

Strategic Potential of DPRK's Mineral Resources for Integration into Global Critical Mineral Supply Chains

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Strategic Potential of DPRK's Mineral Resources for Integration into Global Critical Mineral Supply Chains

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Abstract

The Democratic People's Republic of Korea (DPRK, commonly known as North Korea) is widely recognized as a resource-rich country with potentially significant rare earth elements (REEs), graphite, magnesite, and tungsten, yet its mineral resources remain largely disconnected from global critical mineral supply chains. This study assesses their long-term strategic potential by combining cross-source evidence evaluation with a five-dimensional comparative risk matrix covering resource confidence, processing capability, infrastructure, institutional and investment conditions, and sanctions exposure. The analysis compares reported resource estimates with peer-reviewed reassessments, production evidence, and foreign investment experiences in the DPRK.

The results reveal substantial differences in evidentiary confidence and development readiness across the four mineral groups. REEs and tungsten face the highest relative development risks, reflecting weak deposit-level verification, limited processing evidence, and infrastructure constraints, whereas graphite and magnesite have stronger production or project histories. Nevertheless, the relatively lower risk scores of graphite and magnesite should not be interpreted as evidence of near-term investability, as sanctions exposure, institutional discontinuity, and infrastructure constraints remain significant across all four mineral groups.

The DPRK should therefore be viewed not as an immediate alternative supplier but as a contingent, long-term option for supply chain diversification. Realizing this potential would require independent resource verification, technological and infrastructure upgrading, credible investment and contractual arrangements, and changes in the geopolitical and sanctions environment.

Keywords: DPRK; Critical minerals; Supply chain diversification; Economic security; Geopolitics

JEL Classification: Q32; Q34; F51; L72

1 Introduction

The global energy transition has become inseparable from geopolitical competition over critical minerals. Initially driven by the climate objectives of the Paris Agreement, the energy transition has increasingly evolved into a strategic reorganization of global industrial supply chains to secure access to critical mineral resources. Recent geopolitical developments have further highlighted the strategic importance of these resources, demonstrating that critical minerals are essential not only to clean energy technologies but also to national security, technological competitiveness, and economic resilience. Consequently, critical minerals are no longer viewed merely as industrial inputs for decarbonization but increasingly as strategic assets shaping economic security and geopolitical influence.

This geostrategic importance is reinforced by the growing imbalance between rapidly increasing demand and the limited availability of critical mineral supplies. According to the International Energy Agency (IEA), demand for key critical minerals is projected to increase sharply under the Net Zero Emissions (NZE) Scenario by 2040, with lithium demand rising approximately ninefold, graphite nearly fourfold, and nickel, cobalt, and rare earth elements (REEs) approximately doubling relative to 2023 (IEA 2024). Recent market developments suggest that this projected increase in demand is already materializing: global lithium demand increased by nearly 30% in 2024, while demand for nickel, cobalt, graphite, and REEs also continued to rise, largely driven by clean energy technologies (IEA 2025). These developments highlight

that securing reliable supplies of critical minerals has become an essential prerequisite for achieving global decarbonization goals (Zhu et al. 2025; Gielen et al. 2019; Sovacool et al. 2020).

Against this backdrop of surging demand, the geographic concentration of production and processing has emerged as a defining structural vulnerability of the energy transition. China dominates the mining and processing of several critical minerals, particularly rare earth elements (REEs), and maintains a leading position in the refining of lithium, cobalt, and graphite (CSIS 2024; IEA 2024). This concentration has heightened concerns about resource nationalism and resource weaponization, in which critical minerals are increasingly used as instruments of geopolitical leverage through export controls and other trade measures (Hynek 2023; Vekasi 2023; Yang 2024). These developments have reinforced the recognition that supply chain resilience has become an essential component of economic security.

Major economies have responded by actively pursuing supply chain diversification through strategic industrial policies and international cooperation. In the United States, recent policy initiatives have evolved from the Minerals Security Partnership (MSP) toward the 2026 Critical Minerals Ministerial and the Forum on Resource Geostrategic Engagement (FORGE), while the European Union has promoted the Critical Raw Materials Act (CRMA) to strengthen resilient and diversified critical mineral supply chains (Vivoda and Loginova 2024; Overland and Loginova 2023; European Commission 2024). Together, these initiatives reflect a growing international consensus that excessive dependence on a single supplier of critical minerals poses significant risks to economic security and industrial competitiveness (Gulley et al. 2018; Gielen et al. 2019; Overland 2019).

Despite these diversification efforts, current strategies remain largely focused on politically aligned suppliers with established investment environments. Consequently, relatively little attention has been paid to resource-rich regions that remain excluded

139 from global supply chains because of geopolitical or institutional constraints ([Vivoda](#)
140 [and Loginova 2024](#); [Overland and Loginova 2023](#)). This suggests that achieving long-
141 term supply chain resilience may require a broader perspective that considers not only
142 existing partner countries but also the future strategic potential of resource holders
143 that are currently inaccessible.

147 Previous studies on the Democratic People’s Republic of Korea (DPRK) have
148 concentrated on geological characterization, resource potential, and the historical and
149 political context of extraction. [Park et al. \(2023\)](#) reassessed reported critical-metal
150 occurrences, including REEs, lithium, and beryllium, and emphasized the need for
151 additional exploration before economic significance can be established. Deposit-scale
152 studies have also clarified the geology of sites such as the Apdong Nb-Ta deposit ([Kim](#)
153 [et al. 2023](#)). From a different perspective, [Winstanley-Chesters \(2018\)](#) used captured
154 administrative records, mine plans, and production documents to show that extraction
155 was embedded in political institutions, social infrastructure, and projects of socialist
156 modernity. This historical work indicates that mineral assets are shaped not only by
157 geology and project economics but also by ownership, state control, labor organization,
158 infrastructure provision, and political legitimacy.

167 These research strands leave an unresolved question: how do uncertain resource
168 evidence and institutionally embedded extractive structures interact with contem-
169 porary processing constraints, investment conditions, sanctions, and global supply
170 chain requirements? The present study addresses this gap by translating geological
171 and political-institutional evidence into comparable dimensions of resource confidence,
172 processing capability, infrastructure, investment conditions, and sanctions exposure.

177 Against this background, the DPRK warrants renewed attention as a resource
178 holder that remains largely excluded from global critical mineral supply chains. Insti-
179 tutional and commercial sources report substantial mineral occurrences and resource
180 estimates, but most are based on historical records, government disclosures, or indirect
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assessments rather than internationally recognized reporting standards such as JORC or NI 43-101 (Park et al. 2023; KOMIR 2025). Political uncertainty and sanctions have also restricted foreign participation, as illustrated by the contrasting experiences of Chinese, South Korean, and other investors (U.S.-China Economic and Security Review Commission 2010; KOMIR 2025; Noland and Stanton 2012).

Accordingly, this study evaluates the long-term strategic potential of DPRK mineral resources through a supply chain perspective. It reviews reported mineral endowment and development conditions, examines global supply concentration and resource weaponization, compares foreign investment experiences, and applies a cross-source confidence assessment and comparative risk matrix to four priority mineral groups. The analysis is intended to identify the conditions under which DPRK minerals could become a contingent diversification option rather than to present them as an immediately available supply source.

1.1 Data and analytical approach

To improve transparency and reproducibility while retaining the study’s review-based structure, this study applies two connected semi-quantitative procedures. The first evaluates the credibility of reported resource evidence for four priority mineral groups—REEs, graphite, magnesite, and tungsten. The second translates that evidence and the relevant above-ground conditions into a five-dimensional comparative risk matrix.

For the first procedure, all reported values are coded according to mineral, deposit, reference year, quantity, unit, grade basis, reporting category, and source lineage. Mineral occurrence, mineralization potential, reported resources, reserves, designed production capacity, estimated production, and realized production are treated as distinct categories. Consequently, a subsurface resource estimate is not compared directly with annual production or designed capacity.

