The present work was submitted to
the German-Mongolian Institute for Resources and Technology

MINERALS CRITICAL FOR MONGOLIA'S DEVELOPMENT : A SUGGESTION FOR CRITERIA

Bachelor's Thesis

By

Enkhjin Enkhtur

Study program: Industrial Engineering

Student ID: B2100222

1st Supervisor/Examiner: Prof. Enkhzaya Chuluunbaatar

2nd Supervisor/Examiner: Mr. Mendbayar Melscho

Ulaanbaatar/Nalaikh

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Statutory Declaration

Enkhtur, Enkhjin — Last Name, First Name

B2100222 — Student ID Number

I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

MINERALS CRITICAL FOR MONGOLIA'S DEVELOPMENT:

A SUGGESTION FOR CRITERIA

I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Nalaikh, 05/28/2025

Place, Date

Signature

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I extend my sincere gratitude to all those who have contributed to completing this thesis. Without their consultation, this thesis wouldn’t have gone far without their sharing knowledge and valuable support. It is pleasure to express my deepest gratitude

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Abstract

Mongolia is known as a resource wealth country, and lacks a structured proper methodology for identifying and prioritizing critical minerals essential for its long-term economic development and industrial development. As the global green energy transition, the demand for the key minerals such as lithium, cobalt, nickel and rare earth elements is increasing due to their essential role in clean energy technologies.

Developed countries are already securing their access to critical minerals, increasing competition in global markets by developing structured methodologies for classifying critical minerals based on economic importance, supply chain risks, and technological relevance. Meanwhile, Mongolia still lacks a systematic approach and risks missing strategic opportunities without a clear national policy to define and manage these minerals. This absence of policy and strategy clarity not only limits economic benefits but also hinders Mongolia's ability to integrate into international supply chains, attract investment, and maximize the value of its mineral resources.

Furthermore, this thesis work's methodology is literature based and reviews the methodology, experiences of the countries & their further works related to critical minerals by research, literatures. This research addresses this gap by analysing existing approaches and proposing criteria that specifically fits Mongolia's unique economic conditions which aligns with the strategy of Mongolia's development. Key factors such as economic security, industrial diversification, and sustainability are incorporated into the proposed classification criteria.

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1. Introduction

1.1 Background

Mongolia is a country rich in mineral resources, which play a critical role in its economic development. The mining sector has been the main influencer of the country's economy, with minerals such as coal, copper, and gold contributing significantly to its GDP & national economic well-being.(1) In recent years, however, there has been growing attention to the importance of rare earth elements and other critical minerals that are essential for the global transition to renewable energy and technological advancements.(2)

The world's increasing reliance on these global critical minerals such as lithium, cobalt, and rare earth elements (REE), presents both challenges and opportunities for Mongolia.(3) These minerals are vital components in the manufacturing of electric vehicles, renewable energy systems and advanced technologies.(4) Despite Mongolia's rich mineral resources, the country currently lacks a structured framework for systematically identifying and prioritizing the minerals critical to its sustainable economic development.(5)

Globally, countries like the United States, China, and Australia have already developed systems to define and manage critical minerals based on their national security, economic needs, and long-term development strategies.(6) However, Mongolia does not have a clear, structured approach for identifying which minerals are most crucial for its own growth. The absence of such a system disturbs Mongolia's ability to align its mineral resources with national development goals and the country's energy transition efforts.

This research aims to address this gap by proposing criteria that can help define critical minerals in the context of Mongolia's specific needs, considering the country's economic priorities, technological & sustainability development .

1.2 Problem statement

Despite Mongolia's rich mineral wealth, the country currently lacks a structured and systematic approach to identifying and prioritizing the minerals critical to its long-term sustainable development. While many countries have developed frameworks to manage critical minerals based on national priorities and global trends, Mongolia hasn't established such a framework yet. This lack of a clear strategy limits the country's ability to manage its mineral resources effectively, resulting in missed opportunities for aligning its mineral sector with broader economic, industrial, and energy goals.

The main problem this thesis aims to address is the absence of a clear, well-defined set of criteria to identify which minerals are critical for Mongolia's development. Without such a framework, Mongolia faces challenges in effectively managing its mineral resources aligning with its own well-being, particularly in a global context where the demand for critical minerals is rapidly growing due to the shift towards green energy and technological innovations.

This research will explore how Mongolia can develop a criteria-based approach to identify critical minerals that are not only vital for economic security but also crucial to supporting the country's long-term industrial, technological, and energy transition goals.

1.3 Research Questions

This thesis aims to answer the following research questions to help define the criteria for identifying critical minerals for Mongolia:

- How do other countries define critical minerals and what lessons can be applied to Mongolia's situation?
- How do global trends in mineral demand, especially for renewable energy and technology, affect Mongolia's mineral strategy?
- What criteria and key factors should guide Mongolia in identifying and prioritizing minerals critical for its sustainable development?

1.4 Research methodology

1.4.1 Research design

This thesis is based on a qualitative, literature-based approach by examining global frameworks, academic researches, mostly secondary data analysis such as review of reports, policy documents in order to gain the insight, analyze and compare findings and adapt to suitable experiences which can align with Mongolia's development strategy to suggest criteria for defining critical minerals of Mongolia. This study relies entirely on the secondary data sources such as scientific publications, policy documents and industry reports.

1.4.2 Comparative Analysis

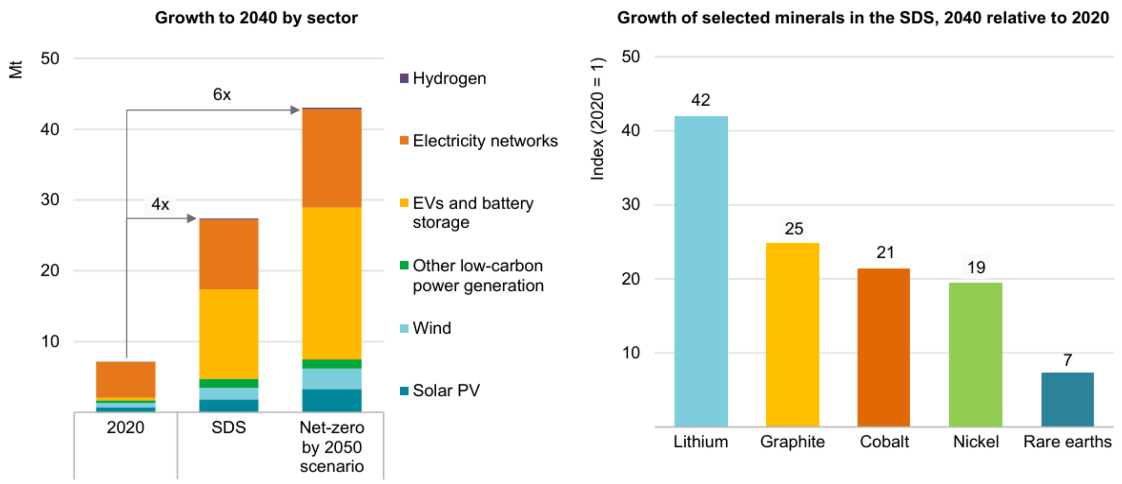
To develop the proposed criteria, the study conducts a comparative analysis of the critical mineral frameworks of the United States, the European Union and Australia. This comparison helps to understand the key focus areas, main concerns, and the methodologies used by these countries. By examining these frameworks, the thesis identifies relevant considerations based on its insight in order to provide Mongolia-Specific criteria.

2. Literature review

2.1 Global Mineral Demand & Supply

The global shift towards renewable energy sources such as clean technologies has driven the demand for minerals essential for their industry and maintenance. Since 2020, The need for the critical minerals such as lithium, cobalt, nickel, and rare earth elements which are core minerals of clean transactions has rapidly increased. Lithium, Nickel and cobalts have advantages such as giving batteries greater performance and longevity. REEs minerals are mostly used to make such as powerful magnets for wind turbines. Additionally, clean energy technologies require more materials than traditional energy sectors, which has contributed to the rising demand. For example, an average electric car requires six times more mineral inputs compared to a conventional car.(7)

The global clean energy translation will play a crucial role according to the IEA's climate-driven scenario (Figure 1.) In order to achieve net-zero globally by 2050, mineral demand for clean energy technologies would increase by at least 4 times to meet climate goals. Minerals such as Lithium demand could be 13 to 42 times higher, cobalt 6 to 21 times higher, REEs 3 to 7 times higher than today, depending on how climate policies and technologies develop.(7)



Notes: Mt = million tonnes. SDS refers to "Sustainable Development Scenario" under the Paris Accord.

Figure 1. Estimated clean energy mineral demand, 2040.

Source: International Energy Agency, The Role of Critical Minerals in Clean Energy Transitions

Between 2020-2022, the demand for lithium increased by 30%, while demand for nickel, cobalt, graphite, and rare earth elements grew by 8% to 15%. However, supply hasn’t been able to keep up with this rising demand, causing price changes. In 2023, lithium prices dropped by 75%, while cobalt, nickel, and graphite fell between 30% and 45%. Although prices for some minerals, like copper, remain high. The rapid demand growth made China and Indonesia start producing more, which was more than the market. Since there was plenty of supply and less immediate demand, prices dropped.

The production of critical minerals is concentrated in few places, making it easy for problems like natural disasters, pandemics, or political conflicts to disrupt the supply. China continues to lead in producing refined critical minerals, with over 90% of battery-grade graphite and 77% of refined rare earth elements expected to come from China by 2030. This concentration can lead to problems like political conflicts, trade disputes, or disruptions caused by extreme events.(8)

Looking ahead, there is a need for new mining projects and improvements in refining technologies to meet the increasing demand. In today's situation, most supply for refined lithium, nickel, cobalt, and rare earth elements comes from the top producers, with China playing a key role (9). *(Figure 2.)*

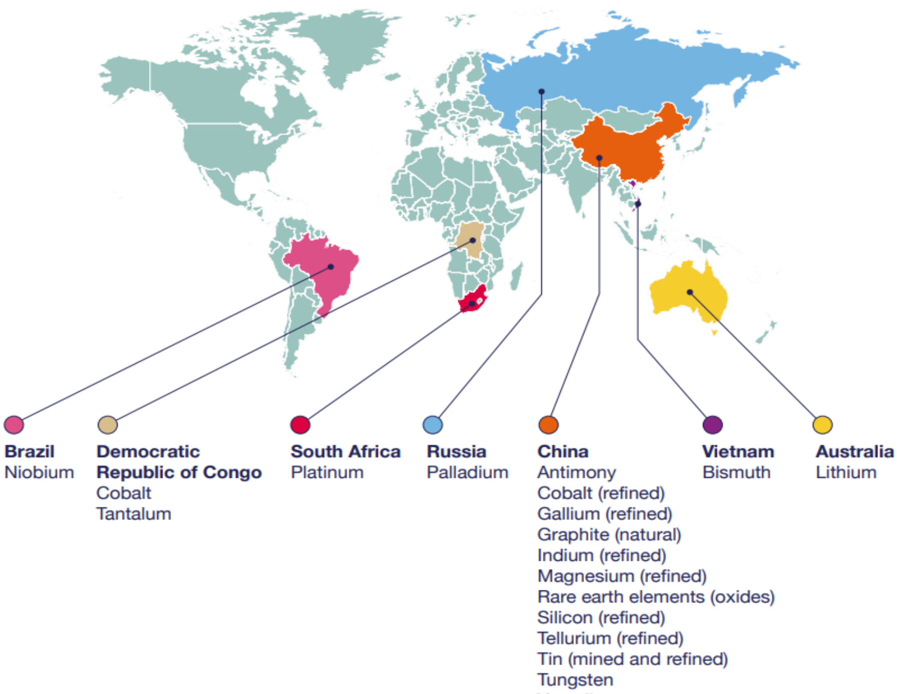


Figure 2. (Top producers globally of the critical minerals)

Source: Data from the UK Critical Minerals Intelligence Centre, 2022

In 2024, the global supply of minerals faces many challenges. These challenges include a heavy reliance on a few regions for production, increasing demand for minerals needed for green energy, and risks from disruptions caused by geopolitical events, environmental issues, and social factors.

