in-5-year-energy-mines-development-plan/

Moerenhout, T., Glynn J., & Lee L. 2023. *Critical mineral constraints and energy system models*. Columbia University Center on Global Energy Policy. https://www.energypolicy.columbia.edu/publications/critical-mineral-supply-constraints-and-their-impact-on-energy-system-models/

McCullough E., & Nassar N. T. (2017). Assessment of critical minerals: updated application of an early warning screening methodology. *Mineral Economics, 30*, 257–272. https://link.springer.com/article/10.1007/s13563-017-0119-6

McNutty B. & Joewitt, S. (2021). Barriers to and uncertainty in understanding and quantifying global critical mineral and element supply. *iScience, 24*, Article 102809. https://www.sciencedirect.com/science/article/pii/S258900422100777X/pdfft?md5=57e59ef570265118cb99253e4c2233a9&pid=1-s2.0-S258900422100777X-main.pdf

Messad, P. (2023, October 26). *Métaux stratégiques : la France prépare son grand inventaire minier* ["Strategic metals: France prepares its major mining inventory"]. Euractiv. https://www.euractiv.fr/section/energie-climat/news/metaux-strategiques-la-france-prepare-son-grand-inventaire-minier/?_ga=2.254299592.1585708988.1712245033-2065413129.1712245033

Mindat. (n.d.-a). *Cobalt*. https://www.mindat.org/min-52440.html

Mindat. (n.d.-b). *Gold*. https://www.mindat.org/min-52454.html

Mindat. (n.d.-c). *Lithium*. https://www.mindat.org/min-52473.html

Mindat. (n.d.-d). *Tantalum*. https://www.mindat.org/min-52510.html

Mindat. (n.d.-e). *Tin*. https://www.mindat.org/min-52525.html

Mindat. (n.d.-f). *Tungsten*. https://www.mindat.org/min-52513.html

Mineralprices.com. (n.d.). *Japan's critical minerals list*. https://mineralprices.com/critical-minerals/japan

Ministry of Mines. (2023). *Thirty critical minerals list released* [Press release]. Government of India. https://pib.gov.in/PressReleasePage.aspx?PRID=1942027

Nassar, N. T., & Fortier, S. M. (2021). *Methodology and technical input for the 2021 review and revision of the U.S. critical minerals list*. United States Geological Survey. https://pubs.usgs.gov/of/2021/1045/ofr20211045.pdf

National Research Council. (2007). *Minerals, critical minerals, and the U.S. economy*. National Research Council, National Academy of Sciences. https://nap.nationalacademies.org/resource/12034/critical_minerals_final.pdf

Natural Resources Canada. (2022). *The Canadian critical minerals strategy: From exploration to recycling: Powering the green and digital economy for Canada and the world*. https://www.canada.ca/content/dam/nrcan-rncan/site/critical-minerals/Critical-minerals-strategyDec09.pdf

Organisation for Economic Co-operation and Development. (2016). *OECD due diligence guidance for responsible supply chains of minerals from conflict-affected and high-risk areas* (Third Ed.) https://doi.org/10.1787/9789264252479-en.

Philippines seeks more sites for critical minerals in govt-led exploration. (2023, September 19). Reuters. https://www.reuters.com/article/idUSKBN30P0C8/

Pope, N., & Smith, P. (2023). *Brazil's critical and strategic minerals in a changing world*. Igarapé Institute. https://igarape.org.br/wp-content/uploads/2023/10/Critical-and-Strategic-Minerals.pdf

Ramdoo, I. (forthcoming). *Critical raw materials in Africa, Caribbean and Pacific States* (background paper). Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development & Organisation of African, Caribbean and Pacific States Secretariat.

