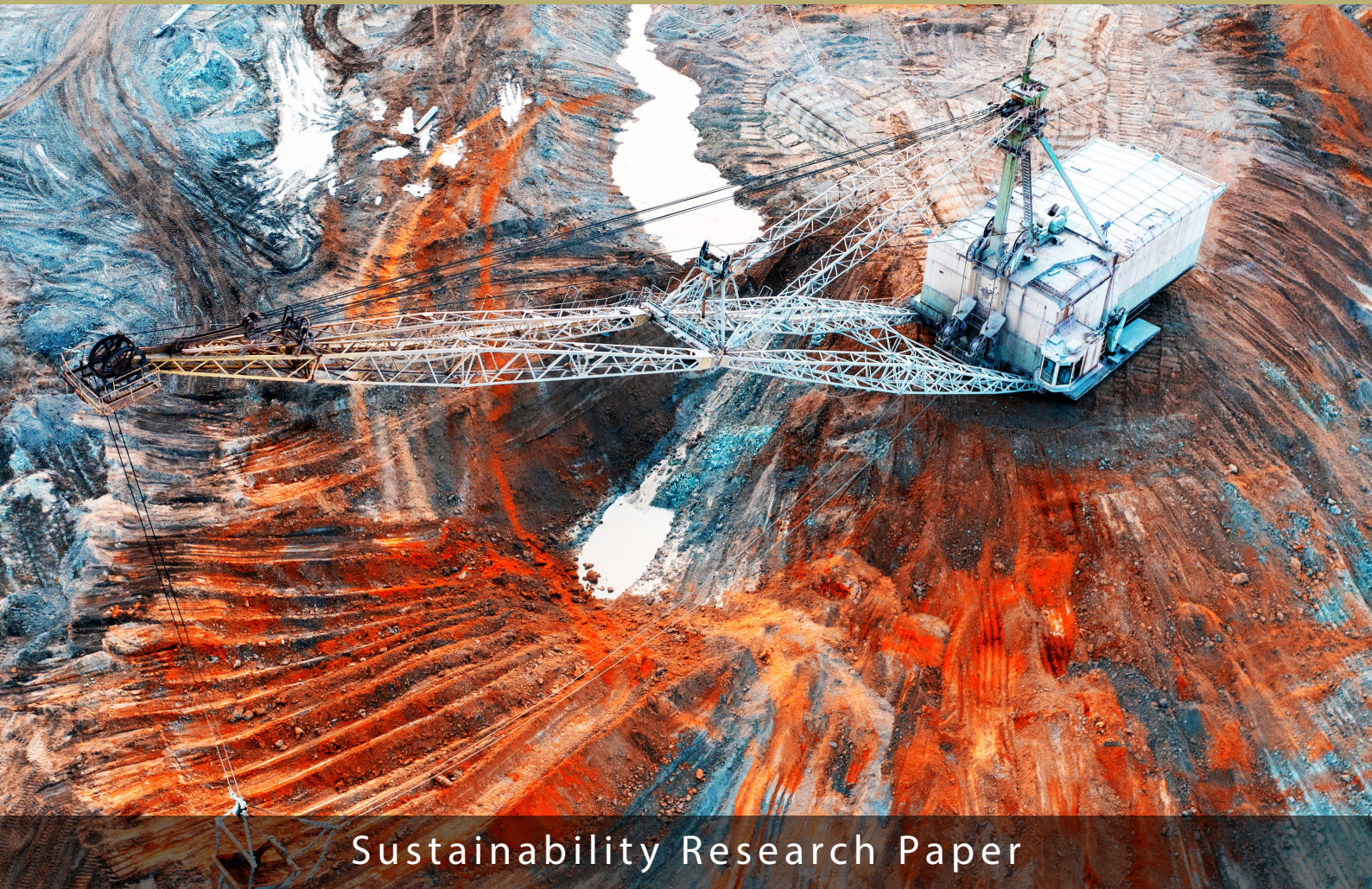




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In Search of Critical Minerals: Challenges and Opportunities



Sustainability Research Paper

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Critical minerals have become central to the global energy transition, advanced manufacturing, digital technologies and defence. As governments place greater emphasis on supply chain resilience and economic security, access to these resources is increasingly shaping industrial policy, geopolitical competition and international partnerships. However, highly concentrated supply chains, long project development timelines and dependence on a small number of processing countries continue to create significant strategic vulnerabilities. What makes a mineral "critical"? Why have critical minerals become a geopolitical priority? What role can the Gulf region play in global critical mineral value chains?