To tackle these challenges, countries are developing national strategies, setting up stockpiling systems, and working together internationally. Initiatives like the Minerals Security Partnership help countries share information and resources to secure mineral supplies and promote sustainable practices.

Looking ahead, it is important for nations to work together and adopt innovative and sustainable approaches to ensure a stable and reliable supply of critical minerals for future needs.

2.2 Existing Practices in Defining Critical Minerals

2.2.1 United States

In the United States, mineral commodities play a crucial role in the economy. The U.S. Geological Survey estimated that in 2021, mineral resources contributed to the creation of goods and services worth $3.3 trillion, which represents nearly 15% of the total U.S. GDP. This highlights the significant economic importance of minerals, underlining why it is essential to identify and manage critical minerals effectively. The U.S. has established practices for defining critical minerals, relying on various methodologies that assess supply risk, dependency, and economic impact.(10)

According to the United States Geological Survey (USGS) , the US was 100 % net import reliant for 12 of the 50 critical minerals on the 2022 CML such as graphite, manganese, niobium etc. Moreover, more than 50 % net import reliant for an additional 29 which includes antinomy, barite, bauxite, tellurium, titanium etc. (Figure 3.) In 2023, China was the leading producer for 29 of the 50 critical minerals on the 2022 Critical Mineral List.

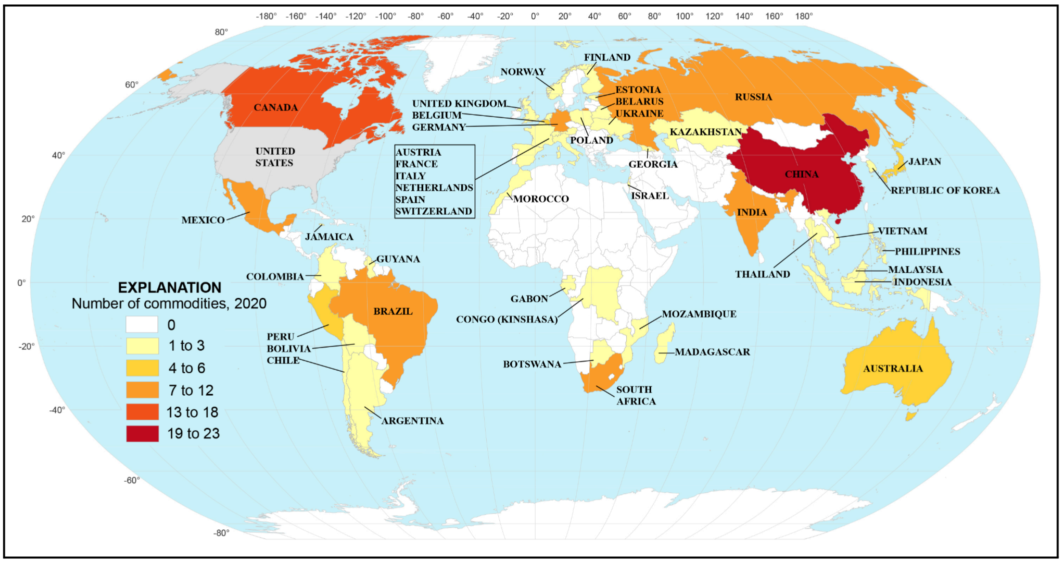


Figure 3. (US minerals net import reliance in 2020)

Source: United States Geological Survey

In the United States, critical minerals are defined based on their essential role in advanced technologies and the significant risks associated with their supply chains. These minerals are crucial for supporting various industries, including energy, defense, electronics, and manufacturing.(10)

Criteria for Defining Criticality:

To be classified as critical, U.S assumed that generally mineral must meet specific criteria:

- **Essential Functionality**:

Critical minerals are required for specific technologies like batteries, semiconductors, wind turbines, and defense systems. For instance, lithium and cobalt are essential for electric vehicle batteries, while rare earth elements (REEs) such as neodymium are critical for high-performance magnets used in renewable energy technologies.

- **High Supply Risk**:

These minerals are at risk of supply disruptions due to factors such as geopolitical conflicts, environmental challenges, or limited domestic extraction. For example, the U.S. relies heavily on imports for rare earth elements, making supply chains at risk of disruptions.Those 2 main considerations define the minerals critical for the US. In 2020, Updated approach evaluates supply risk based on 3 factors such as likelihood of supply disruptions, e dependency of the U.S. manufacturing sector on foreign supplies, and the vulnerability of U.S. This approach improved the original method used to make the CML. The new method keeps the measure of how much the U.S. relies on imports but makes the production concentration measure better by focusing on countries outside the U.S. and considering how willing and able those countries are to keep supplying the U.S. It also changes the way importance is assessed by turning it into a more measurable assessment of how vulnerable U.S. manufacturing is to supply problems.(10)

Also, according to the supply chain, the U.S evaluates the disruption of each stage of the supply chain which includes extraction, processing, and end-use applications. Each stage of the supply chain is assessed for risks and opportunities:

- **Extraction**:

The U.S. is heavily reliant on other countries for the extraction of many critical minerals, as it does not have sufficient domestic production of certain minerals like rare earth elements (REEs) and cobalt. In fact, a significant portion of the extraction of minerals, such as lithium, cobalt, and rare earth metals, is concentrated in countries like China, the Democratic Republic of the Congo, and others. The U.S. has some mining operations, but domestic extraction still faces challenges like regulatory restrictions, environmental concerns, and limited mining capacity for certain minerals.

- **Processing and Refining**:

The U.S. has limited processing capacity for critical minerals such as rare earths, which are primarily processed in China. This lack of domestic processing capability makes the U.S. vulnerable to supply chain disruptions in the event of geopolitical tensions or trade restrictions. The U.S. has begun efforts to develop domestic processing facilities and reduce its reliance on foreign processing, but progress is slow.(10)

Types of U.S Critical Minerals:

The 2022 CML list includes particularly REE and metals for clean energy technologies.

- **Battery Materials**:

Lithium, cobalt, and nickel are critical for manufacturing batteries used in electric vehicles and energy storage systems. The demand for these materials is rapidly increasing as the shift towards renewable energy gains momentum.

- **Semiconductors and Electronics**:

Silicon, gallium, and germanium are vital for producing semiconductors and electronic devices, which are essential for modern computing and communication technologies.

- **Rare Earth Elements (REEs)**:

Elements like neodymium and dysprosium are crucial for advanced magnets used in wind turbines, electric vehicles, and military applications. The production of REEs is concentrated in a few countries, creating significant supply risks for the U.S.(10)

USGS Efforts in Assessing and Mapping Critical Mineral Resources

The U.S Energy Act of 2020 and the Infrastructure Investment and Jobs Act (IIJA) direct the USGS to assess and research critical mineral resources in the U.S. The USGS is conducting a national assessment to identify known and undiscovered critical minerals, with a focus on mapping and studying the geology of areas with potential resources. This includes geophysical, geochemical, and geological surveys to better understand where these minerals might be located. The Earth MRI program, created under the IIJA, is accelerating these efforts and using existing data from various USGS programs to complete the mapping. The goal is to complete a national assessment and mapping by 2026, helping to secure a stable supply of critical minerals for the U.S. economy and national security. *(Figure 4.)*

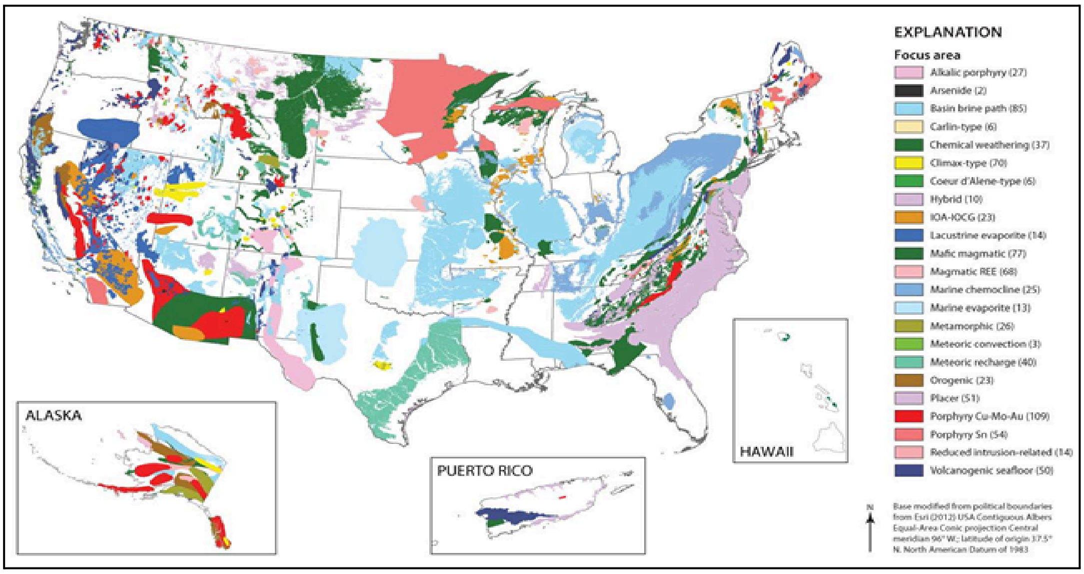


Figure 4. (National Map of Potential Critical Mineral Resources)

Source: Jane M. Hammarstrom et al., National Map of Focus Areas for Potential Critical Mineral Resources in the United States, U.S. Geological Survey, USGS Fact Sheet 2023–3007, February 2023, https://doi.org/10.3133/ fs20233007.

2.2.2 European Union

The European Union (EU) defines Critical Raw Materials (CRMs) through the European commissions for every three years as materials essential for key industries, such as renewable energy, electronics, and transportation, and at risk of supply disruption. To address the growing concern of securing valuable raw materials for the EU economy, the Commission launched the European Raw Materials Initiative in 2008. It is an integrated strategy that establishes targeted measures to secure and improve access to raw materials for the EU. One of the priority actions of the Initiative was to establish a list of Critical Raw Materials (CRMs) at the EU level. The Commission established the first list in 2011 and committed to update it at least every three years to reflect market, production and technological developments. (11)

In the 2023 CRM list, 70 raw materials were assessed, following 34 raw materials are defined as CRM for EU. Four new materials were assessed: neon, krypton, xenon and roundwood. Titanium metal has been assessed in addition to titanium. Aluminium and bauxite have been merged for consistency reasons. Copper and nickel do not meet the CRM thresholds but are included on the CRM list as strategic raw materials in line with the Critical Raw Materials Act. (Table 1.)