Schrijvers, D., Hool, A., Blengini, G. A., Chen, W.-Q., Dewulf, J., Eggert, R., van Ellen, L., Gauss, R., Goddin, J., Habib, K., Hagelüken, C., Hirohata, A., Hofmann-Amtenbrink, M., Kosmol, J., Le Gleuher, M., Grohol, M., Ku, A., Lee, M.-H., Liu, G. … Wäger, P. A. (2020). A review of methods and data to determine raw materials criticality. *Resources, Conservation and Recycling 155*, Article 104617. https://doi.org/10.1016/j.resconrec.2019.104617

S&P Global. (2023). *The future of copper: Will the looming supply gap short-circuit the energy transition?* https://www.spglobal.com/marketintelligence/en/mi/info/0722/futureofcopper.html

Takuma W., Nansal, K., & Nakajima, K. 2020. Review of critical metal dynamics to 2050 for 48 elements. *Resources, Conservation and Recycling 155*, Article 104669. https://doi.org/10.1016/j.resconrec.2019.104669

United States Department of Energy. (2023a). *Critical materials assessment* (Draft Report). https://www.energy.gov/sites/default/files/2023-05/2023-critical-materials-assessment.pdf

United States Department of Energy. (2023b). Notice of Final Determination on 2023 DOE Critical Materials List. https://www.energy.gov/sites/default/files/2023-07/preprint-frn-2023-critical-materials-list.pdf

United States Geological Survey. (2023). *Mineral commodity summaries*. https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf

Viebahn P., Soukup, O., Samadi, S., Teubler, J., Wiesen, K., & Ritthof, M. (2015). Assessing the need for critical minerals to shift the German energy system towards a high proportion of renewables. *Renewable and Sustainable Energy Reviews 49*, 655–671. https://doi.org/10.1016/j.rser.2015.04.070

Appendix A. List of Critical Minerals in Selected Countries

	European Union, 2023[12]	United States, Updated in 2023[13]	Canada 2022[14]	Australia, 2023[15]	United Kingdom, 2022[16]	South Africa, 2022	India, 2023[17]	Japan (updated 2024)[18]	China (2016–2020)[19]	Brazil, 2023[20]	South Korea, 2023[21]
	Critical and strategic raw materials	Critical minerals list (2021) and Critical minerals for energy (2023)	Critical minerals	Critical and Strategic Minerals	Critical minerals		Critical minerals	Critical minerals	Energy/ metallic/ non-metallic	Strategic and Critical Minerals G1/G2/G3	Critical and strategic minerals
Aluminum	✓*	✓	✓						✓	✓	✓
High-purity alumina				✓							
Antimony	✓	✓	✓	✓	✓		✓	✓	✓		✓

12 Source: European Council, 2024.
13 Source: United States Department of Energy, 2023b.
14 Sources: Natural Resources Canada, 2022; Government of Canada, 2022a; 2022b.
15 Source: Department of Industry, Science and Resources, 2023.
16 Source: International Energy Agency, 2022.
17 Source: Ministry of Mines, 2023.
18 Source: Mineralprices.com, n.d.
19 Source: Pope & Smith, 2023. See Appendix B.
20 Source: Pope & Smith, 2023.
21 Source: International Energy Agency, 2023a.

	European Union, 2023[12]	United States, Updated in 2023[13]	Canada 2022[14]	Australia, 2023[15]	United Kingdom, 2022[16]	South Africa, 2022	India, 2023[17]	Japan (updated 2024)[18]	China (2016–2020)[19]	Brazil, 2023[20]	South Korea, 2023[21]
Arsenic	✓	✓		✓							
Baryte	✓	✓									
Beryllium	✓	✓		✓			✓	✓			
Bismuth	✓	✓	✓	✓	✓		✓	✓			✓
Borates	✓							✓			
Cadmium							✓				
Cesium		✓	✓								
Chromium		✓	✓	✓		✓		✓	✓		✓
Cobalt	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Coking coal	✓					✓					
Copper	✓	☐	✓				✓	✓		✓	✓
Electrical steel		☐									
Fluorine		☐		✓				✓			
Fluorspar	✓	✓	✓						✓		