231 Evidence is classified through a four-level, claim-specific hierarchy. Level 1 consists
232 of commercial or media claims for which the underlying exploration method is not
233 publicly disclosed. Level 2 consists of government or institutional estimates compiled
234 from historical records or indirect investigations. Level 3 consists of peer-reviewed geo-
235 logical reassessments, sample-based studies, or other studies in which the analytical
236 basis is disclosed. Level 4 consists of direct evidence of activity or output, including
237 dated satellite observations, documented commercial production, and verified ship-
238 ments. The hierarchy is applied to the specific claim being evaluated: for example,
239 satellite imagery may provide Level 4 evidence of surface activity, but it does not
240 directly verify subsurface tonnage or ore grade.

241 Numerical divergence is calculated only where two or more sources report the same
242 deposit, reporting category, unit, and grade basis:

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$$D = \frac{X_{\max} - X_{\min}}{X_{\min}} \times 100,$$

255 where $X_{\max}$ and $X_{\min}$ represent the highest and lowest directly comparable esti-
256 mates. Where deposit coverage, grade basis, or reporting category differs, the estimates
257 are classified as not directly comparable (N/C), and no percentage is calculated. This
258 prevents apparent numerical similarity from being treated as independent confirma-
259 tion when the values derive from different spatial boundaries or share a common
260 institutional source lineage.

261 Resource-confidence categories are fixed before the risk scores are assigned. High
262 confidence requires three independent and methodologically comparable source lin-
263 eages, a divergence of no more than 30%, and clear disclosure of the estimation method.
264 Medium confidence applies where at least two mutually supporting sources or evidence
265 types exist, but the divergence is 30–100%, reporting definitions differ, or one source
266 is based on realized project evidence rather than an independently estimated resource.

Low confidence applies where the estimate depends primarily on one institutional lin- 277
eage, the divergence exceeds 100%, the claim lacks methodological disclosure, or no 278
independent deposit-scale resource assessment is available. 279
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The second procedure evaluates five dimensions: (1) resource and grade uncer- 281
tainty, (2) beneficiation, separation, and refining capability, (3) infrastructure, (4) 282
institutional and investment conditions, and (5) sanctions exposure. Each dimension 283
is scored from 1, indicating very low risk, to 5, indicating very high risk, using the pre- 284
defined anchors in Table 1. To connect the two procedures, the resource-confidence 285
category is converted directly into the first risk dimension: High confidence corresponds 286
to a resource-risk score of 2, Medium confidence to 3, and Low confidence to 4. Scores 287
of 1 and 5 are reserved, respectively, for internationally reportable reserve evidence 288
and for unsupported or non-transparent claims without a usable resource basis. 289
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Equal weighting is used because the matrix is designed as a transparent comparison 297
of development barriers rather than a project-level financial model. The scores are 298
based exclusively on evidence discussed in the preceding sections. Missing information 299
is not replaced with assumed values; instead, the absence of verifiable evidence is 300
reflected in the relevant risk score and confidence assessment. 301
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During manuscript preparation, the authors used OpenAI’s ChatGPT to assist 305
with language editing, structural organization, LaTeX formatting, and consistency 306
checks. The authors reviewed and edited the output, verified the cited sources and 307
quantitative statements, and take full responsibility for the final manuscript. 308
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Table 1 Scoring anchors for the comparative risk assessment.

Dimension	1	2	3	4	5
Resource/grade	Internationally reportable resource/reserve	≥ 3 independent, comparable estimates; $\leq 30\%$ divergence	Multiple but partly inconsistent sources	Single institutional lineage or large divergence	Unsupported or non-transparent claim
Processing	Commercial high-purity output	Commercial concentrate and verified downstream route	Historical or pilot-scale output	Research-stage capability only	No verified capability
Infrastructure	Stable recent operation	Production with manageable constraints	Chronic constraints but limited operation possible	Severe degradation or long interruption	Infrastructure unavailable or unverified
Institution/investment	Enforceable protection	Stable joint operation	State control but documented operation	Recurrent intervention or contractual disputes	No viable protection or repatriation mechanism
Sanctions	No relevant restriction	Licensing or reporting requirements	Indirect constraints	Direct restriction with uncertain exemption	Direct prohibition on trade or investment

Note: Scores 1 and 5 indicate the lowest and highest risk, respectively. The resource/grade score is directly mapped from the cross-source confidence assessment: High = 2, Medium = 3, and Low = 4. A score of 1 requires internationally reportable resource or reserve evidence, whereas a score of 5 indicates that no transparent and usable resource basis is available.

2 Mineral Resources and Mining Conditions in the DPRK	369
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2.1 Mineral Resources in the DPRK	374
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The DPRK is reported to host a diverse range of metallic, non-metallic, and energy	376
minerals, including iron ore, copper, lead–zinc, tungsten, magnesite, graphite, lime-	377
stone, and coal (Chung 2019). Approximately 500 mineral types have been identified,	378
of which about 200 are considered to have industrial or economic value; institutional	379
classifications include 21 metallic and 19 non-metallic mineral groups (Kim et al.	380
2005). A detailed classification of the reported mineral resources is provided in Online	381
Resource 1, Table S1.	382
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Despite the abundance and diversity of mineral occurrences, the actual quan-	388
tity and economic value of DPRK mineral resources remain highly uncertain. No	389
internationally reportable reserve statements are currently available, and most pub-	390
lished estimates are derived from historical exploration records, government reports,	391
or indirect assessments rather than systematic geological investigations conducted	392
under internationally recognized reporting standards (Chung 2019 ; Park et al. 2023).	393
Consequently, geological occurrences, reported resource estimates, and internationally	394
reportable mineral resources or reserves must be distinguished when evaluating the	395
country’s mining potential.	396
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Furthermore, the commercial development of mineral resources is constrained not	403
only by geological uncertainty but also by limited exploration, aging mining infras-	404
tructure, insufficient processing and refining capacity, and restricted access to foreign	405
investment and advanced mining technologies. These factors substantially limit the	406
economic feasibility of many reported mineral deposits, despite their potentially	407
significant geological endowment (Park et al. 2023).	408
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2.1.1 Metallic Minerals

Metallic minerals have historically supported the DPRK’s industrial production and exports. Reported commodities include iron ore, copper, lead, zinc, gold, silver, tungsten, molybdenum, and nickel, with many deposits concentrated in North and South Hamgyong and North and South Pyongan provinces ([Chung 2019](#)). KOMIR’s compiled database identifies approximately 235 metallic mines among 703 reported mining sites ([Korea Mine Rehabilitation and Mineral Resources Corporation n.d.](#)).

The Musan Iron Mine and Geomdeok lead–zinc complex are the most frequently cited large operations, while smaller polymetallic deposits contain copper, tungsten, molybdenum, and precious metals. Their reported scale and grade, however, are drawn mainly from historical or institutional records rather than internationally verified resource models. Commercial development also remains constrained by power shortages, aging equipment, limited processing capacity, and restricted access to investment and technology ([Chung 2019](#); [Park et al. 2023](#)).

2.1.2 Non-metallic Minerals

Reported non-metallic occurrences include magnesite, graphite, apatite, limestone, fluorite, talc, and kaolin. Magnesite and graphite are the most relevant to this study: Daeheung and Ryongyang have historically served as major magnesite production centers, while graphite has gained strategic importance through its use in lithium-ion battery anodes and other advanced technologies ([Chung 2019](#); [Park et al. 2023](#)).

Limestone and apatite remain important for domestic cement and fertilizer production, but mine-level information on grade, capacity, and current operating status is limited. Large institutional resource estimates for non-metallic minerals should therefore be treated as reported resource estimates rather than internationally reportable reserves, and further exploration and technical assessment would be required before commercial potential could be established with confidence.

2.1.3 Critical Minerals

REEs, graphite, and tungsten appear on the final U.S. 2025 List of Critical Minerals, which contains 60 minerals (U.S. Department of the Interior 2025; Park et al. 2023). Magnesium is listed, but magnesite is not separately designated. Because classifications differ across jurisdictions, this study treats magnesite as a strategically relevant industrial mineral associated with refractory and magnesium value chains rather than as a universally classified critical mineral.