SUSTAINABILITY RESEARCH PAPER

This research paper is part of a 12-month series published by the Al-Attiyah Foundation every year. Each in-depth research paper focuses on a current sustainability topic that is of interest to the Foundation's members and partners. The 12 technical papers are distributed to members, partners, and universities, as well as made available on the Foundation's website.



- Critical minerals are emerging as strategic assets at the centre of the global energy transition, the digital economy, advanced manufacturing and defence. Their growing importance is driving a resurgence of industrial policy, increased geopolitical competition and renewed concerns about supply chain resilience and supply security.
- Criticality is increasingly determined by supply chain concentration, geopolitical exposure and strategic importance rather than volumetric scarcity alone.
- The energy transition, electrification, advanced manufacturing, digitalisation, artificial intelligence and growing defence requirements are driving demand for critical minerals.
- A defining feature of modern industrial policy is the shift from maximising efficiency towards supply chain resilience and security of supply.
- Many critical mineral supply chains remain highly concentrated, creating vulnerabilities to supply disruptions and geopolitical tensions.
- Refining is more concentrated than mining, with the top three countries controlling around 86% of capacity.
- China's dominance across numerous critical mineral value chains demonstrates that processing capacity, industrial capability and downstream integration can generate greater strategic influence than resource ownership alone.
- Bringing new mineral supply to market is a slow, capital-intensive process constrained by exploration, permitting, financing and infrastructure challenges.
- For resource-rich countries, critical minerals provide an opportunity to drive industrialisation, value addition and economic diversification.
- The Gulf region is uniquely positioned to play a growing role in financing, processing and coordinating global critical mineral value chains.



Table 1: Representative Categories of Commonly Recognised Critical Minerals

CRITICAL MINERALS POWER MORE THAN BATTERIES

Key mineral groups underpin clean energy, semiconductors, defence, industry and nuclear technologies

Category	Critical minerals	Key applications
Battery & energy transition minerals	Cobalt, copper, graphite, lithium, manganese, nickel, vanadium	Electric vehicles, battery storage systems, renewable energy infrastructure, electricity networks
Rare earth elements (REEs)	Cerium, dysprosium, lanthanum, neodymium, praseodymium, terbium, yttrium	Permanent magnets, wind turbines, electric vehicles, robotics, defence systems, electronics
Technology & semiconductor metals	Gallium, germanium, indium, silicon, tellurium	Semiconductors, fibre optics, solar PV, telecommunications, advanced electronics
Platinum group metals (PGMs)	Iridium, palladium, platinum, rhodium, ruthenium	Catalysts, hydrogen technologies, fuel cells, automotive applications, industrial processes
Industrial & strategic minerals	Antimony, beryllium, boron, fluorspar, niobium, tantalum, tungsten, scandium	Aerospace, defence systems, specialty alloys, chemicals, advanced manufacturing
Nuclear & advanced energy minerals	Uranium, hafnium, zirconium	Nuclear energy generation, reactors, advanced energy technologies

Al-Attiah Foundation, based on Australian Government (2023) and USGS (2025)

According to the United States Energy Act of 2020, minerals are considered critical if they meet three criteria:

1. Strategically important to the economy or national security.
2. Required for the manufacture of critical products or technologies.
3. Characterised by elevated supply risk or supply chain concentration.

Unlike conventional mineral classifications, criticality is not an inherent characteristic of a mineral itself. Rather, criticality reflects the interaction between a mineral's economic importance and the risk associated with securing a reliable supply.

Consequently, what is considered "critical" varies across countries and over time, shaped by differences in industrial structures, resource endowments, technological priorities, geopolitical considerations and supply chain dependencies. A mineral regarded as critical in one jurisdiction may not be considered critical elsewhere. Furthermore, technological change, market developments and geopolitical events can rapidly alter criticality assessments.^{10,1}



Although there is no universally accepted definition of criticality, nor a universally recognised list of critical minerals, most criticality assessment frameworks are based on the interplay of economic, technological, supply chain, geological and geopolitical dimensions. As a result, critical mineral lists typically comprise a combination of battery minerals, technology metals, rare earth elements (REEs), platinum group metals (PGMs), industrial minerals and specialty metals.^{3,24}

The demand drivers for critical minerals are a result of several converging global trends primarily related to the transition to net zero emissions, decarbonisation of energy systems, modern electricity networks, battery storage systems, proliferation of electric vehicles, hydrogen technologies, advanced manufacturing, semiconductor production, defence modernisation, rapid digitalisation and artificial intelligence.^{14,1,8} Therefore, access to critical minerals is a prerequisite for achieving or maintaining economic competitiveness, technological leadership, energy security and national security.