	European Union, 2023[12]	United States, Updated in 2023[13]	Canada 2022[14]	Australia, 2023[15]	United Kingdom, 2022[16]	South Africa, 2022	India, 2023[17]	Japan (updated 2024)[18]	China (2016–2020)[19]	Brazil, 2023[20]	South Korea, 2023[21]
Gallium	✓	✓	✓	✓	✓		✓	✓			✓
Germanium	✓	✓	✓	✓			✓	✓			
Graphite	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Gold									✓	✓	
Hafnium	✓	✓		✓			✓	✓			
Helium	✓		✓	✓							
Indium		✓	✓	✓	✓		✓	✓			✓
Iron						✓			✓	✓	
Lead						✓					✓
Lithium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Magnesium	✓	✓	✓	✓	✓			✓			✓
Manganese	✓	✓	✓	✓	○	✓		✓		✓	✓
Molybdenum			✓	✓							✓
Nickel	✓	✓	✓	✓	○		✓	✓	✓	✓	✓

	European Union, 2023[12]	United States, Updated in 2023[13]	Canada 2022[14]	Australia, 2023[15]	United Kingdom, 2022[16]	South Africa, 2022	India, 2023[17]	Japan (updated 2024)[18]	China (2016–2020)[19]	Brazil, 2023[20]	South Korea, 2023[21]
Niobium	✓	✓	✓	✓	✓		✓	✓		✓	✓
Phosphate rocks	✓								✓	✓	
Phosphorus	✓				○		✓				
Potash			✓				✓		✓	✓	
Rare-earth elements	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rhenium				✓			✓	✓			
Selenium				✓			✓	✓			✓
Silicon		□		✓			✓	✓		✓	✓
Silicon carbide		□									
Silicon metal	✓				✓						
Sulphur											
Tantalum	✓	✓	✓	✓	✓		✓	✓		✓	✓
Strontium	✓						✓	✓			✓

	European Union, 2023[12]	United States, Updated in 2023[13]	Canada 2022[14]	Australia, 2023[15]	United Kingdom, 2022[16]	South Africa, 2022	India, 2023[17]	Japan (updated 2024)[18]	China (2016–2020)[19]	Brazil, 2023[20]	South Korea, 2023[21]
Tellurium		✓	✓	✓	✓		✓	✓			
Rubidium		✓						✓			
Tin		✓	✓		✓		✓		✓	✓	✓
Thallium								✓		✓	
Titanium	✓	✓	✓	✓			✓	✓		✓	✓
Tungsten	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Vanadium	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Uranium						✓		✓		✓	
Zinc		✓	✓			✓					✓
Zirconium		✓		✓			✓	✓	✓		✓
Platinum Group Metals (PGMs) - six metals											
Ruthenium	✓	✓	✓	✓	○	✓	✓	✓			
Rhodium	✓	✓	✓	✓		✓	✓	✓			
Palladium	✓	✓	✓	✓	✓	✓	✓	✓			✓
Osmium	✓	✓	✓	✓		✓	✓	✓			

	European Union, 2023[12]	United States, Updated in 2023[13]	Canada 2022[14]	Australia, 2023[15]	United Kingdom, 2022[16]	South Africa, 2022	India, 2023[17]	Japan (updated 2024)[18]	China (2016–2020)[19]	Brazil, 2023[20]	South Korea, 2023[21]
Iridium	✓	✓	✓	✓	○	✓	✓	✓			
Platinum	✓	✓	✓	✓	✓	✓	✓	✓			✓

**Bauxite/alumina/aluminum*

United States Department of Energy, 2023a. Materials with an ☐ are not on the DOE CM list; ○ UK watch list.

Source: Compiled by authors.

Appendix B. Mapping Selected Minerals and Metals Against Energy Transition and Digital Technologies

	ENERGY TRANSITION TECHNOLOGIES						DIGITAL TECHNOLOGIES			SOCIETY		
	Solar photovoltaics	Wind turbines	Electric vehicles			Hydrogen	Smartphones, tablets, & laptops	Data transmission networks	Data storage servers	Electronics and appliances	Food, kitchen utensils, and household products (cleaners, paints, etc.)	Medicine (including dental implants, surgical tools, and machines)
			Li-on batteries	Fuel cells	Electric tractor motors	Electrolyzers						
Copper	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓
Cobalt		✓	✓	✓		✓	✓			✓		✓
Nickel	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓
Manganese		✓	✓	✓		✓	✓	✓	✓	✓		✓
Lithium			✓	✓			✓	✓		✓		✓
REEs		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Chromium		✓		✓	✓	✓	✓		✓	✓		✓
Zinc	✓	✓				✓		✓	✓		✓	✓
PGMs				✓		✓	✓	✓	✓	✓	✓	✓
Aluminum	✓	✓	✓	✓	✓	✓		✓	✓			
Vanadium						✓						