REEs are important to permanent magnets, electronics, renewable-energy systems, and defense applications; graphite is a key battery-anode material; and tungsten is used in high-performance industrial and defense products. These uses make the reported DPRK occurrences relevant to long-term supply chain diversification, but strategic relevance does not establish commercial availability.

Despite this potential, considerable uncertainty remains regarding the quantity, grade, and economic recoverability of DPRK critical mineral resources. Many reported REE deposits are relatively low-grade and would require large-scale beneficiation and sophisticated separation processes—technologies currently unavailable in the DPRK—to become economically viable (Park et al. 2023). The absence of independently verified resource and reserve data further complicates long-term assessment. Even if commercially significant deposits are confirmed, modern refining and separation capacity would be required to produce high-purity inputs for battery, semiconductor, and permanent-magnet industries. The source comparison also reveals substantial differences in both data quality and reporting category (Table 2). For REEs, the KOMIR material reproduces national claims of 20–48 million tonnes and deposit-level figures such as approximately 17 million tonnes at Ryongpo with a reported REO grade of 2%. Park et al., by contrast, synthesized approximately 17.5 million tonnes of mineralization across Ryongpo, Cheolsan, and Abdong at an average grade of about 0.5–0.7%, while finding no clear evidence of large-scale activity at the three sites (Park et al.

2023; Korea Mine Rehabilitation and Mineral Resources Corporation n.d.). These figures should not be treated as fully independent resource estimates because they partly share Korean institutional source lineages and do not conform to international reporting standards.

The evidence hierarchy is particularly visible in the REE case. The initial SRE Minerals announcement represents a commercial, pre-drilling claim and reported approximately 216 Mt of mineralization potential at Ryongpo. Korean institutional sources subsequently reported much lower deposit-level figures, while Park et al. reassessed the principal deposits through geological literature and satellite observations. These sources should not be interpreted as three fully independent resource estimates. Rather, they represent different evidentiary levels: a commercial claim, an institutional compilation, and a peer-reviewed reassessment supported by direct observations of surface activity.

Although the approximately 17 Mt institutional figure for Ryongpo and the approximately 17.5 Mt synthesized figure reported by Park et al. appear numerically close, no divergence percentage is calculated because the latter covers three deposits and applies a different grade basis. Their numerical proximity is therefore treated as contextual evidence, not as independent confirmation of a resource estimate.

Graphite has the strongest project-level evidence because the Jeongchon project reached production and shipment. Magnesite also has a documented production history, whereas tungsten lacks recent deposit-scale verification. REEs show the largest gap between strategic attention and evidentiary confidence. Across all four groups, future supply chain relevance depends on independent verification, technological upgrading, infrastructure improvement, and changes in the geopolitical and investment environment.

KOMIR's compiled database identifies approximately 703 mining sites. The largest reported provincial concentrations are in South Pyongan (153 sites), North Hamgyong

Table 2 Cross-source evidence, comparability, and confidence for four priority DPRK mineral groups.

Mineral	KOMIR-reported resource or project evidence	Peer-reviewed reassessment or direct evidence	USGS production evidence	Divergence	Resource confidence
REEs	National claims of 20–48 Mt; Ryongpo reported at approximately 17 Mt with a reported grade of 2% REO; estimation methods and deposit definitions are incomplete.	Park et al. synthesize approximately 17.5 Mt of mineralization across Ryongpo, Cheolsan, and Abdong at an average grade of 0.5–0.7%; satellite imagery shows no clear evidence of large-scale activity at the three sites.	No internationally reportable DPRK reserve statement.	N/C	Low
Graphite	Approximately 2.0 Mt on an FC 100% equivalent basis; the Jeongchon project reports 6.25 Mt of ore at 5.53% fixed carbon, together with documented production and shipment.	No deposit-scale reassessment in Park et al.; Jeongchon provides realized project evidence of beneficiation and concentrate production.	Estimated production of 6,000 t in 2018.	N/C	Medium
Magnesite	Approximately 6.0 Bt on an MgO 45% basis; Daeheung and Ryongyang records report large deposits and historical production.	Project-level data are reproduced in academic literature, but no recent independent deposit-scale resource estimate is available.	Estimated production of 70,000 t in 2018.	N/C	Medium
Tungsten	Approximately 246 kt on a WO ₃ 65% basis.	No recent independent deposit-scale reassessment was identified in the reviewed sources.	USGS-estimated mine-concentrate content of 1,410 t in 2018; no project-level production record was identified.	N/C	Low

Notes: N/C indicates that numerical estimates are not directly comparable, whereas confidence refers to the credibility and convergence of the underlying resource and grade evidence; therefore, N/C does not preclude a Medium confidence assessment where independent evidence types are mutually supportive. The REE values differ in deposit coverage and grade basis, and the KOMIR and Park et al. values partly share Korean institutional source lineages. USGS figures refer to estimated annual production rather than subsurface resources and are not used to calculate resource-estimate divergence. Confidence does not refer to the certainty of historical production.

(94), North Pyongan (85), and South Hamgyong (83). The full regional distribution by mineral category is reported in Online Resource 1, Table S2.

Mining is concentrated in the Hamgyong and Pyongan regions, where major metallic and industrial-mineral sites are located. State ownership and centralized management limit direct foreign participation, although mines such as Musan, Geomdeok, Daeheung, and Ryongyang have attracted external interest because of their reported scale and location (Fig. 1).

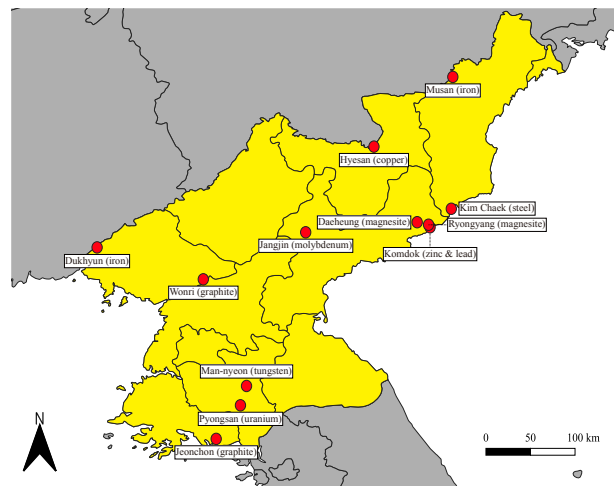


Fig. 1 Location of selected mineral deposits and processing sites in the DPRK. The underlying database identifies approximately 703 mining sites, with the largest reported concentrations in South Pyongan, North Hamgyong, North Pyongan, and South Hamgyong (Online Resource 1, Table S2). Markers identify selected sites; marker color does not indicate operational status or foreign ownership. Base map: Natural Earth (public domain). Map lines delineate study areas and do not necessarily depict accepted national boundaries

2.2 Structural Limitations of Mineral Resource Production in the DPRK

Although the DPRK is considered to possess substantial mineral resources and significant geological potential, its actual mineral production remains far below the estimated resource base (Chung 2019). This discrepancy reflects a range of structural constraints

that limit the exploration, extraction, processing, and commercialization of mineral resources.

The most fundamental constraint is the shortage of electricity. Mining operations, including extraction, beneficiation, transportation, and smelting, require a stable and continuous power supply. However, chronic instability in electricity generation and distribution has made continuous mining operations difficult in many parts of the DPRK (Chung 2019). This limitation is particularly critical for metallic mineral production, where beneficiation and smelting processes require substantial energy inputs.

In addition to power shortages, aging mining equipment and limited technological capacity continue to reduce production efficiency. Many mines rely on obsolete facilities, while modern exploration techniques, mechanized mining systems, and automation technologies have been introduced only to a limited extent. Consequently, production efficiency remains low, and resource recovery rates are significantly below those achieved in modern mining operations (Chung 2019).