To ensure a stable supply of raw materials, especially Critical Raw Materials (CRMs), a solid and regularly updated knowledge base is essential. In response to a specific action from the 2015 Circular Economy Communication, the European Commission developed the EU Raw Materials Information System (RMIS). The first version, RMIS 1.0, was launched in March 2015. The advanced version, RMIS 2.0, was introduced in November 2017 as a centralized information platform for both primary and secondary raw materials.(11)

In 2015, the European Commission released a study on Material System Analysis (MSA) to track and assess the flows of CRM , covering the entire lifecycle from extraction to recycling.

2023 Critical Raw Materials for EU			
aluminium/bauxite	coking coal	lithium	phosphorus
antimony	feldspar	LREE	scandium
arsenic	fluorspar	magnesium	silicon metal
baryte	gallium	manganese	strontium

beryllium	germanium	natural graphite	tantalum
bismuth	hafnium	niobium	titanium metal
boron/borate	helium	PGM	tungsten
cobalt	HREE	phosphate rock	vanadium
		copper*	nickel*

Table 1. (CRM list for European Union 2023)

Source: European Commission. Critical Raw Materials for the EU

China provides 98% of the EU' s supply of (REE), Turkey provides 98% of the Eu's supply of borate and South Africa provides 71% of the EU's needs for platinum and an even higher share of the platinum group metals iridium, rhodium, and ruthenium. The EU relies on single EU companies for its supply of hafnium and strontium. (Figure 5.)

To access those CRMs, the EU has currently no other choice than importing the ores and concentrates or the refined materials from other countries to feed its industries and markets. Hafnium is the only CRM for which an EU Member State (France) is the global main producer. For hafnium and indium, the Member States produce enough primary materials to avoid significant extra-European imports.

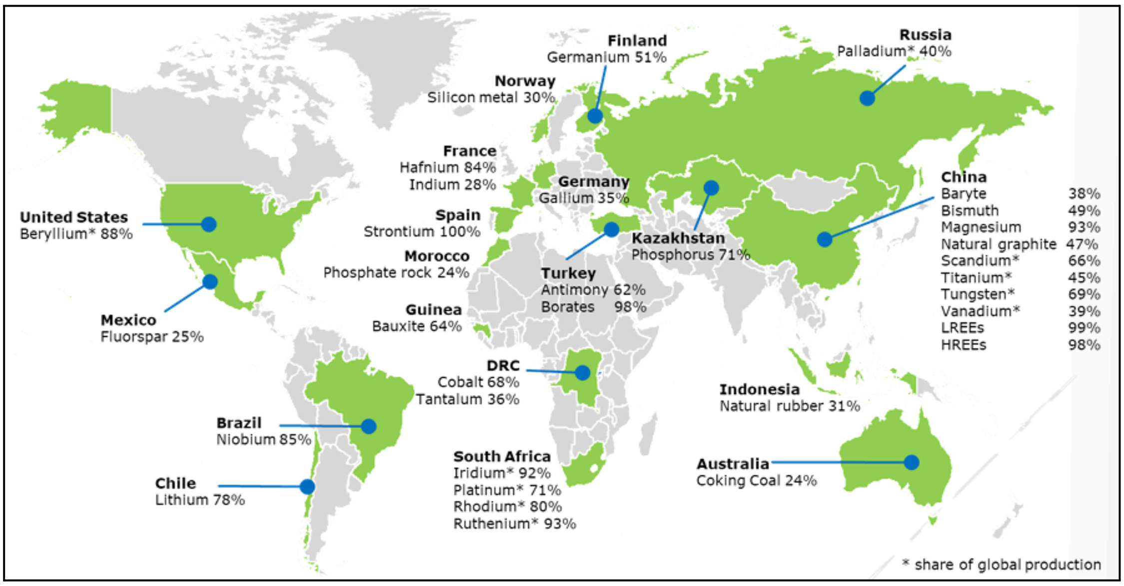


Figure 5. (Biggest supplier countries of CRMs to the EU)

Source: European Commission report on the 2020 criticality assessment

Economic importance and supply risk are the two main parameters used to determine criticality for the EU.(11) Additionally, other following factors have to be considered in defining critical minerals of the EU: *(Figure 6).*

1. **Economic Importance**

CRMs are prioritized based on their critical role in supporting strategic sectors within the EU, including innovation and sustainability.

2. **Supply Risk**

The EU assesses supply risk by examining geopolitical dependencies, market concentration, and political stability in supplier countries.

3. **Substitution Potential**

Materials with limited substitution options are classified as CRMs due to higher vulnerability to supply disruptions.

4. **Recycling and Circular Economy**

The potential for recycling and the efficient use of secondary raw materials are integral to the definition of CRMs, promoting sustainability.

5. **Technological and Market Changes**

The EU continuously updates its CRM list to reflect changes in technology and market demands, ensuring materials are aligned with emerging industrial needs.

6. **Alignment with Strategic Goals**

CRMs are integrated into broader EU policies, such as the Green Deal, focusing on sustainability and innovation.

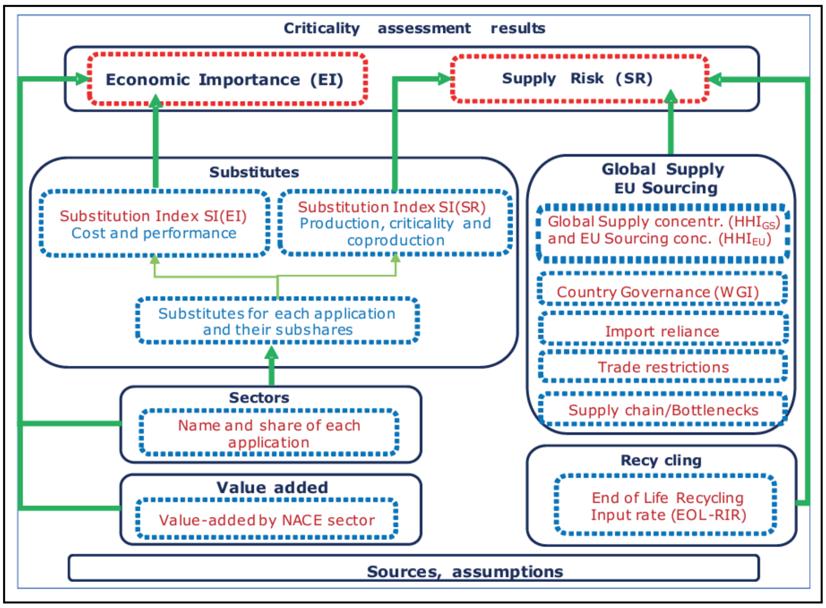


Figure 6. (Overall structure of the criticality methodology)

Source: Study in critical raw materials for EU 2023

These indicators help evaluate the risk of supply disruption and guide the classification of materials as CRMs. The European Commission updates the CRM list every three years through collaboration with bodies like the European Raw Materials Alliance (ERMA).(11)

2.2.3 Australia

Australia plays a critical role in the global supply of 19 minerals (Aluminum, iron ore, lithium, gold, lead, diamond, rare earth elements etc.) in significant amounts, from over 350 operating mines.(Figure 7.)

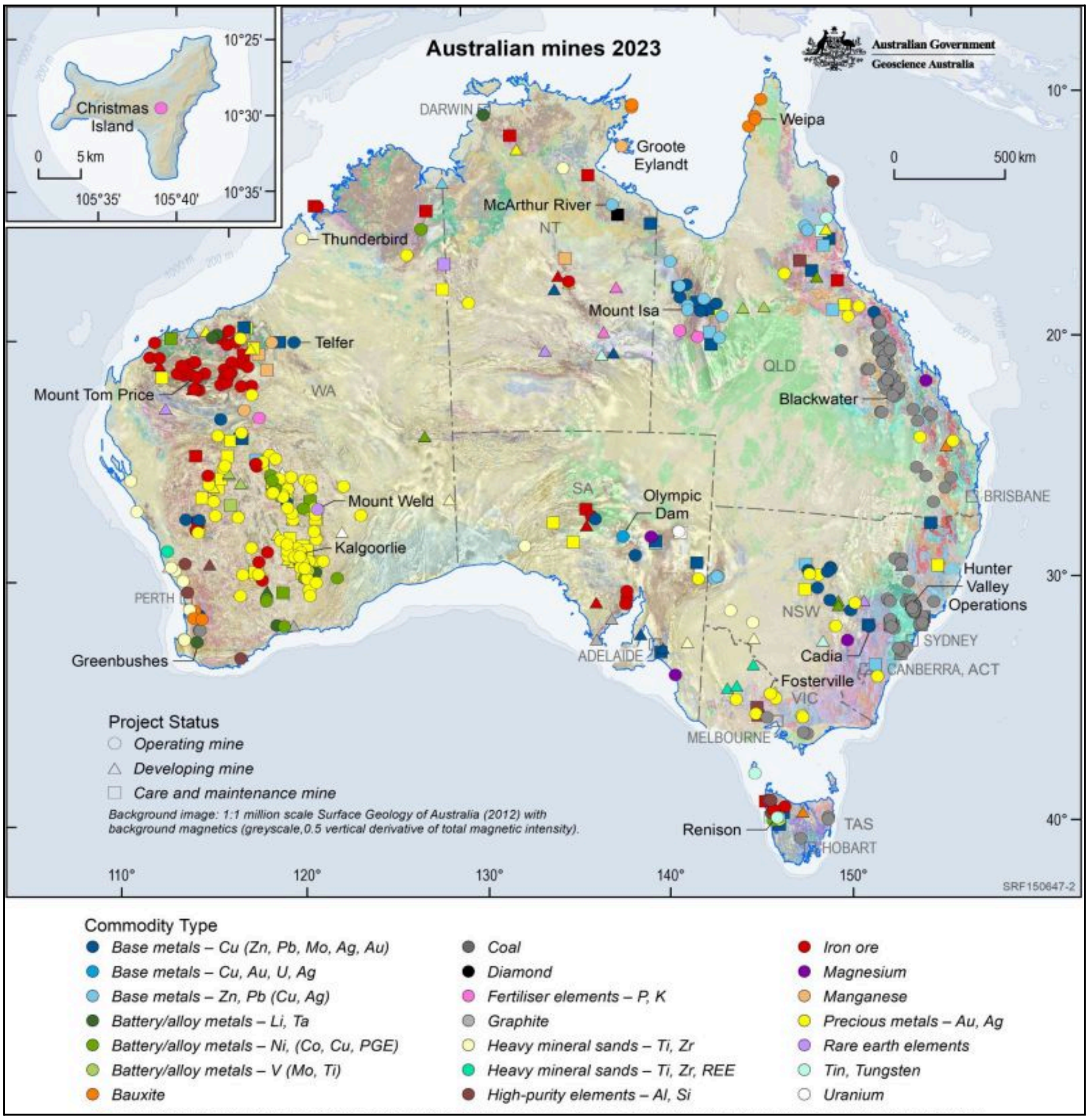


Figure 7. (Australian mines 2023)

Source: Australia's Identified Mineral Resources (AIMR 2023)

Also, Australia is number 1 lithium producer and one of the biggest mining examples in resource exploration, extraction, production.. Almost 80 % of the Australian continent remains underexplored and still considered as significant potential to discover new deposits. The government of Australia defines a critical mineral as a metallic or non metallic element or mineral that has two characteristics same as many many countries:

1. Essential for modern technologies, economies, or national security
2. Risk of supply chain disruption

Additionally, there are two criteria to consider as critical, it must have moderate to high geological potential for resources with Australia and there must be strong demand for it from Australia's strategic international partners.(12)

Australia's most recent CRM announced in 2023 and updated later including Nickel. The country produces 22 of the 36 critical minerals identified by its government. Also, the Government announced the "Critical Minerals Strategy 2023-2030" framework to grow Australia's critical minerals sector. The strategy sets priorities across 6 focus areas.