	ENERGY TRANSITION TECHNOLOGIES						DIGITAL TECHNOLOGIES			SOCIETY		
	Solar photovoltaics	Wind turbines	Electric vehicles			Hydrogen	Smartphones, tablets, & laptops	Data transmission networks	Data storage servers	Electronics and appliances	Food, kitchen utensils, and household products (cleaners, paints, etc.)	Medicine (including dental implants, surgical tools, and machines)
			Li-on batteries	Fuel cells	Electric tractor motors	Electrolyzers						
Molybdenum	✓	✓		✓	✓	✓						
Graphite			✓	✓		✓	✓			✓		✓
Silicon	✓	✓	✓		✓		✓	✓	✓	✓		✓
Niobium		✓	✓							✓		✓
Iron	✓	✓		✓	✓	✓		✓	✓	✓		✓
Gallium	✓						✓	✓	✓	✓		✓
Germanium	✓	✓	✓	✓			✓	✓	✓	✓		✓
Titanium			✓	✓		✓				✓		✓
Gold			✓	✓		✓	✓	✓	✓	✓		✓
Potassium						✓						
Silver	✓			✓			✓	✓	✓	✓		✓
Tin	✓		✓					✓	✓	✓		✓

Source: European Commission, 2023a: Hilson, forthcoming; IEA, 2023b; Kowalski & Legendre: 2023; Ramdoo, forthcoming.

Appendix C. Data Checklist and Key Indicators of Risks Regarding Geological Consideration

1. What minerals are available in my country?

Factors to consider	Data to be collected	Unit/indicators
Geological and subnational considerations		
Geological data	a. Geological mapping	• Percentage of territory covered by geological mapping • Geophysical maps
	b. Mineral occurrences	• Maps of mineral occurrences
Mining potential	a. List of deposits	• Map of mines and identified deposits • Database of existing projects
	b. Comprehensive information for each deposit	• Location • Commodity • 3D model • Volume of ores and grade of mineralization • Resources estimates • Reserves estimates • Mineral processing pathways • Last feasibility study and all previous technical reports

Factors to consider	Data to be collected	Unit/indicators
	C. Mineral associations	• Multi-element geochemical composition of each deposit • By-production potential for mineral and metals • By-production potential in percentage of mineral value in the deposit • List of main elements in deposits expected to end-up in tailings • List of potential radioactive elements in the deposit (uranium, thorium, radium…) • List of potential heavy metals in the deposit (lead, zinc, cadmium…)
	d. Access to infrastructures	• Map of transportation network (roads, rails, rivers, airports, ports…) • Map of electricity network • Map of water resources
Land use	a. Potential overlap with environmentally sensible areas	• Map of world heritage sites • Map of conservation areas and biodiversity hotspots
	b. Potential overlap with human usages	• Map of community developments

Possible information sources:

- national geological surveys, statistics, and cadastral information
- foreign geological surveys
- companies' exploration reports
- pre-feasibility and feasibility studies
- national geophysical and geological campaigns
- other experts' reports

Appendix D. Data Checklist and Key Indicators of Risks Regarding Production, Economic, and Market Considerations

2. How much do I produce? Geological and subnational considerations

Factors to consider	Data to be collected	Unit/indicators
Reserves data	a. Reserves by commodity	• See Appendix C
Production data	b. Production by commodity; by size of mining activities (historical, actual, and potential)	• Historical and current production in volume • Historical and current production by value • Estimated growth in production by commodity in-country for ongoing mining activities • No. of exploration permits • Feasibility studies completed, and estimated reserves • No. of projects under construction and in final stage of construction • Production growth for similar commodities in other producing countries
	c. Depletion time of reserves	• Years
	d. The degree of mineral concentration in-country	• Herfindahl-Hirschman Index (HHI)
	e. Mineral production in total mining production (by mineral).	• % share of national mining production • % share of global production
	f. Minerals produced as co-product and by-products.	• % share of national mining production • % share of global production