Another major limitation is the lack of processing and refining capacity. Most mineral resources require beneficiation and refining before they can be utilized in downstream industries. However, the DPRK lacks modern processing facilities capable of producing high-purity mineral products. This constraint is particularly significant for critical minerals such as REEs and graphite, both of which require advanced separation and purification technologies before industrial application (Park et al. 2023). At Ryongpo, Cheolsan, and Abdong, multi-temporal satellite imagery reviewed by Park et al. (2023) showed no clear evidence of large-scale REE mining or appropriately scaled processing infrastructure. This observation supports an assessment of present activity and infrastructure, although it does not directly determine subsurface resource quantity or grade.

691 Institutional factors further constrain the development of the mining sector.
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693 Operating under a state-led, centrally planned economic system, the DPRK's min-
694 ing industry provides limited opportunities for market-based investment, technology
695 transfer, and international cooperation. As a result, the adoption of modern mining
696 technologies and long-term productivity improvements has remained slow.
697

699 Taken together, these structural constraints—including unstable electricity sup-
700 ply, outdated mining equipment, insufficient processing and refining capacity, and
701 institutional limitations—substantially restrict the commercial development of DPRK
702 mineral resources. Consequently, despite its considerable geological potential, the
703 DPRK has yet to translate its mineral resource endowment into sustainable industrial
704 production.
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712 **2.3 Current Status of Sanctions Against the DPRK**

713
714 One of the most significant constraints on foreign investment in the DPRK mineral sec-
715 tor is the international sanctions regime imposed by the United Nations and individual
716 countries. Since the DPRK's nuclear and missile programs prompted a series of increas-
717 ingly stringent sanctions, international cooperation in mineral resource development
718 has become substantially restricted.
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720

722 In particular, United Nations Security Council (UNSC) Resolutions 2371 and
723 2375 prohibit or severely restrict the export of major DPRK commodities, including
724 coal, iron, iron ore, lead, lead ore, and seafood, with the objective of reducing the
725 country's foreign currency earnings ([United Nations Security Council 2017a,b](#)). As
726 a consequence, international trade and foreign investment in the DPRK mining sec-
727 tor have become extremely limited, significantly reducing opportunities for resource
728 development through international cooperation.
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734 Subsequently, UNSC Resolution 2397 further strengthened existing sanctions by
735 imposing additional restrictions on petroleum products and requiring the repatriation
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of overseas DPRK workers ([United Nations Security Council 2017c](#)). These measures further exacerbated the operational challenges faced by the mining sector, as stable energy supplies are essential to mining, mineral processing, and smelting.

In addition to multilateral sanctions, unilateral sanctions imposed by individual countries, particularly the United States, further restrict financial transactions, technology transfer, and investment cooperation with the DPRK. Secondary sanctions targeting foreign entities conducting business with the DPRK also increase the legal and financial risks associated with mineral resource development projects, thereby discouraging potential investors.

Despite these extensive sanctions, limited mining-related activities involving some Chinese companies have occasionally been reported ([Chung 2019](#)). However, these activities have generally remained small in scale and have not developed into sustained, large-scale international investment projects due to ongoing political and institutional constraints.

Sanctions constrain not only commodity exports but also the organizational form of mineral development. The UN sanctions framework includes restrictions on procuring specified minerals from the DPRK and generally prohibits new joint ventures and cooperative entities with DPRK persons or entities, subject to limited exemptions ([United Nations Security Council 2026](#)). Consequently, even minerals not individually named in a particular commodity prohibition remain exposed to restrictions on finance, technology transfer, shipping, insurance, and joint investment.

In summary, the current sanctions regime continues to impose substantial constraints on international investment and cooperation in the DPRK mining sector. Accordingly, any discussion of future mineral resource development should be interpreted as a scenario based on the easing or removal of sanctions. This assumption constitutes the fundamental analytical premise of the present study. Therefore, the

investment strategies discussed in the following sections are presented as long-term policy scenarios rather than immediate policy recommendations.

3 Global Critical Mineral Dependency and Resource Weaponization

The possible relevance of the DPRK to critical mineral security must be considered within a global system characterized by concentrated mining, processing, and trade. This section distinguishes supply-side concentration from the import dependence of major consuming economies and then examines resource nationalism and resource weaponization.

3.1 Global Supply Concentration and Import Dependence of Critical Minerals

Critical mineral risk arises not only from scarcity but also from the concentration of mining and refining in a small number of countries. In 2022, the top three producing countries accounted for 65–92% of mine production for the minerals shown in Table 3; refining concentration in 2024 ranged from 78% for nickel to 97% for REEs (OECD 2025; IEA 2025).

Table 3 Share of the top three producing countries in mine production and refining of selected critical minerals.

Critical mineral	Mine production (2022)	Refining (2024)
Cobalt	78%	89%
Lithium	92%	96%
Nickel	65%	78%
Rare earth elements (REEs)	90%	97%

Sources: (OECD 2025; IEA 2025).

Supply is therefore concentrated at both the mining and refining stages (Table 3), and this concentration translates into substantial import dependence among major economies (Table 4). The United States remains highly import-dependent for graphite, REEs, cobalt, and tungsten; the EU is especially exposed in heavy-REE separation and refining; and South Korea and Japan rely heavily on China for graphite, REEs, and lithium (U.S. Geological Survey 2025; European Commission 2026; Kim et al. 2024). Canada and Australia are major producers, but both still identify downstream refining concentration as a strategic vulnerability (Government of Canada 2024; Department of Industry, Science and Resources 2023).

Table 4 Dependence on China for selected critical minerals in major economies.

Mineral	South Korea (2023)	Japan (2023)	United States (2020–23)	EU
Natural graphite	98.7%	88.2%	43%	–
Rare earth elements	62.1%	69.9%	70%	100%*
Lithium	54.9%	59.7%	≈0%	–

Note: EU value refers to heavy rare earth elements. EU graphite and lithium are omitted because China’s dominance occurs primarily at the refining and processing stage rather than direct imports. U.S. lithium imports originate mainly from Chile and Argentina.

Sources: (Kim et al. 2024; U.S. Geological Survey 2025; European Commission 2026).

The two tables capture different dimensions of the same structural problem: Table 3 measures concentration on the supply side, whereas Table 4 shows how that concentration is transmitted to importing economies. Supply chain resilience therefore depends on diversified upstream sources as well as processing capacity, stockpiling, and cooperation with reliable partners.

3.2 Resource Nationalism, Resource Weaponization, and Supply Chain Diversification

Resource nationalism encompasses policies through which resource-holding states strengthen control over extraction, foreign investment, exports, and downstream processing. Resource weaponization is narrower: it uses control over strategically important materials as diplomatic or economic leverage (Xu et al. 2024; Hynek 2023; Yang 2024).

Indonesia’s 2020 ban on unprocessed nickel exports illustrates a resource-nationalist effort to attract domestic refining and battery investment. The policy stimulated downstream investment but was challenged by the European Union at the World Trade Organization, demonstrating the tension between industrial upgrading and trade obligations (Xu et al. 2024; Guberman et al. 2024).

China’s position in REE mining, separation, refining, and magnet production provides a clearer example of geopolitical leverage. Since 2023, export controls have expanded from gallium and germanium to graphite, antimony, tungsten-related materials, selected heavy REEs, and permanent magnets (Table 5). The widening scope suggests a shift toward strategic control of multiple upstream and downstream segments rather than a series of isolated trade interventions (IEA 2025; Liu et al. 2023; Moon et al. 2025; CSIS 2025).

Import-dependent states also intervene actively. The United States initiated a Section 232 investigation into processed critical minerals in April 2025, and a January 2026 proclamation directed negotiations with trading partners and contemplated price floors and further import-adjustment measures (The White House 2025, 2026). Project Vault subsequently added strategic financing and stockpiling to this policy mix (Export-Import Bank of the United States 2026). These measures show that supply chain competition involves both producer controls and importer-led trade, financing, procurement, and industrial-policy instruments.