First, they aim to support strategically important projects by reducing risks, attracting finance, promoting exploration, and enhancing R&D and licensing frameworks. They also seek to attract international intellectual property to improve refining and processing capabilities. (12)

Second, the government focuses on attracting investment and building international partnerships by optimizing trade policies, facilitating business engagement, and strengthening global relationships.

Third, First Nations engagement is prioritized, ensuring respect for land rights and creating economic opportunities for communities.

Fourth, Australia aims to lead in Environmental, Social, and Governance (ESG) performance by maintaining high standards and streamlining environmental approvals.

Fifth, unlocking investment in infrastructure is a key priority, with collaboration between industry and jurisdictions to support critical minerals projects. Finally, growing a skilled workforce through education, migration policies, and community outreach is essential to support the sector’s growth. These areas aim to build a sustainable and globally competitive critical minerals sector in Australia and it will create jobs and economic opportunities for national benefits.(12)

2.3 Comparison of U.S , EU and Australia

After analyzing these existing practices, The U.S, EU and Australia each approach the definition and management of the critical minerals with different perspectives and priorities. However, all three recognize the economic importance and supply risk of the critical minerals. The U.S focuses on national security and vulnerability of its manufacturing sector, while the EU prioritizes long-term sustainability, circular economy and alignment with its sustainability goals. Australia, as a major producer, focuses on sustainable resource extraction since it is producer of 26 critical minerals, building strategic partnerships, and leveraging its geological potential. (Table.2)

Aspect	United States	European Union	Australia
Mineral richness	-Rich in minerals, but reliant on many CRM	-Mostly reliant on imports	-Major producer of many critical minerals
Basis	Focus on economic importance + supply risk (import dependence, geopolitics).	List updated every 3 years; focus on economic value + supply risk.	Focuses on minerals essential to tech, clean energy, and defense.
Key Focus Criteria of defining “Critical Mineral”	- Reduce foreign dependency - Boost domestic mining,processing - Secure for defense, clean energy sectors.	- Secure supply for EU industries - Reduce import risk - Boost recycling, support Green Deal goals.	- Be a global, reliable supplier - Grow downstream processing - Support global clean energy transition.
Common consideration	-Economic importance, competitiveness -Supply risk -Key role in green clean technologies -Alignment with net-zero 2050 goal		
Top Minerals	Lithium, cobalt, nickel, REEs, graphite, manganese, gallium, etc.	Lithium, cobalt, REEs, antimony, gallium, magnesium etc.	Lithium, cobalt, nickel, REEs, vanadium, tantalum, tungsten, etc.
Main Challenges	- Over Reliance on China - Limited domestic refining	- Import dependence (China, Africa) - Limited EU production	- Heavy export of raw materials - Limited local refining - Global market

	- Fragmented supply chains.	- Need for circular economy integration.	dominated by China. - Keep the Geological potential

Table 2. (Comparison of existing practice)

Source: Made by based on researches of U.S, EU & Australia's critical mineral

All three regions are also putting effort into research to better understand critical mineral needs, improve mineral strategic plans for national benefits. In the future, they plan to continue investing in research domestically and internationally and developing strategies to ensure a stable supply, global partnerships.

2.4 Mongolia's Minerals & Development Priorities

Mongolia heavily relies on its rich mineral resources for economic growth. Mining is the dominant sector of the Mongolian economy, contributing approximately 72% of industrial production, 87% of exports, 75% of foreign direct investment (FDI), and 25% of the total GDP. (Figure 8.)

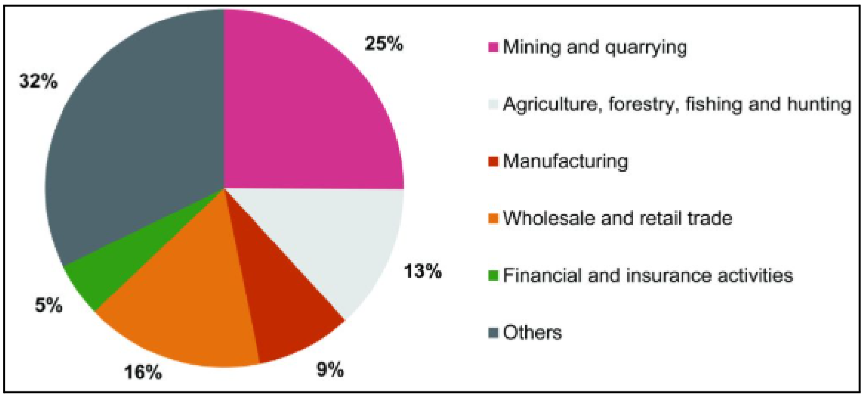


Figure 8. (GDP of Mongolia by sector)

Source: National Statistics Office

Due to the small size of the Mongolian market and limited access to capital and advanced technology, around 88% of Mongolia's minerals are exported in their raw form without any processing. The country has around 6,000 known mineral deposits, with 600 explored and 200 actively being mined. Key minerals include copper, coal, gold, and uranium, making mining a crucial part of Mongolia's economy. (13)

Mongolia ranks 12th globally in copper resources with 53.4 million metric tonnes, 17th in copper production, and 5th in copper ore exports. Mongolia's coal reserves stand at

36.6 million tonnes , while its fluorspar reserves, at 35.9 million tonnes, rank 4th globally. Mongolia also has identified rare earth elements reserves of 3.1 million tonnes and confirmed lithium of 1.16 million tonnes. Due to lack of capital and technology, 88% of Mongolia's minerals are exported to mainly China without value-added processing. (14)

Current Policies related to "strategically important minerals" industry

in 2006, Mongolia revised its Minerals law, and Article 4, defines a "**Strategically important minerals deposits**" as deposit that has a significant impact on national security, the country's economy, and social development, or one that produces or has the potential to produce products amounting to more than 5% of Mongolia's annual GDP. In accordance with this, the Government approved a list of deposits classified as strategically important mineral deposits through Resolution No.27 in 2007 titled " On classifying certain deposits as strategically important mineral deposits. (16)

Mongolia's development strategy is based on its Vision 2050, a comprehensive long-term plan aimed at fostering sustainable economic growth and improving the well-being of its citizens. (15)Vision 2050 outlines nine fundamental goals, including:

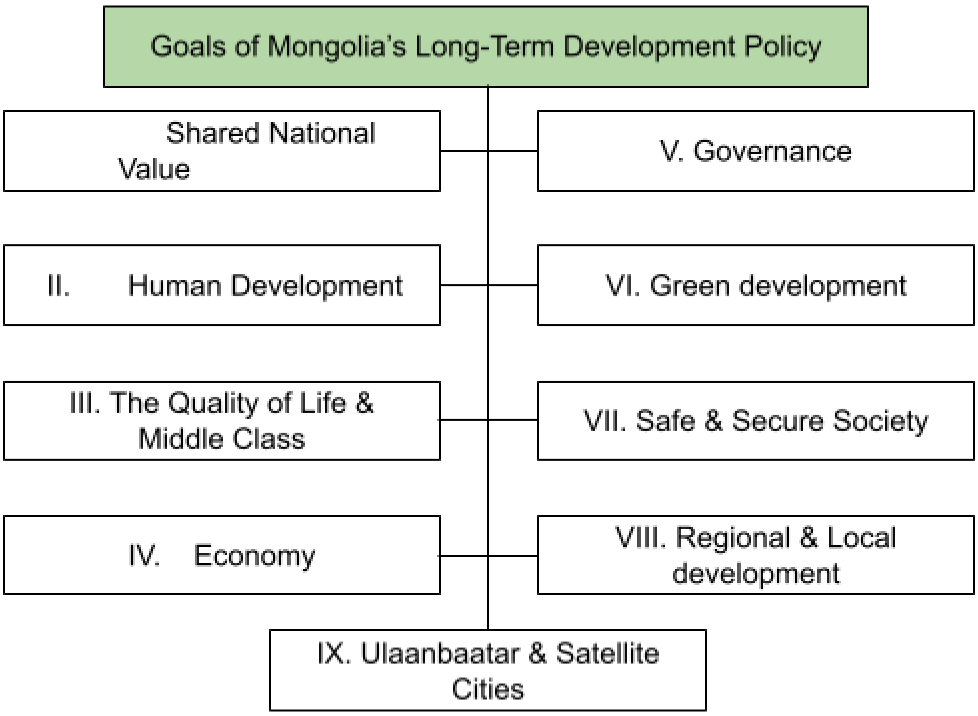


Figure.9 (The Goals of Mongolia's Long-Term Development Policy, in Vision 2050)

Source: Vision 2050, "LONG-TERM DEVELOPMENT POLICY OF MONGOLIA"

Vision 2050 considers all kinds of aspects which are measures of development. Country's well being or development is not only defined by economic aspects but also human health, education, political situation, environment etc. (Figure.9)

To establish a strategic foundation, Vision 2050 analyzes the current situation of Mongolia's development in terms of its advantages, disadvantages, opportunities and threats.(16)

It emphasizes reducing the country's reliance on commodity exports by developing value-added industries and promoting sustainable mining practices. Infrastructure development and foreign investment are pivotal elements of this vision, as they enable the integration of Mongolia into global markets and support the efficient exploitation of its mineral resources.