Unprecedented levels of concern regarding resource scarcity, supply chain vulnerabilities, geopolitical competition and strategic dependencies have challenged long-standing assumptions underpinning the multilateral rules-based trading system. In response, governments across both developed and developing economies are increasingly adopting industrial policies aimed at strengthening strategic sovereignty over critical resources, technologies and supply chains.⁹

The resurgence of industrial policy has been accompanied by the emergence of the concept of "securonomics", a term coined by the UK Chancellor of the Exchequer, Rachel Reeves. Securonomics reflects a shift away from unmanaged free-market economics, and instead prioritising long-term supply chain security, sovereign domestic capability and state-led strategic partnerships.¹⁹

Globalisation reduced the importance of geographic constraints by enabling production to be distributed across international supply chains. However, recent geopolitical events have exposed the vulnerabilities associated with unmitigated free markets. As a result, governments are seeking to re-establish some form of control over critical and strategic resources.^{9,19}

While economic competitiveness remains the dominant driver, governments are increasingly pursuing industrial policy to address a broader range of concerns, including:

- Technological leadership
- National and energy security
- Geopolitical influence
- Supply chain resilience

- Climate change mitigation and decarbonisation
- Domestic industrial development and job creation

This broader set of objectives has led governments to adopt a wide range of policy instruments such as:

- Export restrictions
- Import tariffs and quotas
- Domestic subsidies and grants
- State-backed financing
- Strategic stockpiling;
- Localisation requirements
- Export incentives
- Greater scrutiny of foreign direct investment (FDI)





Industrial policy activity has been concentrated among a relatively small number of major economies, with China, the US and the EU accounting for 48% of global policy measures implemented. Their respective approaches provide useful insights into how governments are responding to the strategic challenges and opportunities presented by critical minerals.⁹

China

China represents perhaps the most advanced example of long-term industrial policy applied to critical minerals. Indeed, many contemporary concerns regarding critical mineral supply chains can be traced to China's emergence as the dominant actor across multiple mining, processing, refining and downstream manufacturing value chains. As a result, governments have become increasingly concerned that a single country represents a potential point of failure for a growing number of strategically important minerals and technologies.

These concerns have been reinforced by several high-profile instances in which China has demonstrated its ability and willingness to leverage its position within critical mineral supply chains.^{3,18}

A landmark example occurred in 2010, when rare earth exports from China to Japan were effectively suspended following a maritime dispute in the East China Sea. In December 2023, China introduced restrictions on the export of certain rare earth extraction, separation and processing technologies, reinforcing concerns among importing nations regarding dependence on Chinese technical expertise and processing capacity. More recently, escalating trade tensions between China and the U.S. have led to a series of export controls on critical minerals and related technologies, including restrictions on gallium, germanium, graphite, antimony, tungsten, selected rare earth elements and rare earth processing technologies.¹⁸

United States

The U.S. has increasingly integrated critical minerals into its broader economic security, industrial policy and foreign policy frameworks. Growing concerns regarding supply chain concentration have elevated critical minerals from a resource issue to a matter of profound geopolitical importance. As evidenced by its efforts to secure critical mineral supply chains through engagement with Ukraine, the Democratic Republic of Congo (DRC) and Greenland.^{18,21}

The contemporary U.S. approach to critical minerals emerged under the Biden administration, primarily through the Inflation Reduction Act (IRA). This represented one of the most significant industrial policy interventions in recent U.S. history, using tax incentives, subsidies, procurement preferences and domestic content requirements to stimulate investment in clean energy technologies, advanced manufacturing, battery supply chains and critical minerals processing. The IRA was particularly significant in linking climate objectives with industrial development.¹⁸

However, the direction of U.S. industrial policy shifted under President Donald Trump's administration. While maintaining a strong emphasis on domestic manufacturing, supply chain resilience, strategic competition and economic security, the focus has shifted away from climate-driven industrial policy towards broader investment, tax and competitiveness measures. The One Big Beautiful Bill (OB BB) effectively supersedes many of the industrial policy ambitions previously associated with the IRA by prioritising investment incentives, domestic production, reindustrialisation and economic growth, rather than climate change mitigation as the primary policy objective.