Table 5 China’s critical mineral export controls, 2010–2025

Effective	Targeted product(s)	China’s global position	Downstream exposure	Source
Sep 2010	REEs (embargo on Japan)	Near-total control of global REE supply at the time	Triggered Japan’s diversification; later WTO dispute	(Yang 2024 ; Office of the United States Trade Representative 2014)
Aug 2023	Gallium, germanium	~90% of gallium and ~60% of germanium production	U.S. net import reliance 100% (Ga) and >50% (Ge); China ≈53%/54% of U.S. imports	(Blackwood and DeFilippo 2024)
Dec 2023	Graphite permits	~78% of mine production; refines >90%	Korea ≈93% of anode material, Japan ≈90% of graphite from China; U.S. 33–43%	(Benson and Denamiel 2023 ; U.S. Geological Survey 2025)
Sep 2024	Antimony	48% of global production; 32% of reserves	63% of U.S. antimony imports; defense-critical input	(Baskaran and Schwartz 2024)
Feb 2025	Tungsten, tellurium, bismuth, molybdenum, indium	Leading global tungsten producer	Battery, defense, and electronics inputs	(Moon et al. 2025)
Apr 2025	Medium/heavy REEs + permanent magnets	~100% of heavy REE separation and refining	EU 100% dependent on China for heavy REEs; magnet chains globally exposed	(CSIS 2025 ; European Commission 2026)

For the DPRK, this environment creates two simultaneous conditions. Its reported mineral occurrences may attract long-term strategic interest, but sanctions, institutional uncertainty, and limited processing capacity prevent meaningful near-term participation. The following section therefore examines foreign investment experiences to identify the above-ground risks that have repeatedly constrained development.

967 **4 Foreign Investment Experiences in the DPRK**
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969 **Mineral Sector**
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972 **4.1 Chinese Investment and Sanctions Circumvention**
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974 China was the largest foreign investor in the DPRK before the tightening of interna-
975 tional sanctions, accounting for an estimated 57% of FDI stock, with mining among
976 the principal sectors ([Lee 2021](#)). Projects were generally structured as joint ventures
977 in which the DPRK provided mining rights, resources, and labor while Chinese firms
978 supplied capital, equipment, and technical expertise. DPRK entities often retained
979 substantial management control ([Korea Mine Rehabilitation and Mineral Resources](#)
980 [Corporation n.d.](#)).
981
982 Project histories reveal the fragility of this model. The Musan iron project was sus-
983 pended after contractual disputes, and wage and equity demands reportedly prompted
984 the temporary withdrawal of Chinese personnel from the Hyesan copper project ([Korea](#)
985 [Mine Rehabilitation and Mineral Resources Corporation n.d.](#)). Weak contract enforce-
986 ment, administrative intervention, infrastructure deficiencies, and inconsistent product
987 quality further raised costs and reduced commercial reliability ([Lee 2021](#); [Chung 2019](#);
988 [Choi et al. 2015](#)).
989
990 Following the progressive strengthening of United Nations Security Council sanc-
991 tions after 2016, official mineral trade and new investment activities were largely
992 suspended. UN Panel of Experts reports subsequently documented sanctions-evasion
993 activities, including coal shipments involving reported disabling of Automatic Identi-
994 fication System (AIS) transponders and ship-to-ship transfers. These reports concern
995 alleged sanctions-evasion trade rather than legitimate international investment and
996 should not be read as evidence of continued formal investment ([United Nations](#)
997 [Security Council 2021, 2022](#)).
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Accordingly, China’s experience provides two analytically distinct forms of evidence. Pre-sanctions projects illuminate joint-venture structures, management control, infrastructure investment, and contractual instability. Post-sanctions transactions indicate continuing demand under restrictive legal conditions but do not demonstrate stable or sustainable foreign investment.

4.2 South Korean Investment and Inter-Korean Cooperation

Inter-Korean mineral cooperation expanded during the 2000s as South Korea sought industrial raw materials and the DPRK sought foreign exchange and mining modernization. KORES (now KOMIR) led joint surveys and projects at sites including Jeongchon graphite, Geomdeok lead–zinc, and the Ryongyang and Daeheung magnetite mines ([Chung 2014](#)).

The Jeongchon project provides the clearest evidence of implementation. It was organized as a 50:50 joint venture: the South Korean side supplied mining, beneficiation, and transport equipment, while the DPRK side provided mining rights, land, labor, electricity, and water. The project reported 3,154 t of production during 2007–2009 and 850 t of shipments to South Korea by 2010 ([Korea Mine Rehabilitation and Mineral Resources Corporation n.d.](#)). Private firms also pursued anthracite and dimension-stone projects, although most remained limited or incomplete.

These projects did not survive deteriorating political relations, the May 24 Measures, and the strengthening of international sanctions. The experience shows that demonstrated production capability and product specifications were insufficient to ensure continuity without a predictable political and investment environment ([Chung 2014](#)).

1059 4.3 Other International Investment Experiences

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1061 Investment from countries other than China and South Korea was generally small and
1062 concentrated in surveys, feasibility studies, preliminary negotiations, or one-off com-
1063 mitments ([Lee 2021](#); [Chung 2019](#)). Few initiatives progressed to sustained commercial
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1065 operation.
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1067 This limited participation reflects weak investor protection, uncertainty over
1068 contract enforcement and profit repatriation, inadequate power and transport infras-
1069 tructure, and growing restrictions on finance and technology transfer. Abundant
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1071 reported mineral occurrences were therefore insufficient to attract durable invest-
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1073 ment without transparent governance, reliable legal protections, and a favorable
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1075 international environment.
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1082 4.4 Implication of Previous Foreign Investment Experiences

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1084 The investment experiences discussed above illustrate both the strategic potential
1085 and the practical limitations of developing DPRK mineral resources. Although widely
1086 reported mineral occurrences attracted interest from several countries and companies,
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1088 most investment and cooperation projects did not develop into stable, long-term oper-
1089 ations. The outcomes show that resource potential alone was insufficient to overcome
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1091 political, institutional, and contractual risks ([Table 6](#)).
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1093 The comparison shows that capital commitments and commercial interest did not
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1095 overcome uncertainty over management control, contract enforcement, political rela-
1096 tions, and sanctions. South Korean projects likewise demonstrate that technically
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1098 implemented cooperation can be halted by political discontinuity, while most other
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1100 international initiatives remained preliminary.
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1102 Taken together, these cases identify above-ground conditions—investment security,
1103 contract enforcement, political relations, infrastructure, and sanctions—as the most
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Table 6 Comparison of foreign investment experiences in the DPRK mineral sector.

Investor	Pre-sanctions scale and structure	Continuity and interruption	Post-sanctions status and interpretation
China	Approximately 57% of DPRK FDI stock; mining was a major sector. Chinese parties generally supplied capital, technology, and equipment, while the DPRK provided resources and labor and retained substantial management control.	Project-specific and intermittent; contractual disputes, renegotiation, and operational interruptions affected several projects.	Formal large-scale investment and mineral trade became heavily constrained. Reports of disabled AIS transponders or ship-to-ship transfers concern sanctions-evasion trade and are not treated as evidence of FDI continuity.
South Korea	Public- and private-sector projects included the Jeongchon graphite joint venture and surveys of major magnesite and lead-zinc mines.	Documented production and shipment occurred at Jeongchon, but most cooperation halted after the deterioration of inter-Korean relations and the May 24 Measures.	Projects remain suspended; prior production demonstrates technical capability but not political or institutional continuity.
Others	Generally small or one-off commitments involving surveys, feasibility studies, preliminary negotiations, or announced infrastructure-for-resource arrangements.	Limited; few initiatives progressed to sustained commercial operation.	Most projects remained preliminary, stalled, inactive, or unimplemented.

Sources: (Lee 2021; Chung 2014, 2019; Korea Mine Rehabilitation and Mineral Resources Corporation n.d.; United Nations Security Council 2021, 2022); USGS Minerals Yearbook 2020–21.

immediate barriers to development. The evidence assessment also shows that geological and metallurgical uncertainty remains material for several priority minerals.