In today's current situation, Mongolia has started taking actions to define and prioritize critical minerals. Last May, Mongolian Critical Minerals Association (MCMA) proposed to designate 11 minerals as critical and planned to prepare mineral's nationwide data of Mongolia. The Ministry of Mining and Heavy Industry has started a tender, allocating 30 billion MNT for this year to do geophysical surveys. (17)

The Oyu Tolgoi copper-gold mine is the largest mining project in Mongolia and plays a major role in the country's GDP. Other large mining operations like Erdenet and Tavan Tolgoi contribute heavily as well. Mining accounts for about 30% of government revenue, 18.6% of GDP, and 80% of export earnings. However, this reliance on mining creates challenges. Mongolia's economy is vulnerable to fluctuations in global commodity prices, causing periods of instability, especially when prices drop.(18)

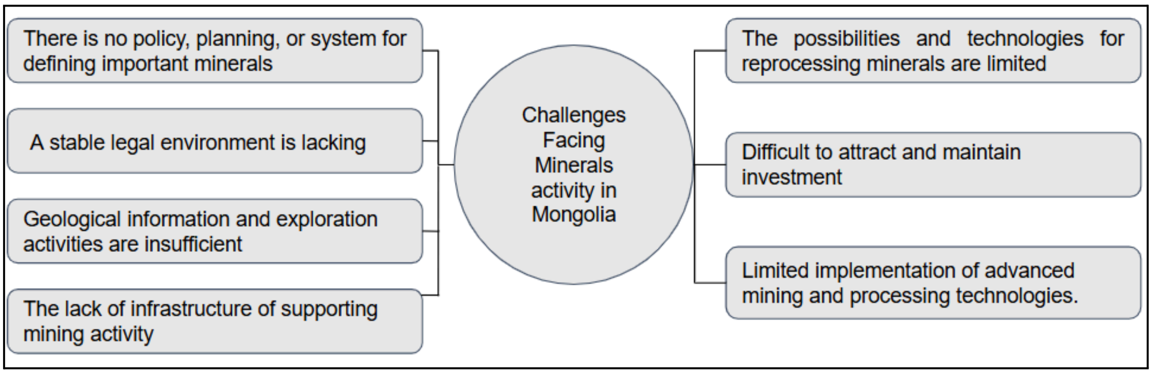


Figure 10. (Challenges facing minerals activity in Mongolia)

Environmental issues are a major concern in the mining sector, especially related to coal mining, which affects land, water, and air quality. There are also concerns about unclear policies regarding “strategic” mineral deposits, which do not follow the same legal and policy requirements as other mining operations. This has led to criticism from civil society, who worry about the sustainability and fairness of mining activities.(Figure.10)

Despite these challenges, Mongolia is working to address them. The government is introducing programs like the Gold II initiative to increase gold production, and it is negotiating to develop strategic deposits such as Tavan Tolgoi and Gatsuurt. These efforts aim to make mining more sustainable while supporting the country’s long-term development goals.

3. Result

3.1 Suggested Criteria for Defining Critical Minerals for Mongolia

In order to address defining the criticality of minerals of Mongolia, this study proposes a single comprehensive criterion. The criteria looks into the four important aspects based on the current situation of Mongolia, and these four main criteria applies each mineral categorization and assess the mineral with its sub-criterias which considers how it wants to grow according to the Vision 2050 plan and other factors such as supply risk disruption, global demand, future development relevance, economic importance that push its development forward through defining critical minerals and its proper management. (Figure.11)

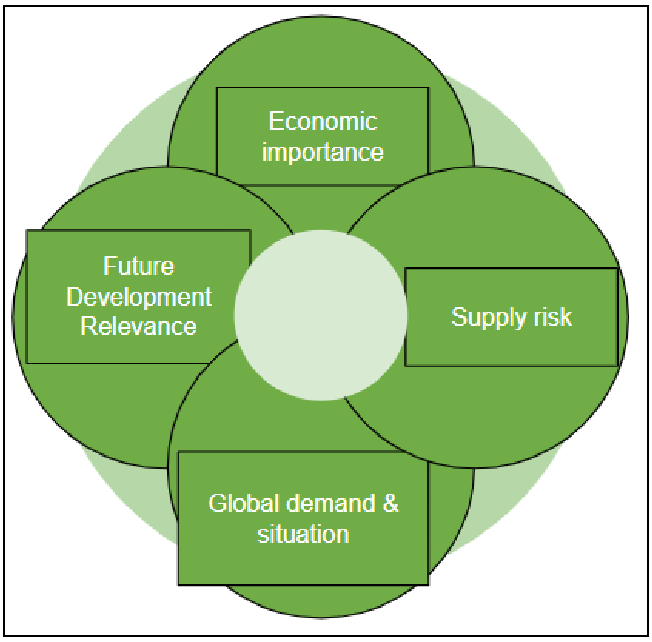


Figure 11. (Key criteria for defining critical minerals for Mongolia)

3.1.1 Categorizing minerals based in their current status in Mongolia

Diversifying minerals is a crucial first step before dividing into four main criterias which are currently contributing minerals, minerals with near & long term future potential and minerals needing import. By understanding where each potential mineral stands in its lifecycle within Mongolia, then in the next step, can apply the economic supply risk, industrial diversification, and sustainability criteria with appropriate emphasis and develop tailored strategies that can address specific challenges and opportunities associated with each category. This initial step of looking at different minerals and their stage of development provides a more detailed and relevant understanding. (Figure. 12)

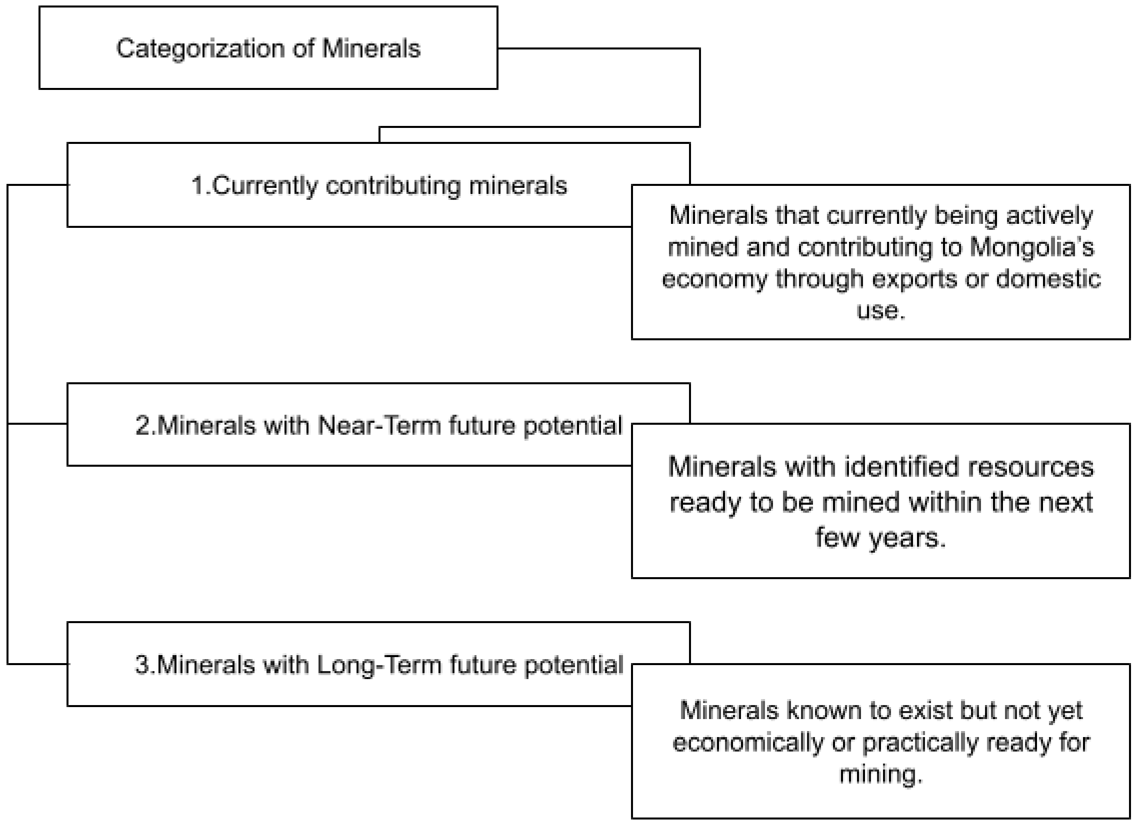


Figure.12 (First criteria of minerals)

I. Currently contributing minerals:

Following criteria will proceed to evaluate its level of current contribution using the following weighted criterias in order to determine whether the mineral is "Currently contributing mineral". (Figure.13)

The first and most fundamental step to determine if a mineral is 'Currently contributing' to Mongolia's economy is to establish whether it is actively being mined or is part of ongoing operational processes.

This is a crucial initial filter because a mineral can only generate measurable economic benefits such as export revenue, income & employment, if it is currently being extracted and processed. After this filter, the next stage , also shown in Figure.13 , involves looking at factors like their earnings from exports, contributions to the government, the number of jobs they create and their overall impact on Mongolia's economy (GDP). This criteria proposes how to define any given mineral contributing mineral is or not.

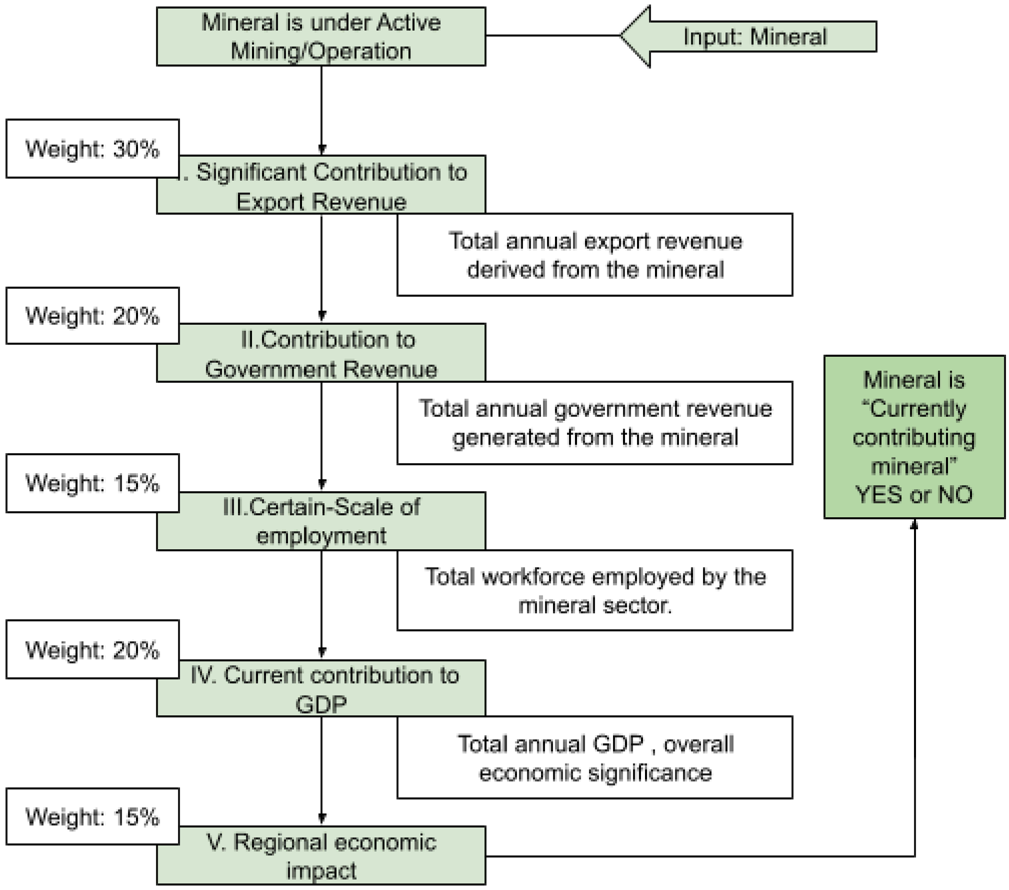


Figure.13(Criteria for defining "Currently contributing mineral")