Factors to consider	Data to be collected	Unit/indicators
	g. Minerals exported, by volume and by value.	• Types of minerals exported • Exports by volume • Exports by value • % Minerals exports as a share of total exports • % share of country's minerals exports in global exports (by commodity)
	h. Share of minerals produced by ASM	• Production by type of commodity • Production by value • Production by volume
	i. Alternative sources of supply, by source: • Recycling • Reprocessing of mining of wastes and tailings • Any potential minerals from deep seabed mineral resources	• Types of minerals and metals recycled domestically. • Share of recycled products as a share of total product • Projected supply growth from recycling • Types of minerals produced from mine wastes/tailings • Share in total mineral produced • Projected supply growth from reprocessing of tailings • Estimated volume

Factors to consider	Data to be collected	Unit/indicators
Demand for minerals	a. Domestic demand by commodity	• Estimated domestic demand by commodity in-country • Types of minerals by industrial need • % share minerals sold to domestic industries • Estimated growth in demand by commodity • Elasticity of mineral demand
	b. Domestic demand by applications and by sectors	• Estimated growth in domestic demand by application • Estimated growth in domestic demand by sector • Elasticity of demand for specific applications • Elasticity of demand by sector
	c. External demand by commodity by application and by sector	• Estimated growth in global demand by application • Estimated growth in global demand by sector
	d. Likeliness that technological changes will affect minerals demand	• New technologies by application • Critical minerals mix by technology

Possible information sources:

- national statistics
- mining companies’ reporting

3. How important is the mining sector to my country?

Factors to consider	Data to be collected	Unit/indicators
Contribution of the mining sector to the economy	a. Overall economic contribution of mining	• % Share of mining sector to national income • % Share of mining sector to GDP • Contribution of mining to foreign revenues
	b. Contribution of mining to employment	• % share of direct mining employment in total employment, by gender • % share of indirect mining employment in total employment, by gender
	c. Public sector investment in mining sector	• Share of public investment in mining sector to total public investments (by type of activity from exploration to closure) • Share of public expenditure on R&D and innovation on mining and mineral-related activities • No. of patents, industrial designs filed (related to mining value chains)
	d. Private investment in mining	• Share of domestic private investments in mining to total domestic private investments (in exploration; in production; in refineries and smelting) • Share of foreign direct invest (FDI) in mining to total FDI
Information on producing companies	a. Prospection and exploration phase	• Number of prospection and exploration permits delivered • Exploration budgets by commodities, by stage and by company type • Growth in exploration budget over time by commodities, by stage and by company • Investment projects in the pipeline
	b. Production phase	• Number of exploitation permits delivered by location and by commodity • Number of producing companies by mine site

Factors to consider	Data to be collected	Unit/indicators
	b. Production phase	• Number of producing companies by commodities (including by- and co- products identified in feasibility studies but not necessarily produced) • Number of producing companies by size • Number of investment projects in the pipeline by types of investment (greenfield, brownfield, extension, mergers & acquisitions) • Mergers & acquisitions history and planned • Ownership structures of producing companies (and nationality of owners) • In-country geographical distribution of producing companies, by commodities and by size.
	c. Mining and refining capacity	• Types of minerals and metals refined/ smelted in-country • Volume and value of minerals and metals refined and smelted in-country • Share of refined and smelted production sold to domestic industries • Share of refined and smelted production exported • Planned mining and refining projects
Trade data	a. Exports	• List of export trading partners for mining • Key exports by commodities in volume • Key exports by commodities in value • Share of exports by commodities in total mining exports • Key exports by trading partner in value • Key exports by trading partner in volume • Share of mining exports by trading partners on total mining exports

Factors to consider	Data to be collected	Unit/indicators
	b. Imports	• List of importing trading partners for mining • Key imports by commodities in value • Key imports by commodities and in volume • Share of imports by commodities in total mining imports • Key imports by trading partner in value • Key imports by trading partner in volume • Share of mining imports by trading partners on total mining imports
	c. Trade balance	• Overall trade balance for mining • Export dependency ratio on mining • Import dependency ratio on mining • Time series change in share of trading partners in mining imports and exports
	d. Share of country in global trade	• % share of country in global trade by commodity • Herfindahl-Hirschman Index (HHI)
	e. Trade measures in place	• By commodity, if applicable (e.g., export licensing; export restrictions etc.) • Performance requirements, if applicable • Restrictions on sectors or specific minerals for investment • Incentives to stimulate mining-related industrial development or development of mining activities