4.5 Comparative Risk Assessment of Priority Minerals

Table 7 applies the scoring anchors in Table 1 to the four priority mineral groups. Institutional and sanctions risks are assessed at the country level rather than the mineral level because, under current conditions, the DPRK investment environment and the common restrictions affecting foreign investment, joint ventures, finance, technology transfer, and market access are binding across all four mineral groups. Mineral-specific

variation is therefore captured through the resource, processing, and infrastructure dimensions.

Equal weighting is used because the matrix is intended as a transparent comparison rather than a project-level investment model. The scores are based on the evidence reviewed in the preceding sections. Where mineral-specific evidence is limited, uncertainty is reflected in the relevant resource, processing, or infrastructure score rather than concealed through assumed values.

Table 7 Comparative risk matrix for selected DPRK mineral groups under current conditions.

Mineral	Resource	Processing	Infrastructure	Institution	Sanctions	Total
REEs	4	5	5	4	5	23
Graphite	3	3	3	4	5	18
Magnesite	3	3	3	4	5	18
Tungsten	4	3	4	4	5	20

Note: 1 = very low risk; 5 = very high risk. Institution and sanctions scores are country-level assessments and are therefore held constant across the four mineral groups. The resource score is mapped directly from the cross-source confidence assessment in Table 2: High confidence = 2, Medium confidence = 3, and Low confidence = 4. A score of 1 requires internationally reportable resource or reserve evidence, whereas a score of 5 indicates that no transparent and usable resource basis is available. The matrix compares relative development barriers under current conditions and does not constitute a mineral resource or reserve estimate, or a project feasibility analysis.

Graphite and magnesite receive the lowest relative totals because documented production or processing histories provide stronger evidence of operational capability. Graphite’s medium resource-confidence rating is supported by the Jeongchon project’s reported ore grade, realized concentrate production, and shipment record. Magnesite likewise has a long production history and deposit-level institutional records, although its large reported resource estimates remain unverified under internationally recognized reporting standards. These lower relative scores do not imply near-term investability: both mineral groups remain highly exposed to sanctions, infrastructure deficiencies, and institutional discontinuity.

REEs receive a resource-risk score of 4, a processing score of 5, and an infrastructure score of 5. The processing and infrastructure scores are supported by the multi-temporal satellite analysis of Ryongpo, Cheolsan, and Abdong presented in Figs. 4–6 of [Park et al. \(2023\)](#). At Ryongpo, the limited change in the apparent mine-waste or tailings area over time suggests that mining activity was discontinued or remained exceptionally small, while no appropriately scaled milling facility was identified near the reported deposits. No obvious large-scale mining or processing infrastructure was identified at Cheolsan or Abdong, although the precise locations of these two deposits remain uncertain.

The infrastructure score of 5 therefore reflects the absence of verified, operationally scaled infrastructure in the available evidence, rather than evidence that no infrastructure of any kind exists. Satellite imagery is used to assess observable surface activity and facilities, but it is not treated as validation of subsurface tonnage, ore grade, or economic recoverability.

Tungsten receives a processing-risk score of 3 because the USGS reports estimated mine-concentrate content of 1,410 t in 2018, providing evidence of historical or limited concentrate production rather than research-stage capability alone. However, this estimate is not supported by recent project-level information on the producing mine, operating facilities, concentrate quality, recovery rates, or production continuity. No verified downstream route from concentrate to high-purity tungsten products was identified. Tungsten therefore remains relatively high-risk overall because its resource evidence is weak and its infrastructure and downstream processing conditions remain poorly documented. Overall, the matrix refines the paper’s original argument: above-ground conditions remain the most immediate barriers, but their effects vary by mineral and interact with unresolved resource and metallurgical uncertainty.

1243 5 Conclusion

1244

1245 This study assessed the long-term strategic relevance of four reported DPRK min-
1246 eral groups by combining a cross-source evidence evaluation with a five-dimensional
1247 comparative risk matrix and a review of foreign investment experience. The results
1248 show marked differences in both evidence quality and development readiness. Graphite
1249 has the strongest project-level record because the Jeongchon project reached bene-
1250 ficiation, production, and shipment, while magnesite has a documented production
1251 history. REEs and tungsten, by contrast, show larger gaps between strategic interest
1252 and deposit-level verification.

1253

1254 The REE evidence hierarchy summarized in Section 2.1.3 illustrates why reported
1255 endowment cannot be equated with an economically recoverable reserve. Commer-
1256 cial claims, institutional estimates, and peer-reviewed reassessment differ in method,
1257 spatial coverage, grade basis, and evidentiary strength. The available record does not
1258 establish that economic resources are absent, but it does show that strategic attention
1259 currently exceeds the confidence of public geological and operational evidence.

1260

1261 The comparative matrix reaches a consistent conclusion. REEs receive the high-
1262 est relative risk score, followed by tungsten, while graphite and magnesite score lower
1263 because of stronger production or processing histories. These rankings do not identify
1264 immediately investable projects: sanctions and institutional risk remain high across all
1265 four groups, and even the lower-scoring minerals require updated resource verification,
1266 metallurgical testing, infrastructure rehabilitation, transparent contractual arrange-
1267 ments, environmental and social due diligence, and verified downstream routes. The
1268 DPRK should therefore be viewed as a contingent long-term diversification option
1269 rather than a near-term supplier.

1270

1271 Two pathways warrant further comparison. A limited bilateral reopening could con-
1272 nect DPRK minerals primarily to existing China-centered investment, transport, and
1273 processing networks. A multilateral, standards-based pathway would require greater
1274

transparency and independent verification but could provide broader diversification
benefits. Expanding U.S. trade, strategic-financing, and stockpiling measures may
eventually place DPRK minerals between established China-centered networks and
emerging U.S.-aligned mineral-security arrangements ([The White House 2025, 2026](#);
[Export-Import Bank of the United States 2026](#)). Future research should compare the
commercial, institutional, social, environmental, and geopolitical implications of these
pathways at the mineral and project levels.

The study contributes by distinguishing reported occurrences, institutional
resource estimates, production evidence, and internationally reportable reserves; link-
ing evidence confidence to a reproducible mineral-level risk matrix; and integrating
geological uncertainty with the political and institutional characteristics of extractive
development in the DPRK.

Supplementary information

Online Resource 1: Supplementary Tables S1 and S2 provide the detailed institu-
tional classification of reported DPRK mineral resources and the reported provincial
distribution of mining sites.

Data availability

This study is based on published academic literature, official policy documents, pub-
licly available reports, and institutional project records cited in the manuscript. No
new geological sampling, drilling, or proprietary mineral resource or reserve esti-
mation was conducted. The analytical framework and score rationales are reported
in Sect. 1.1 and Tables 1, 2, and 7. Online Resource 1 provides detailed back-
ground data on reported mineral classifications and the regional distribution of mining
sites. Additional coding records may be made available by the corresponding author

1335 upon reasonable request, subject to restrictions applicable to non-public institutional
1336 materials.