The criteria of "Currently contributing mineral" incorporates weighted criteria in order to determine whether a given mineral fulfills the criteria and each criterion is assigned a score of High (3), Medium (2), Low (1) and associated with a percentage weight reflecting its relative importance. A Total Weighted Score (TWS) is then estimated by each criterion's score by its weight and used to categorize the mineral's contribution level into one of four categories which are "Not significant contributor" to "Strongly contributing". (Table.3)

	High (Score: 3)	Medium (Score: 2)	Low (Score: 1)
Export Revenue (30%)	more than 30%	10-30 %	lower than 10%
Government Revenue (20%)	more than 10%	3-10 %	lower than 3 %
Employment (15%)	more than 30,000	8000-30,000	lower than 8000
GDP Contribution (20%)	more than 8%	3-8 %	lower than 3 %
Regional Impact (15%)	Primary local's economic driver	Significant impact on local's development	Low impact local's development
Weighted Score = Score × (Assigned Weight)			
Total Weighted Score (TWS)	Strongly Contributing: TWS > 2.5 Moderately Contributing: TWS ~ 1.8 - 2.5 Marginally Contributing: TWS ~ 1.2 - 1.8 Not a Significant Current Contributor < 1.2		

Table.3 (Weighting of criteria : Mineral is "Currently Contributing Mineral")

According to the following criteria, Copper is defined as "Strongly Currently Contributing mineral" for Mongolia with high risk in criterions. (Table.4)

Example:

Mineral	Criterion	Weight (%)	Estimated Score	Weighted Score
Copper	Significant Export Revenue	30	High (3)	0.90
	Government Revenue	20	High (3)	0.60
	Employment	15	High (3)	0.45
	GDP Contribution	20	High (3)	0.60
	Regional Economic Impact	15	High (3)	0.45
Total		100%		3.00
TWS 3 > 2.5		Copper is "Strongly Contributing Mineral"		

Table.4 (Example :Whether Copper is "Currently Contributing Mineral")

Stage 1: Main criteria for currently contributing minerals

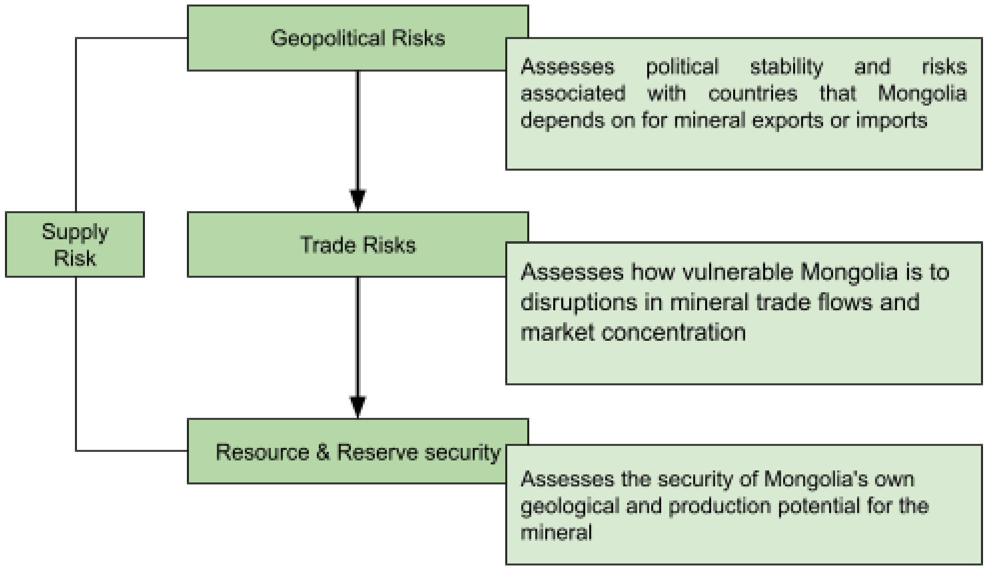


Figure.14 (Criticality criteria of mineral: Supply risk)

A mineral's economic importance is evaluated by the criterion "Currently Contributing Mineral". Following this, the main criteria of "Supply risk" of the mineral is considered, consisting of three key categories: "Geopolitical risks" , "Trade risks" and "Resource & Reserve security". (Figure.14)

Each 3 categories includes further sub-criterias such as 'Political stability', 'Export risk' etc.(Table.5)

Main Criteria	Criterion	Sub-Criteria	Measures
Supply Risk	**I. Geopolitical Risks**	Political Stability of Partner Countries	Assess main countries Mongolia trades with are politically stable or unstable.
		Export Restriction Risk	Analyze the partner countries possibility of restriction that could affect mineral supply
	II.Trade Risks	Market Concentration	Analyze mineral's market share of major players.
		Price Volatility	Analyze price fluctuations through supply chain

	III.Resource & Reserve Security	Domestic Reserve size relative to Demand	Analyze minerals's capacity related to demand & future needs
		Mineral's Reserve Life	Analyze the mineral's reserve of Mongolia
		Investment/Development Risk	Analyze current or obstacles that could restrict supply.

Table.5 (Sub-Criteria of supply risk)

Each sub-criteria is evaluated using Table 6, which provides the detailed evaluation method and assigns weighting to both the sub-criteria and the three main criteria, where the weighting reflects the relative importance or influence of each factor on the overall supply risk assessment. This weighting ensures that more critical factors have a stronger impact on the final result compared to less important ones. After completing the assessment, the minerals are ranked from highest to lowest score within each main criterion, and the total weighted scores are then used to classify the minerals according to defined ranges, determining whether they are considered high supply risk or not. (Table.6)

Criteria	High (Score: 3)	Medium (Score: 2)	Low (Score: 1)	Importance (%)
Criteria 1:Geopolitical Risks				**30%**
1.1 Political Stability of Partner Countries	Instability, major political risks	Occasional instability, manageable disruptions	Stable partners, no political disruptions	50%
1.2 Export Restriction Risk	Frequent restrictions, high export barriers	Some restrictions, export limits	Minimal restrictions, open trade	50%
Criteria 2: Trade Risks				**30%**
2.1 Market Concentration	Highly concentrated, few dominate global market	Moderate concentration, few large players	Well-diversified suppliers, no single dominance	40%
2.2 Price Volatility	Highly volatile prices, unpredictable costs	Moderate fluctuations, manageable impacts	Stable prices, low fluctuations	60%
Criteria 3: Value Addition & Diversification				**40%**

3.1 Domestic Reserve Size vs Demand	Low reserves, urgent risk of depletion	Moderate reserves, potential gaps in near future	Sufficient reserves for long-term needs	40%
3.2 Mineral Reserve Life	Short reserve life (<10 years)	Medium reserve life (10–20 years)	Long reserve life (>20–30 years)	30%
3.3 Resource & Reserve Security	High barriers, major development challenges	Some barriers, mixed investment	Low barriers, strong investment environment	30%
Weighted Score = Score × (Assigned Weight)				
Total Weighted Score (TWS)	Supply risk is high: TWS > 2.5 Moderately supply risk : TWS ~ 2.0 - 2.49 Marginally supply risk: TWS ~ 1.5 - 1.99 No supply negative risk: TWS < 1.5			

Table.6 (Evaluation of the Criterias of Supply Risk)

Stage 3: Future Development Relevance for “Currently contributing mineral”

In the next criteria, Future development relevance, evaluates how minerals that are currently contributing to Mongolia’s economy align with the country’s long-term development priorities. This criteria is divided into three key components: Alignment with Mongolia’s Long-term development vision, plan, role in Future technologies & Infrastructure and potential for value addition & diversification as illustrated in the following figure. Figure(15)

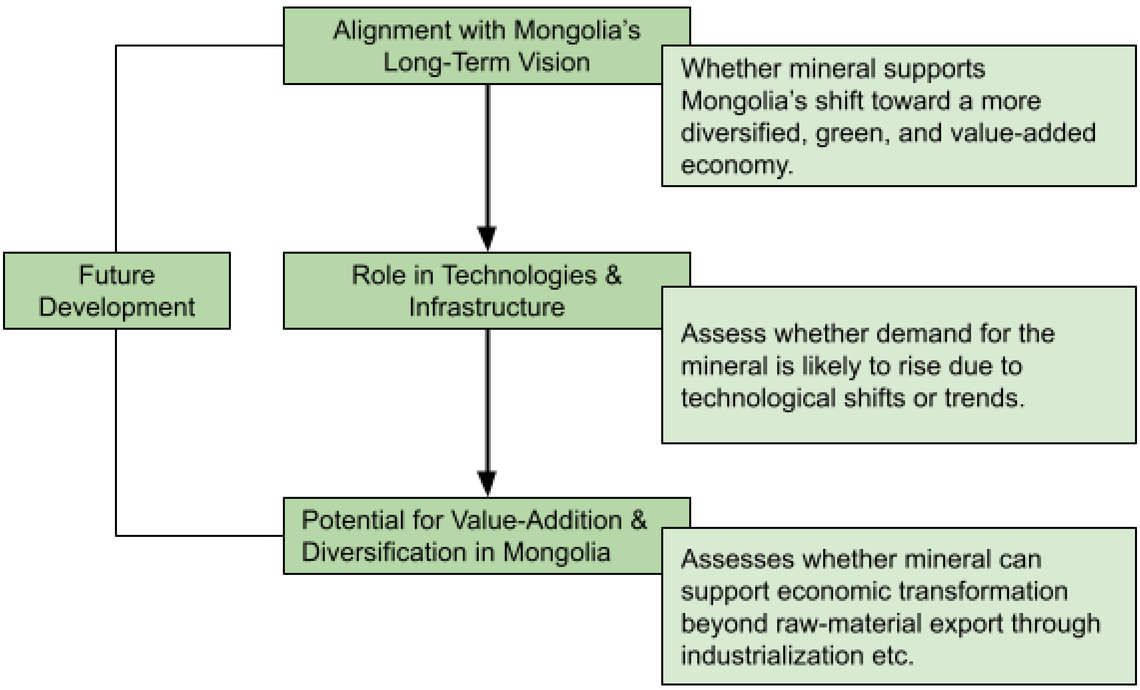


Figure.15 (Criteria: Future Development Relevance for “Currently contributing mineral)

Each of these components is further divided into sub categories to enable a more detailed targeted assessment. These sub-details include an analysis of national strategy alignment, potential to support the green economy transition, its prospective future role in technology and its future contribution to industrial development goals of Mongolia, feasibility of domestic processing of the mineral etc. In order to determine its risk or whether it is fulfilling criteria measures will be taken as outlined in the table. (Table.7)

Main Criteria	Criterion	Sub-Criteria	Measures
Future Development Relevance	I. Alignment with Mongolia's Vision	Possibility to contribute National Strategy plan	Check whether the mineral is included in Vision 2050 or recovery plans.
		Supports Green Economy Transition	Assess if the mineral is used in low-carbon or sustainable technologies in Mongolia
		Fits the Industrial Development Goal	Evaluate the mineral's link to national industrial or regional projects of Mongolia
	II. Role in Future Technologies & Trends	Usage in Emerging Technology	Analyze mineral's application in tech like EVs, renewables, semiconductors.
		Projected Demand growth	Assess forecasts on mineral demand
		Substitution Risk	Assess how easily the mineral can be replaced in critical uses.
	III. Value Addition & Diversification	Possibility for Domestic Processing	Assess the potential for local refining, processing, or manufacturing.
		Support for New Industrial Chains	Assess if the mineral can open value-added industries in Mongolia
		Potential to Attract Strategic Investment	Assess interest from global investors in downstream development.