4. Which minerals are essential to my country's strategic objectives?

Factors to consider	Data to be collected	Unit/indicators
Industrial development considerations	a. Country's industrial roadmap (current and future plans)	• Scope of industrial policies where mining is relevant • Key technological and industrial sectors in-country and globally for which critical minerals are indispensable
	b. Beneficiation and midstream capabilities	• *(See also information in Appendix B)* • Number of refiners/smelters in operation • Investment pipeline in refining/smelting • Share of minerals produced domestically supplied to local refiners/ smelters • Production by type/volume/value of refiners/smelters • Plans to build refineries/ smelters and their expected capacity (timeline projections) • Share of country's exports of refined/smelted products • Share of country's imports of refined/smelter products
	c. Downstream capabilities	• List of sectors/industries that currently require mineral resources produced domestically • List of (critical) mineral-intensive sectors/industries identified as potential drivers for future growth • % share of domestic demand for critical minerals mined in my country (current and projected) by sector/industry • % share of global demand for critical minerals mined in my country (current and projected) by sector/ industry

5. Are there any minerals that I do not produce (or not sufficiently produce) but are key to my domestic industries?

Factors to consider	Data to be collected	Unit/indicators
Domestic availability of critical minerals	a. Reliance on imports and vulnerability of supply chains	• Key domestic industries that rely heavily on imports of specific minerals in high demand • Key minerals imported for specific industries, by type, volume, and value • Top importing partner countries • Degree of concentration of mineral production by producing countries • Import dependency ratio by mineral and by country • Top producing countries of minerals imported and their share in global production

6. Will current fiscal approaches and policies ensure that producing countries collect an appropriate share of the financial benefits arising from the extraction of their critical minerals?

Factors to consider	Data to be collected	Unit/indicators
Fiscal considerations	a. Current fiscal contribution of the mining sector	• Types of fiscal instruments in place relevant to mining • Contribution of mineral resources to government fiscal revenues by type of instrument • Contribution of mineral resources to export revenues
	b. Pricing models	• Types of mineral pricing methods and practices (incl. any specific commodity pricing methods)
	c. Benefit-sharing tools	• Types of financial benefit-sharing systems and instrument

Factors to consider	Data to be collected	Unit/indicators
	d. Future fiscal considerations	Guiding questions for policy discussions: • Are there alternative financial benefit-sharing models that would be more appropriate for critical minerals considering governments' broader policy goals? • Are there gaps to consider in the valuation of mine tailings and how they are considered in mining and/or tax legislation? • Do current fiscal regimes capture potentially valuable by-products and co-products? • Are there benefit-sharing opportunities along the critical minerals value chain that require further consideration (tools such as ringfencing, tax incentives, valuation of minerals; and practice issues such as state participation, ownership of mining rights by large end users in the value chain, administrative capacity for tax administration)?

Appendix E. Data Checklist and Key Indicators of Risks Regarding Social and Environment Considerations

7. What are the key social issues I need to consider to constructively engage with mining-affected communities and ensure benefits for society at large?

Factors to consider	Data to be collected	Unit/indicators
Social considerations	a. Existing mining-neighbour communities	• A database of mining projects that coexist with local communities • A map that identifies potential overlap between mining projects and local communities' land (and Indigenous People's land where applicable)
	b. Community participation and a repository of community development agreement plans and their scope, where relevant	• Agreements with Indigenous Peoples • Local employment as a share of employment at mine site, by gender • Local procurement as a share of operational expenditures at mine site, disaggregated by gender where available • Social services provided by mining companies
	c. Community consultations and engagements	• Grievance mechanisms, where applicable • Conflicts history with communities • Case law on conflicts with communities