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1341

1342 References

1343

1344 Baskaran G, Schwartz M (2024) China's antimony export restrictions: The impact on

1345

1346 U.S. national security. Center for Strategic and International Studies, URL [https:](https://www.csis.org/analysis/chinas-antimony-export-restrictions-impact-us-national-s)

1347

1348 [//www.csis.org/analysis/chinas-antimony-export-restrictions-impact-us-national-s](https://www.csis.org/analysis/chinas-antimony-export-restrictions-impact-us-national-s)

1349

1350 [ecurity](https://www.csis.org/analysis/chinas-antimony-export-restrictions-impact-us-national-s)

1351

1352 Benson E, Denamiel T (2023) China's new graphite restrictions. Center for Strategic

1353

1354 and International Studies, URL [https://www.csis.org/analysis/chinas-new-graphite](https://www.csis.org/analysis/chinas-new-graphite-restrictions)

1355

1356 [e-restrictions](https://www.csis.org/analysis/chinas-new-graphite-restrictions)

1357

1358 Blackwood M, DeFilippo C (2024) Germanium and gallium: U.S. trade and Chi-

1359

1360 nese export controls. Tech. Rep. EBOT-332, U.S. International Trade Commission,

1361

1362 Washington, DC, URL [https://www.usitc.gov/publications/332/executive-briefin](https://www.usitc.gov/publications/332/executive-briefings/ebot-germanium-and-gallium.pdf)

1363

1364 [gs/ebot-germanium-and-gallium.pdf](https://www.usitc.gov/publications/332/executive-briefings/ebot-germanium-and-gallium.pdf)

1365

1366 Choi JH, Kim J, Im S, et al (2015) Economic cooperation between north korea and

1367

1368 china and its implications for inter-korean economic cooperation. Policy Analysis

1369

1370 15-13, Korea Institute for International Economic Policy (KIEP)

1371

1372 Chung WJ (2014) A study on investment potential for development and manufacturing

1373

1374 of mineral resources in North Korea. Tech. Rep. Policy Issue Paper 14-13, Korea

1375

1376 Energy Economics Institute

1377

1378 Chung WJ (2019) Mineral resource industry of North Korea and Two Koreas coop-

1379

1380 eration. Journal of the Korean Society of Mineral and Energy Resources Engineers

56(2):204–211. <https://doi.org/10.32390/ksmer.2019.56.2.204>

CSIS (2024) The consequences of China's new rare earths export restrictions. Center	1381
for Strategic and International Studies, URL https://www.csis.org/analysis/consequences-chinas-new-rare-earths-export-restrictions	1382
	1383
	1384
	1385
	1386
CSIS (2025) China's new rare earth and magnet restrictions threaten U.S. defense	1387
supply chains. Center for Strategic and International Studies, URL https://www.csis.org/analysis/chinas-new-rare-earth-and-magnet-restrictions-threaten-us-def	1388
	1389
	1390
	1391
	1392
	1393
Department of Industry, Science and Resources (2023) Critical minerals strategy 2023–	1394
2030. Tech. rep., Australian Government, no DOI	1395
	1396
	1397
	1398
European Commission (2024) Critical raw materials act: Regulation (eu) 2024/1252.	1399
Tech. rep., European Commission, Brussels, URL https://eur-lex.europa.eu/legal	1400
	1401
	1402
	1403
	1404
European Commission (2026) Critical raw materials. Directorate-General for Internal	1405
Market, Industry, Entrepreneurship and SMEs web page, no DOI	1406
	1407
	1408
Export-Import Bank of the United States (2026) EXIM Approves Project Vault Loan	1409
to Launch America's Strategic Critical Minerals Reserve and Support Manufactur-	1410
ing Jobs. Press release, URL https://www.exim.gov/news/project-vault , accessed	1411
	1412
20 August 2026	1413
	1414
	1415
Gielen D, Boshell F, Saygin D, et al (2019) The role of renewable energy in the global	1416
energy transformation. Energy Strategy Reviews 24:38–50. https://doi.org/10.101	1417
	1418
	1419
	1420
	1421
Government of Canada (2024) Canadian critical minerals strategy annual report 2024.	1422
Canada.ca, no DOI	1423
	1424
	1425
	1426

1427 Guberman D, Schreiber S, Perry A (2024) Export restrictions on minerals and metals:
 1428
 1429 Indonesia's export ban of nickel. Tech. rep., U.S. International Trade Commission,
 1430 Washington, DC, URL [https://www.usitc.gov/publications/332/working-papers/](https://www.usitc.gov/publications/332/working-papers/ermm_indonesia_export_ban_of_nickel.pdf)
 1431 [ermm_indonesia_export_ban_of_nickel.pdf](https://www.usitc.gov/publications/332/working-papers/ermm_indonesia_export_ban_of_nickel.pdf)
 1432
 1433
 1434 Gulley AL, Nassar NT, Xun S (2018) China, the United States, and competition for
 1435
 1436 resources that enable emerging technologies. Proceedings of the National Academy
 1437
 1438 of Sciences 115(16):4111–4115. <https://doi.org/10.1073/pnas.1717152115>
 1439
 1440 Hynek N (2023) Weaponization of interdependence and the geopolitics of critical
 1441
 1442 minerals. Geopolitics <https://doi.org/10.1080/14650045.2023.2192432>
 1443
 1444 IEA (2024) Global critical minerals outlook 2024. Tech. rep., International Energy
 1445
 1446 Agency, Paris, URL [https://www.iea.org/reports/global-critical-minerals-outlook](https://www.iea.org/reports/global-critical-minerals-outlook-2024)
 1447 [-2024](https://www.iea.org/reports/global-critical-minerals-outlook-2024)
 1448
 1449
 1450 IEA (2025) Global critical minerals outlook 2025. Tech. rep., International Energy
 1451
 1452 Agency, Paris, URL [https://www.iea.org/reports/global-critical-minerals-outlook](https://www.iea.org/reports/global-critical-minerals-outlook-2025)
 1453 [-2025](https://www.iea.org/reports/global-critical-minerals-outlook-2025)
 1454
 1455
 1456 Kim G, Lee HK, Lee B, et al (2024) Japan's strategic critical minerals policy and
 1457
 1458 implications for Korea. Kiep policy brief, Korea Institute for International Economic
 1459
 1460 Policy, no DOI
 1461
 1462 Kim N, Han Lee B, Koh SM, et al (2023) Zircon geochronology, Hf isotope, and
 1463
 1464 rare earth element geochemistry of the Apdong Nb-Ta deposit in North Korea. Ore
 1465
 1466 Geology Reviews 154:105327. <https://doi.org/10.1016/j.oregeorev.2023.105327>,
 1467
 1468 URL <https://www.sciencedirect.com/science/article/pii/S0169136823000422>
 1469
 1470 Kim YD, Park HS, Kim SY, et al (2005) A study on the mine development of
 1471
 1472 North Korea and the Inter-Korean mineral resources cooperation. Economic and

Environmental Geology 38(2):197–206	1473
	1474
KOMIR (2025) Investment in North Korean resource development. Tech. rep., Korea	1475
Mine Rehabilitation and Mineral Resources Corporation, Seoul	1476
	1477
	1478
Korea Mine Rehabilitation and Mineral Resources Corporation (n.d.) U.S. investment	1479
in North Korea’s resource development. Tech. rep., Korea Mine Rehabilitation and	1480
Mineral Resources Corporation, Wonju, Republic of Korea, in Korean	1481
	1482
	1483
	1484
Lee JK (2021) Trends and issues of foreign direct investment in North Korea. URL	1485
https://www.kdi.re.kr/eng/research/reportView?pub_no=17419	1486
	1487
	1488
	1489
Liu SL, Fan HR, Liu X, et al (2023) Global rare earth elements projects: New devel-	1490
opments and supply chains. Ore Geology Reviews 157:105428. https://doi.org/10.1	1491
016/j.oregeorev.2023.105428	1492
	1493
	1494
	1495
Moon JW, Xun SY, Chung J, et al (2025) Assessment of critical minerals supply	1496
chain for the United States in perspective of trade restriction by foreign countries.	1497
Resources Policy 110:105726. https://doi.org/10.1016/j.resourpol.2025.105726	1498
	1499
	1500
Noland M, Stanton J (2012) The mining industry of North Korea. Tech. rep., Nautilus	1501
Institute for Security and Sustainability, URL https://nautilus.org/napsnet/napsn	1502
et-special-reports/the-mining-industry-of-north-korea/	1503
	1504
	1505
	1506
OECD (2025) Oecd supply chain resilience review: Navigating risks. Tech. rep., OECD	1507
Publishing, https://doi.org/10.1787/94e3a8ea-en	1508
	1509
	1510
Office of the United States Trade Representative (2014) United States wins victory in	1511
rare earths dispute with China. Office of the United States Trade Representative,	1512
URL https://ustr.gov/about-us/policy-offices/press-office/press-releases/2014/m	1513
arch/us-wins-victory-rare-earths-dispute-china	1514
	1515
	1516
	1517
	1518