Table.7(Criteria: Future Development Relevance)

When evaluating minerals, the alignment with Mongolia's future strategic development carries the highest importance, reflected in weighting of 50% for the first main criterion.

This prioritization emphasizes the fundamental importance of potential critical mineral's deep integration with Mongolia's visioned future & strategic development plans. In the given Table, further details the weighting of the main criteria and their respective sub-criteria within range of high to low assessment. (Table.8)

The scoring range categorizes a mineral's future relevance or contribution to Mongolia's future development based on its Total Weighted Score (TWS): a TWS above 2.5 indicates "Strongly future development relevant" due to good performance, especially in aligning with Mongolia's vision weighting as 50% importance, a TWS between 2.0 and 2.49 signifies "Moderately future relevant," showing reasonable alignment and potential contribution, a TWS between 1.5 and 1.99 suggests "Marginally future relevant," indicating a limited connection to strategic priorities and a TWS below 1.5 denotes "Not strongly future development relevant," implying a weak alignment with Mongolia's long-term objectives as defined by the weighted criteria.

Criteria	**High (Score: 3)**	**Medium (Score: 2)**	**Low (Score: 1)**	**Importance (%)**
Criteria 1: Alignment with Mongolia's Vision				**50%**
1.1 National Strategy Alignment	Clearly prioritized in Vision 2050 and sectoral policies	Indirectly mentioned or partially linked	Not aligned or not included in key national strategies	30%
1.2 Green Economy Transition Support	Essential for green technology	Partially supports green tech	No relevance to green transition	30%
1.3 Industrial Development Fit	Mineral is essential for industrialization of Mongolia	Moderate fit to industrial plans of Mongolia	Limited or no role	40%
Criteria 2: Role in Future Technologies & Trends				**20%**
2.1 Usage in Emerging Technologies	Critical material in future technology	Some emerging technology usage	No emerging technology application	30%
2.2 Demand Growth Forecast in Mongolia	High demand growth expected	Moderate growth projected	Uncertain or low growth	30%
2.3 Substitution Risk	Poor substitutes, essential for performance	Substitute exists but less effective	Easily replaced with other materials	40%
Criteria 3: Value Addition & Diversification				**30%**
3.1 Domestic Processing Potential	Strong feasibility of local refining, smelting , any value-added process	Moderate potential for processing	No feasible or economically viable processing	50%

3.2 Enabler of New Industrial Chains	Enables new value chains or industries	Supports partial value chains	Does not enable new sectors	30%
3.3 Investment Attraction Potential	Strong interest from foreign & strategic investors	Moderate domestic/international investment	Little or no investment interest	20%
Weighted Score = Score × (Assigned Weight)				
Total Weighted Score (TWS)	Strongly future development relevant: TWS > 2.5 Moderately future relevant: TWS ~ 2.0 - 2.49 Marginally future relevant: TWS ~ 1.5 - 1.99 Not strongly future development relevant TWS < 1.5			

Table.8 (Evaluation of Criteria: “Future domestic development relevance”)

Stage 3: Global trend based criteria for “Currently contributing mineral”

After considering criteria based on domestic needs then stage 3 criteria focus on evaluating the global relevance and future potential of minerals that are already actively mined in Mongolia. While Stage 2 assesses these minerals from a domestic perspective, this third stage considers broader international trends to determine whether these resources align with global strategic priorities. It examines factors such as rising global demand, the mineral’s role in the green and digital transitions, inclusion in critical raw materials lists by major economies, and global supply concentration.(Figure .16)

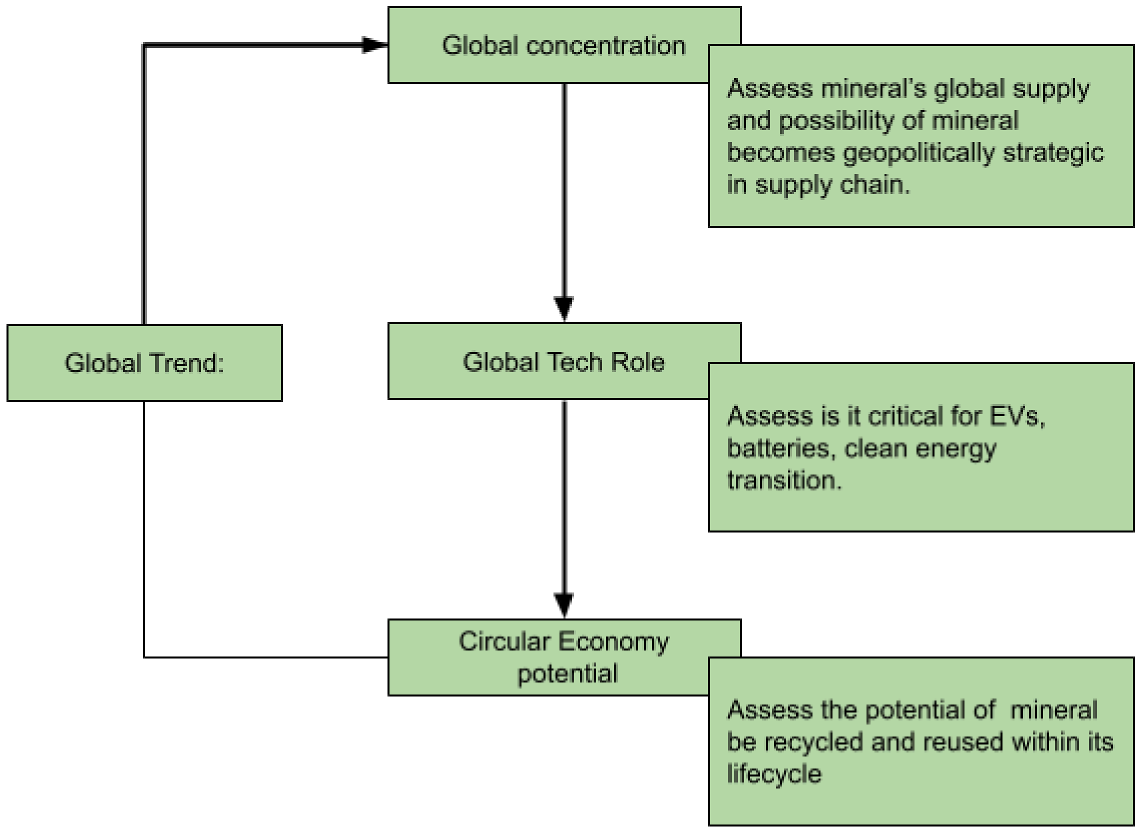


Figure 16.(Global trend based criteria for "Currently contributing mineral")

Evaluation criteria of "Global trend based criteria for "Currently contributing mineral" is illustrated in following Table.9

Criteria	High (Score: 3)	Medium (Score: 2)	Low (Score: 1)	Weight (%)
Criteria 1: Global Concentration				**40%**
1.1 Geographic Concentration of Production	Production hold in very few countries	Production hold in a few key regions/countries	Geographically diverse production	40%
1.2 Geopolitical Stability of Dominant Producers	Significant political instability in key producers	Some political risks in key producers	Generally stable key producers	30%
1.3 Contribution to Decarbonization Targets	Crucial for key green technologies.	Partially supports green efforts.	Not relevant to the green transition goal.	30%
Criteria 2: Global Technology Role				**40%**
2.1 Projected Global Demand Growth in Tech Sectors	Rapidly increasing global tech demand	Moderate global tech demand growth	Limited/uncertain global tech demand growth	50%
2.2 Existing Global Dependence in Strategic Technologies	High global reliance in strategic tech	Moderate global dependence	Limited global dependence	50%

Criteria 3: Circular Economy Potential				20%
3.1 Technological Feasibility of Global Recycling	Well-established, economic recycling tech	Developing recycling tech with limitations	Significant barriers to recycling	100%
Weighted Score = Score × (Assigned Weight)				
Total Weighted Score (TWS)	Strongly global strategic relevance: TWS > 2.5 Moderately global strategic relevance: TWS ~ 2.0 - 2.49 Marginally global strategic relevance: TWS ~ 1.5 - 1.99 Not strongly global strategic relevance TWS < 1.5			

Table.9 (Weighting importance of the each criteria: "Globally trend relevance")

II. Minerals with Near-term future potential

It is essential to consider minerals with near-term future potential because they represent resources that, while not yet major contributors, are positioned to become economically significant within the next five to ten years due to shifting market demands, technological advancements, or geopolitical priorities. These minerals can help Mongolia diversify its mining sector, reduce over-reliance on a few commodities, and respond proactively to upcoming global supply chain needs in near future. To be included in this category, minerals should show signs of rising international demand (e.g, due to energy transition or battery markets), have feasible domestic projects moving toward production, and possess regulatory or infrastructural pathways that allow development within a relatively short period. (Table.10)

Criteria	High (Score: 3)	Medium (Score: 2)	Low (Score: 1)	Weight (%)
Criteria 1: Market Potential				**20%**
1.1 Projected global demand growth	Analyze global market forecasts			40%
1.2 Forecasted price trends	Use international price projections			30%
1.3 Identified international market access	Evaluate trade access, infrastructure to market			30%
Criteria 2: Domestic Capability				**30%**
2.1 Existing exploration projects	Check exploration licenses, company activity			30%
2.2 Feasibility and permitting status	Assess stage in feasibility/permitting			20%

2.3 Infrastructure readiness	Score access to roads, energy, water	50%
Criteria 3: Strategic Importance		**50%**
3.1 Alignment with economic diversification goals	Check alignment with national strategies; rate Low–High	60%
3.2 Potential for downstream processing	Assess industrial processing potential	40%
Weighted Score = Score × (Assigned Weight)		
Total Weighted Score (TWS)	Strongly near-term potential: TWS > 2.5 Moderately near-term potential: TWS ~ 2.0 - 2.49 Marginally near-term potential: TWS ~ 1.5 - 1.99 Not strongly near-term potential TWS < 1.5	

Table.10 (Criteria : Minerals with Near-Term future potential)

Even when evaluating minerals with near-term future potential, the same criteria applied to currently contributing minerals such as supply risk, future development relevance, and global trends criterias should also be considered depending on after evaluation of Table.10

III. Minerals with Long-term future potential

Considering long-term future potential minerals is vital for Mongolia's strategic planning because these resources may not have immediate economic viability but are expected to become critical in the coming decades, driven by future global trends such as advanced manufacturing, green technologies, or defense needs. By identifying and preparing for these long-term opportunities, Mongolia can secure a forward-looking competitive advantage, attract early-stage investment, and shape national innovation strategies to align with emerging industries. Minerals included in this category should have early-stage geological indications, global forecasts signaling future importance, and the need for research, exploration, or technological breakthroughs before they become viable.