8. What environmental issues are essential for the sustainability of my mining sector?

Factors to consider	Data to be collected	Unit/indicators
Climate change	Climate change vulnerability	• Qualitative • Assessment of the country's vulnerability to climate change, where available
Energy	Energy intensity	• kJ/tonne of ore extracted • kJ/tonnes metal processed • kJ/tonnes of metal refined
Air	Greenhouse gas (GHG) emissions	• Tonnes of CO_2e/tonne of ore extracted • Tonnes of CO_2e/tonnes metal processed • Tonnes of CO_2e/tonnes of metal refined • Level of GHG emissions of the mining industry in total country's GHG emissions
	Air quality	• Emission of particulate matter
Water	Water intensity	• Water consumption by mining operation/T produced
	Water quality	• Number of sample results above national or World Health Organization recommendations
Biodiversity	Biodiversity sensitivity	• Existence of protected fauna and flora in the vicinity of the mining project (International Union for Conservation of Nature conservation list)

Appendix F. Data Checklist and Key Indicators of Risks Regarding Geopolitical Considerations

9. Which minerals are considered as "critical" for my main trading partners, and what are their key industrial uses in those markets?

Factors to consider	Data to be collected	Unit/indicators
Market intelligence of third countries	a. Understanding criticality of main trading partners: • A mapping of domestic minerals production against key partners' critical minerals lists • Identification of minerals in partners' critical minerals strategies already exported • Identification of industries and sectors in partner countries that have the highest demand for critical minerals • Identification of key policies and instruments of partner countries to secure access to their critical minerals	• List of countries that have a critical minerals strategy • Scope of (partners) critical minerals strategies • List of minerals that are covered on these lists • Partners' critical mineral exports by type, by volume, by partner, by share • List of industry players in partner countries • List of relevant policy instruments of partner countries

Factors to consider	Data to be collected	Unit/indicators
	b. Mapping domestic and global demand for partners’ critical minerals	• A mapping of domestic sectors and applications that use minerals in critical mineral lists • A mapping of global demand and supply (current and forecasted) of (partners’) critical minerals production • Share of domestic production in global production • What other technologies need critical minerals (other than renewable energy and digital)
	c. Understanding global supply chains • A mapping of global supply chains for (partners’) critical minerals produced domestically • Mapping geographical locations of key parts of supply chains	• Critical minerals produced in partner countries, by sectors and by application • Depth of supply chains by sector and by industry • Share of specific countries in key parts of supply chains by sector and by industry • Identification of potential choke points in global supply chains
	d. Understanding global competition	• Key producing countries of critical minerals: by name and by share of global production • Geographical location of global reserves by critical minerals • Political landscape surrounding key producing countries (i.e., political instability; governance challenges; conflicts; human rights issues)

Appendix G. Data Checklist and Key Indicators of Risks Regarding Governance, Legal, and Regulatory Issues

10. What policies, legislations, regulations have an impact on my mining sector?

Factors to consider	Data to be collected	Unit/indicators
Regulatory frameworks	a. Domestic policies[22] • Plans to elaborate policies for specific minerals or for specific sectors • Plans to develop industries that require mineral feedstocks produced locally	• Mapping of policies by type and scope • List of existing policies/ measures/instruments that have implications on exploration projects • List of existing policies/ measures/instruments that have implications on mining production and processing activities • List of existing policies/ measures/instruments that have implications on international trade of specific minerals, by type of measure • Documentation of plans, and analysis of scope of application and of feasibility • Timeline estimated for their implementation
	b. ESG policies and performance indicators of mining companies	• If available, policies of mining companies regarding ESG • When published, mining companies' ESG performance indicators
	c. International agreements	• Types of agreements and their legal status • Scope of trade agreements with partner countries (with relevant for minerals) • Scope of investment agreements with states (such as bilateral investment treaties) or with companies (mining contracts) that cover mineral production and conditions of exports • Other trade and investment frameworks particularly focused on minerals (such as MOUs, framework agreements)

[22] Examples of policies include mining codes; mining contracts; local content policies; beneficiation strategies; regulations that already identify specific types of minerals for specific purposes.