1519 Overland I (2019) The geopolitics of renewable energy: Debunking four emerging
 1520 myths. *Energy Research & Social Science* 49:36–40. [https://doi.org/10.1016/j.erss.](https://doi.org/10.1016/j.erss.2018.10.018)
 1521 [2018.10.018](https://doi.org/10.1016/j.erss.2018.10.018)
 1522
 1523
 1524 Overland I, Loginova J (2023) Friend-shoring and critical minerals: Exploring the role
 1525 of the Minerals Security Partnership. *Energy Research & Social Science* 100:103085.
 1526 <https://doi.org/10.1016/j.erss.2023.103085>
 1527
 1528
 1529
 1530 Park S, McNulty TP, Ewing RC (2023) Critical metal resources in the Democratic
 1531 People’s Republic of Korea. *International Geology Review* 65(17):2717–2737. [https:](https://doi.org/10.1080/00206814.2022.2151049)
 1532 [//doi.org/10.1080/00206814.2022.2151049](https://doi.org/10.1080/00206814.2022.2151049), URL [https://doi.org/10.1080/00206814.](https://doi.org/10.1080/00206814.2022.2151049)
 1533 [2022.2151049](https://doi.org/10.1080/00206814.2022.2151049), <https://doi.org/10.1080/00206814.2022.2151049>
 1534
 1535
 1536
 1537
 1538 Sovacool BK, Ali SH, Bazilian M, et al (2020) Sustainable minerals and metals for a
 1539 low-carbon future. *Science* 367(6473):30–33. [https://doi.org/10.1126/science.aaz6](https://doi.org/10.1126/science.aaz6003)
 1540 [003](https://doi.org/10.1126/science.aaz6003)
 1541
 1542
 1543
 1544 The White House (2025) Ensuring national security and economic resilience through
 1545 Section 232 actions on processed critical minerals and derivative products. URL
 1546 [https://www.whitehouse.gov/presidential-actions/2025/04/ensuring-national-sec](https://www.whitehouse.gov/presidential-actions/2025/04/ensuring-national-security-and-economic-resilience-through-section-232-actions-on-processed-critical-minerals-and-derivative-products/)
 1547 [urity-and-economic-resilience-through-section-232-actions-on-processed-critical-m](https://www.whitehouse.gov/presidential-actions/2025/04/ensuring-national-security-and-economic-resilience-through-section-232-actions-on-processed-critical-minerals-and-derivative-products/)
 1548 [inerals-and-derivative-products/](https://www.whitehouse.gov/presidential-actions/2025/04/ensuring-national-security-and-economic-resilience-through-section-232-actions-on-processed-critical-minerals-and-derivative-products/), Executive Order 14272
 1549
 1550
 1551
 1552
 1553 The White House (2026) Adjusting imports of processed critical minerals and their
 1554 derivative products into the United States. URL [https://www.whitehouse.gov/pre](https://www.whitehouse.gov/presidential-actions/2026/01/adjusting-imports-of-processed-critical-minerals-and-their-derivative-products-into-the-united-states/)
 1555 [sidential-actions/2026/01/adjusting-imports-of-processed-critical-minerals-and-t](https://www.whitehouse.gov/presidential-actions/2026/01/adjusting-imports-of-processed-critical-minerals-and-their-derivative-products-into-the-united-states/)
 1556 [heir-derivative-products-into-the-united-states/](https://www.whitehouse.gov/presidential-actions/2026/01/adjusting-imports-of-processed-critical-minerals-and-their-derivative-products-into-the-united-states/), Presidential Proclamation of 14
 1557
 1558
 1559
 1560 January 2026
 1561
 1562 United Nations Security Council (2017a) Resolution 2371
 1563
 1564

United Nations Security Council (2017b) Resolution 2375	1565
	1566
United Nations Security Council (2017c) Resolution 2397	1567
	1568
	1569
United Nations Security Council (2021) Report of the panel of experts established	1570
pursuant to resolution 1874 (2009). S/2021/211	1571
	1572
	1573
United Nations Security Council (2022) Report of the panel of experts established	1574
pursuant to resolution 1874 (2009). S/2022/132	1575
	1576
	1577
United Nations Security Council (2026) Security council committee established pur-	1578
suant to resolution 1718 (2006): Sanction measures. United Nations Security	1579
Council, URL https://main.un.org/securitycouncil/en/sanctions/1718 , accessed 19	1580
August 2026	1581
	1582
	1583
	1584
	1585
U.S.-China Economic and Security Review Commission (2010) Chinese infrastructure	1586
and natural resources investments in North Korea. Tech. rep., U.S.-China Economic	1587
and Security Review Commission, Washington, D.C., URL https://www.uscc.gov	1588
/sites/default/files/Research/ChineseInfrastructureandNaturalResourcesInvestme	1589
ntsInNorthKorea.pdf	1590
	1591
	1592
	1593
	1594
U.S. Department of the Interior (2025) Interior department releases final 2025 list of	1595
critical minerals. U.S. Department of the Interior, URL https://www.doi.gov/node	1596
/63691	1597
	1598
	1599
	1600
U.S. Geological Survey (2025) Mineral commodity summaries 2025. https://doi.org/	1601
10.3133/mcs2025	1602
	1603
	1604
Vekasi K (2023) Politics, markets, and rare earth supply chains: Resiliency indicators	1605
for the US, China, and Japan. Review of Policy Research 40(1):5–28. https://doi.	1606
org/10.1111/ropr.12509	1607
	1608
	1609
	1610

1611 Vivoda V, Loginova J (2024) “Friend-shoring” as a panacea to Western critical mineral
 1612 supply chain vulnerabilities. *Mineral Economics* 37(3):533–546. [https://doi.org/10](https://doi.org/10.1007/s13563-023-00402-1)
 1613 [.1007/s13563-023-00402-1](https://doi.org/10.1007/s13563-023-00402-1)
 1614
 1615
 1616 Winstanley-Chesters R (2018) Rare earth minerals, technology metals and extractive
 1617 landscapes in North Korea’s web of political life. *The Extractive Industries and*
 1618 *Society* 5(1):44–51. <https://doi.org/10.1016/j.exis.2017.12.011>, URL [https://www.](https://www.sciencedirect.com/science/article/pii/S2214790X17300679)
 1619 [sciencedirect.com/science/article/pii/S2214790X17300679](https://www.sciencedirect.com/science/article/pii/S2214790X17300679)
 1620
 1621
 1622
 1623 Xu D, Dou S, Zhu Y, et al (2024) Resource nationalism: The intersection of politics
 1624 and economics. *Humanities and Social Sciences Communications* 11:1423. [https:](https://doi.org/10.1057/s41599-024-03949-8)
 1625 [//doi.org/10.1057/s41599-024-03949-8](https://doi.org/10.1057/s41599-024-03949-8)
 1626
 1627
 1628
 1629 Yang FW (2024) Rare earth and resource nationalism: What happened before and
 1630 after China’s embargo on Japan. *Journal of Contemporary China* pp 1–18. [https:](https://doi.org/10.1080/10670564.2024.2335547)
 1631 [//doi.org/10.1080/10670564.2024.2335547](https://doi.org/10.1080/10670564.2024.2335547)
 1632
 1633
 1634
 1635 Zhu X, et al (2025) Critical mineral constraints pressure energy transition and trade
 1636 toward the Paris Agreement climate goals. *Nature Communications* 16. [https://do](https://doi.org/10.1038/s41467-025-59741-y)
 1637 [i.org/10.1038/s41467-025-59741-y](https://doi.org/10.1038/s41467-025-59741-y)
 1638
 1639
 1640
 1641
 1642
 1643
 1644
 1645
 1646
 1647
 1648
 1649
 1650
 1651
 1652
 1653
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