Criteria	**High (Score: 3)**	**Medium (Score: 2)**	**Low (Score: 1)**	**Weight (%)**
Criteria 1: Global Strategic Trends				**20%**
1.1 Long-term global demand projections	Evaluation of mineral based on its global long term demand			40%

1.2 Role in emerging technologies in long-term future	Estimate its long term role based on known or estimated resource data	30%
Criteria 2: Exploration & Resources		**30%**
2.1 Current exploration status	Evaluation of mineral based on geological surveys, early exploration	30%
2.2 Estimated size and quality of reserves	Assess the known or estimated resource	20%
Criteria 3: Innovation		**50%**
3.1 Research and innovation level	Determine its stage in feasibility/permitting in current and future time frame	60%
3.2 Institutional/government support	Assess its future risk about policy support, incentives	40%
Weighted Score = Score × (Assigned Weight)		
Total Weighted Score (TWS)	Strongly long-term future potential: TWS > 2.5 Moderately long-term future potential: TWS ~ 2.0 - 2.49 Marginally long-term future potential: TWS ~ 1.5 - 1.99 Not strongly long-term future potential TWS < 1.5	

Table.11 (Criteria : Minerals with Long-Term future potential)

For **long-term future potential minerals in Mongolia**, After assessing these criteria, the same main four criteria should apply into this criteria depending on its minerals input considering its supply risk , development relevance, national strategy alignment etc.. The criteria should assess underexplored resource potential, Mongolia's ability to attract long-term investment and technology, future infrastructure needs, and alignment with global and domestic trends & strategy like renewable energy and advanced technologies. It should also consider long-term logistical, geopolitical, and environmental challenges, balancing optimistic opportunities with a realistic view of Mongolia's capacity to bring these minerals into global supply chains over time.

3.2 How These Criteria Address Mongolia's Challenges

The criteria proposed for identifying critical minerals in Mongolia are directly tailored to address the structural, economic, and policy-related challenges that the country currently faces. One of the core problems in Mongolia's mineral governance has been the absence of a standardized framework for evaluating the strategic value of minerals beyond mere economic output. Without such a methodology, policy-making has often been reactive rather than proactive, particularly in times of fluctuating global prices or geopolitical uncertainty.

First, by categorizing minerals based on their current contribution, near-term, and long-term potential, this small criteria supports evidence-based decision-making. For instance, minerals that are already generating substantial revenue and employment (such as copper and coal) are assessed not only in terms of their present-day benefits but also through supply chain risk and future relevance. This layered evaluation ensures that Mongolia does not become overly dependent on any single resource and can instead plan diversification strategies grounded in realistic mineral development pathways.

Second, the inclusion of supply risk metrics helps Mongolia confront its vulnerability to geopolitical and trade disruptions. As a landlocked nation heavily reliant on a few trading partners, particularly China, Mongolia's mineral economy is at constant risk of bottlenecks and unreliable trade decisions. By measuring factors such as market concentration and geopolitical risk of partner countries, this suggestion helps to see Mongolia needs to identify where it should diversify its trade relationships or invest in domestic processing capabilities.

Third, the criteria reflect Mongolia's long-term development goals, especially those outlined in Vision 2050. Minerals are no longer assessed solely on their economic value, but also on how they align with sustainability goals, technological innovation, and industrial transformation.

Lastly, this suggestion introduces an innovation in aligning global trends with national strategy. By considering criteria such as international demand, processing feasibility, and global technology roles, Mongolia is better positioned to integrate into critical mineral supply chains at a global level. This could lead to stronger partnerships with countries looking to reduce their own mineral dependence on politically sensitive regions.

In essence, this small suggestion doesn't just classify minerals, it acts as a strategic compass for Mongolia's broader economic and developmental planning, offering a more forward-looking and resilient path than current practices.

4. Discussion

4.1 Interpretation of Suggested Criteria

The suggested criteria developed in this thesis tried to systematic consideration, approach to identifying critical minerals for Mongolia. Unlike comprehensive global frameworks, these criteria are tailored to Mongolia’s own well being, economic, and focus on development vision. The framework includes four major dimensions such as economic contribution, supply risk, development relevance, and alignment with global trends. Together, these help capture the multifaceted role of minerals in national development.

This structured approach also makes it possible for Mongolia to periodically reassess the role of its mineral resources. The scoring and weighting system allows the criteria to remain flexible and scalable. This feature is particularly important as new minerals are discovered or existing ones increase in global importance due to technological advancements, such as with battery materials or rare earth elements.

4.2 Relevance of the Suggested Criteria with Mongolia’s Development Goals

The criteria developed in this thesis are aligned with Mongolia’s long-term development , Vision 2050, which serves as a strategic roadmap for sustainable and inclusive growth. Vision 2050 outlines a comprehensive approach to transitioning from an economy heavily reliant on raw material exports to one that is diversified, knowledge-based, and industrially advanced. It highlights the critical need to reduce the country's dependency on unprocessed mineral exports and to instead focus on domestic value addition through processing and refinement.

In line with these goals, the proposed criteria prioritize minerals that are not only strategically important for the global transition to green and digital technologies, but also those that offer potential for domestic beneficiation. This includes encouraging the development of downstream industries such as mineral processing, metallurgy, and advanced manufacturing. By promoting minerals with high economic value, strong industrial linkages, and potential for technological integration criteria, this criteria puts more importance in it (weightning) when evaluating criteria.

Moreover, Vision 2050 underscores the importance of balanced regional development and equitable economic opportunities across the country. The suggested criteria incorporate regional development considerations by recognizing minerals that can serve as anchors for local economic growth, infrastructure development, and job creation in underdeveloped areas. This ensures that the benefits of mineral resource development are not concentrated in a few regions but contribute to nationwide prosperity.

Overall, the suggested criteria are not only analytically considered but also highly practical. They offer a direct and actionable tool for policymakers to align mineral sector governance with national development priorities. By focusing on value-added processing, industrial diversification, and regional inclusiveness, the framework provides a strategic pathway to achieving the long-term goals outlined in Vision 2050, thereby enhancing the sustainability and resilience of Mongolia's economic development.

4.3 Limitations of the Suggested Criteria

Although the proposed criteria system offers a structured and comprehensive approach, it is not without limitations. One of the main challenges is the reliance on reliable and up-to-date data. For many minerals, especially those that are underexplored or not currently prioritized within Mongolia's mining strategy such data may be incomplete or unavailable. This makes it difficult to apply the framework consistently across the full range of potential mineral resources.

The framework also assumes a certain level of political, economic, and regulatory stability. However, Mongolia's mining sector has experienced shifts in government policy, regulatory approaches, and investment climates in the past. These fluctuations could affect the relevance of some criteria or the strategic importance of specific minerals over time. For example, a mineral currently considered valuable for domestic processing may lose its importance due to changes in market demand or technological developments.

Some assessment factors in the criteria—such as "regional economic impact" or "potential for domestic processing"—are more difficult to measure in practice. These elements often require expert judgment and contextual knowledge, which may vary.

Without clear guidelines or standardized methods, there is a risk that different evaluations could produce inconsistent or biased results.

Moreover, because the methodology uses both qualitative and quantitative data, there is a possibility of subjectivity influencing the scoring process. This could affect the objectivity of the final outcomes if strong oversight and clear procedures are not in place. To ensure fair and reliable assessments, it is important to have institutional support, technical expertise, and transparent evaluation processes.

4.4 Future Research Directions

As Mongolia continues to define and refine its national approach to critical minerals, further research is essential to ensure that the proposed criteria remain effective, inclusive, and responsive to the evolving domestic and global context. While this thesis presents criteria within its limitations, its real-world implementation requires deeper investigation, continuous data collection, and cross-sector validation. Future studies should focus on the empirical application of this work to a broader range of minerals under various scenarios, particularly concentrating on real-time trends in mineral demand, political shifts, and technological innovation.

A key priority for future research should be the case study testing of the methodologies. Selected minerals such as lithium, rare earth elements (REEs), graphite, and tungsten For Mongolia, case studies would allow researchers to assess how well the framework captures the complexity of each mineral’s role, from export readiness to geopolitical dependencies, and provide practical insights for adjustment.

Another crucial area is the integration of Environmental, Social, and Governance (ESG) factors. Currently, the framework emphasizes economic and strategic indicators but does not fully address environmental costs, land rights, or community consent issues that are becoming increasingly central to sustainable resource governance. Future research should explore how to incorporate ESG measures directly into the scoring system. For example, a mineral's lifecycle emissions, potential for local pollution, or community resistance could significantly impact its strategic desirability. This would help align the criteria with global sustainability norms and improve public trust in national mineral strategies.

Moreover, regional-level disaggregation of mineral impacts is a promising direction for future research. Mongolia is vast and geologically diverse, and mineral development often affects certain provinces more than others. Evaluating the regional development potential of minerals such as their ability to reduce rural poverty or stimulate infrastructure growth would enhance the granularity and inclusiveness of the criteria. This could also inform government priorities when deciding between large-scale national projects and smaller, community-centered initiatives.

The evolving geopolitical environment also requires that future research includes scenario planning. Trade relationships, international sanctions, supply chain shifts, and global market disruptions can dramatically alter the criticality of certain minerals. Forecasting tools and simulation models, combined with studies on diplomacy and security, could help strengthen Mongolia's ability to predict and prepare for external disruptions.

Finally, this research area would greatly benefit from interdisciplinary collaboration. Geologists can refine resource potential estimates, economists can assess value chain impacts, environmental scientists can provide insights into sustainability risks, and policy experts can guide institutional reforms. Partnering with international organizations such as the Asian Development Bank, UNDP, or the World Bank could also provide Mongolia with technical expertise, funding, and regional insights.

In conclusion, this work should not be seen as static but as a dynamic tool. It must evolve alongside Mongolia's economic goals, environmental realities, and international partnerships. Future research will play a crucial role in shaping this evolution by expanding the model, refining its assumptions, and ensuring its legitimacy and relevance in the long term.

5. Conclusion

5.1 Summary of Findings

This thesis directly addressed a significant blind spot in Mongolia's mineral development strategy: the lack of a clear method for picking out and ranking critical minerals. By looking at how other countries do it and shaping those ideas to fit Mongolia's economy and long-term aims, this work built a weighted, multi-party system that can be used for national mineral planning. The findings show that this kind of model can help Mongolia see its immediate priorities and future chances more clearly by sorting minerals into three main groups: those already bringing in money, those with potential in the near future, and those strategically important for the long-run.

Coming up with these criteria took a lot of thought. Many first seemed obvious or too general. But actually assessing them turned out to be much more complex, needing detailed sub-considerations, lots of data, and input from experts. So, the scale used, based on Mongolia's development goals and learning from other countries, highlights that Mongolia needs to focus not just on what the world currently demands, but more on minerals that have a high risk of supply issues or trade limits, since Mongolia's economy already leans heavily on mining. Also, not being able to fully process minerals here made considering these critical factors and their importance in the weighting crucial.

Even with this complexity, to achieve the goals of the development plan, there needs to be a focus on creating more value from the minerals, making the economy more diverse, and building more partnerships with countries around the world.

5.2 Contributions to the Field

This thesis contributes to a Mongolia-specific model for critical mineral classification, which has not previously been proposed in published academic literature. It also contributes methodologically by offering a criteria-based structure that is both policy-aligned and internationally informed. Although inspired by frameworks from the U.S., EU, and Australia, the suggested model is tailored to Mongolia's resource base, development challenges, and national goals.

This could serve as a reference for other decision-maker, future researchers who are developing and deeply researching about defining critical minerals tailored to Mongolia.

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