More broadly, the U.S.'s critical minerals strategy reflects a recognition that access to critical minerals can no longer be treated solely as a trade issue. Instead, critical minerals are increasingly viewed as strategic assets that underpin technological leadership, defence capabilities, energy security and long-term economic competitiveness. Unlike China, whose strategy has focused on building dominance across entire value chains, the US's critical minerals strategy is primarily defensive, seeking to reduce strategic dependence, diversify supply chains and restore domestic industrial capabilities.^{7,14}

European Union

The EU faces one of the most challenging positions on critical minerals and energy security among major economic blocs. Unlike resource-rich regions such as North America, Australia or the Middle East and North Africa (MENA), Europe possesses relatively limited domestic reserves of many critical minerals. It remains highly dependent on imported fossil fuels and raw materials. This dependence exposes European industry to supply disruptions, geopolitical risks and price volatility, contributing to a structural competitiveness gap that is particularly evident in energy-intensive sectors.^{7,14}

For several critical minerals, Europe remains heavily dependent on a single supplier country. For example, China supplies approximately 97% of the EU's magnesium requirements, while Türkiye supplies approximately 99% of the EU's boron. In response, the EU adopted the Critical Raw Materials Act (CRMA), which entered into force in 2024 and represents the cornerstone of the EU's critical minerals industrial policy. The CRMA seeks to establish secure, resilient and sustainable supply chains through a combination of domestic production,

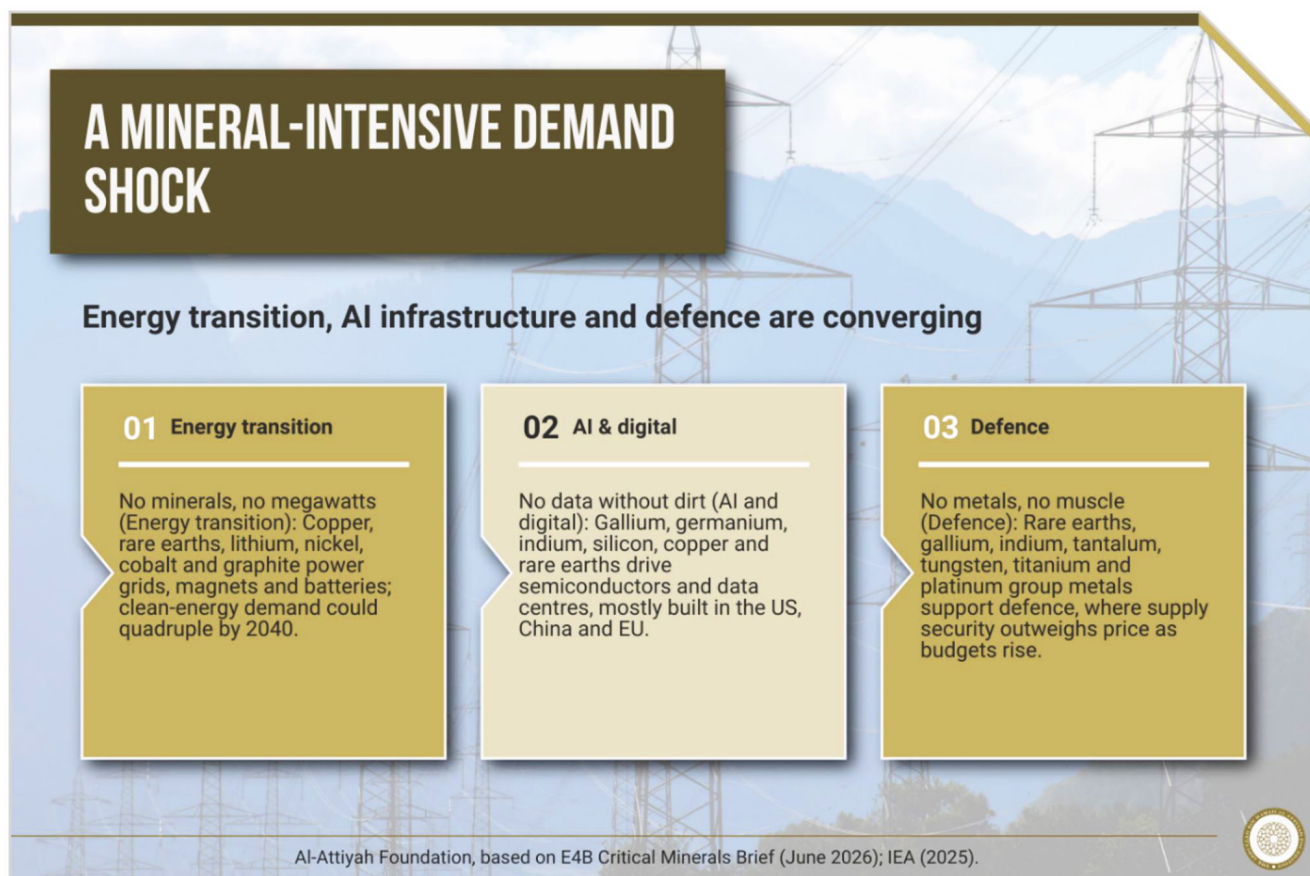
processing, recycling, strategic stockpiling, supply chain monitoring and international partnerships.²⁰