Factors to consider	Data to be collected	Unit/indicators
	d. Other relevant agreements/ contractual obligations	• Existence and content of resource swap deals, that is, agreements to exchange mineral resources for infrastructure or for loans. Offtake agreements (by commodities and relevant industry; length and nature of agreements) • Long-term supply contracts (by commodities and relevant industry; length of contracts, nature of contracts)

11. What global governance frameworks are applicable to my mining sector?

Factors to consider	Data to be collected	Unit/indicators
Global governance frameworks	a. Global frameworks around responsible supply chains	• Extractive Industries Transparency Initiative (EITI) • OECD Due Diligence Guidance on Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas • Section 1502 of the 2010 US Dodd–Frank Act • European Regulations, such as 2017 EU Conflict Minerals Regulation; 2022 Battery Regulation; 2023 EU Critical Raw Materials Act
	b. A mapping of host metals and their co-products and by-products with partners' conflict minerals and critical minerals lists	• Assessment to be conducted by countries that are in conflict-affected or high-risk areas (CAHRAs)

Factors to consider	Data to be collected	Unit/indicators
Risks	Country risk	• Corruption Perception Index (Transparency International) • Resource Governance Index (Natural Resource Governance Institute) • Extractive Industries Transparency Initiative Standards Reporting • World Governance Index (World Bank) • Global Political Risk Index (Eurasia Group) • Policy Potential Index (Fraser Institute) • Human Development Index (United Nations Development Programme) • Global Peace Index (Institute for Economics & Peace) • Civic space (Worldwide Governance Indicators' Voice and accountability)

Source: Adapted from Achzet & Helbig, 2013.

Appendix H. Where Critical and Conflict Minerals Overlap

It should be relevant to highlight that the "conflict minerals" listed below are mined alongside other critical minerals, either as co-products or as by-products of host (conflict) minerals. A case in point is lithium, which is often associated with tin when mined from hard rock, especially in Central and Austral Africa, and currently being explored in some CAHRAs deposits (Manono, located in the Democratic Republic of Congo, is the third largest lithium deposit in the world and the largest hard-rock one; it has been mined for 6 decades over the last century for its tin content). Although associated with (and therefore mined with) tin, lithium is, however, currently not classified as a high-risk or conflict mineral in those CAHRAs. This raises the question about policy inconsistencies and of the potential of risk spillovers not being adequately addressed.

TABLE H1. What other minerals are associated with high-risk and conflict minerals?

Conflict minerals	Associated critical minerals	Countries that listed conflict minerals on critical minerals lists[23]	Comments
Tin[24]	Arsenic, copper, tungsten, zinc, bismuth lithium[25]	Canada, United Kingdom, and United States	Tin is not on EU and Australia critical minerals list
Tantalum[26] (Columbite-Tantalite)	Niobium, rare earth elements, lithium, tungsten, beryllium, tin lithium[27]	Australia, Canada, EU, United Kingdom, and United States	
Tungsten[28] (Wolframite)	Copper, molybdenum, zinc, tin, antimony	Australia, Canada, EU, United Kingdom, and United States	
Gold[29]	Arsenic, copper, zinc, antimony, tungsten, molybdenum	None	Gold is not considered a critical mineral by any country

23 See Appendix A for a comparison of critical minerals lists.
24 Source: Mindat, n.d.-e.
25 Source: Mindat, n.d.-c.
26 Source: Mindat, n.d.-d.
27 Source : Mindat, n.d.-c.
28 Source : Mindat, n.d.-f.
29 Source: Mindat, n.d.-b.

Conflict minerals	Associated critical minerals	Countries that listed conflict minerals on critical minerals lists[23]	Comments
Cobalt[30]	Copper, nickel, gold, zinc, chromium	Australia, Canada, EU, United Kingdom, and United States	Cobalt is not considered a conflict mineral in any legislation. However, mining practices from ASM in regions of the DRC prone to armed conflict and human rights violations confer similar governance challenges to those observed for tin, tantalum, tungsten, and gold. Rising demand for batteries makes it a critical mineral, and hence subject to regulatory pressures for responsible[31].

30 Source: Mindat, n.d.-a.
31 Source: Hönke & Skende, 2022.

IGF

INTERGOVERNMENTAL FORUM
on Mining, Minerals, Metals and
Sustainable Development