Developed vs Developing Economy Approaches

While critical mineral strategies are often associated with advanced economies, resource-rich developing countries are increasingly adopting industrial policies to maximise value creation, economic diversification and industrial development. A key distinction lies in how criticality is perceived. Net-importing economies typically focus on supply security and reducing external dependencies. In contrast, resource-rich exporting economies tend to view critical minerals as opportunities for beneficiation, industrialisation, value addition and economic transformation. Advanced economies generally rely more heavily on direct grants, subsidies and state aid mechanisms. In contrast, developing economies often favour tax incentives, state-backed financing, equity participation and export-related policy measures.^{9,1}



Infographic 1: A Mineral-Intensive Demand Shock



The demand outlook for critical minerals is being driven by several major global trends, including the energy transition, integrated and decentralised electricity networks, the adoption of electric vehicles, battery storage systems, digitalisation, artificial intelligence (AI), advanced manufacturing and increasing defence expenditure. Collectively, these trends are driving a shift from carbon-intensive systems toward technologies that are significantly more mineral-intensive.^{3,15,1}

No Minerals, No Megawatts

The transition to low-carbon energy systems is the single largest driver of future critical mineral demand. Technologies such as electric vehicles (EVs), battery energy storage systems, wind turbines, solar photovoltaic (PV) systems and smart grids all require substantially

greater quantities of mineral inputs than conventional fossil fuel-based technologies. Copper is essential for transmission networks and electrical infrastructure, while rare earth elements are required for permanent magnets used in wind turbines and electric motors. Battery minerals such as lithium, cobalt, nickel, manganese, graphite and vanadium play critical roles in energy storage technologies and electric mobility.

The International Energy Agency (IEA) estimates that demand for minerals used in clean energy technologies could double by 2030 under its Stated Policies Scenario, nearly triple under the Announced Pledges Scenario and quadruple by 2040 under the Net Zero Emissions Scenario.^{15,20,14} These pathways provide the basis for supply-gap stress testing.¹³



No Data Without Dirt

Alongside the energy transition, rapid digitalisation and the emergence of AI are creating a new source of demand for critical minerals. Data centres, semiconductors, telecommunications infrastructure, fibre optics, cloud computing and AI applications all require large quantities of technology metals and specialty minerals. The IEA projects explosive growth in electricity demand from data centres over the coming decade, with more than 85% of new capacity additions expected to occur in the US, China and the EU.^{14,1,18}

This growth is expected to increase demand for minerals such as gallium, germanium, indium, silicon, rare earth elements and copper, which are essential for semiconductors, integrated circuits, fibre-optic systems, advanced electronics and digital infrastructure.¹⁵

No Metals, No Muscle

Defence has emerged as an increasingly important source of demand for critical minerals. In response to geopolitical tensions and conflicts in Eastern Europe, the Middle East and elsewhere, many countries have significantly increased defence spending. Defence technologies rely heavily on critical minerals including rare earth elements, gallium, indium, tantalum, tungsten, titanium and platinum group metals.

Military demand differs from conventional industrial demand in several important respects. It is generally less sensitive to price fluctuations, places greater emphasis on security of supply than cost efficiency and often drives technological innovation that later diffuses into civilian applications. Lithium demand rose nearly 30% in 2024, yet prices fell by more than 80% from 2023 highs, showing that strong demand alone has not secured new supply.

Geographic Concentration

Unlike manufactured goods, mineral deposits are geographically fixed and can only be extracted where geology permits. As a result, critical mineral supply chains are inherently global and often characterised by significant geographic concentration, creating vulnerabilities to potential supply disruption.

Many critical mineral value chains exhibit high levels of geographic concentration. More than 70% of global cobalt production originates from the Democratic Republic of Congo and Indonesia produces about 55% of global nickel supply (IEA, 2025). Beyond mining, China dominates refining of most critical minerals, holding an estimated 70–95% share. In comparison, the top three refining countries control about 86% of capacity and Indonesia alone accounted for 91% of nickel-refining growth from 2020 to 2022.¹³

The concentration of supply can be quantified using measures such as the Herfindahl–Hirschman Index (HHI), where values above 2,000 indicate highly concentrated markets. As illustrated in Table 2, many critical mineral supply chains exceed this threshold, reflecting the dominance of a limited number of producing and processing jurisdictions.^{11,16,5}

Supply Constraints and the Realities of Exploration

The reality of exploration is that bringing new mineral supply to market is a slow, expensive and uncertain process. Mineral discoveries have become increasingly difficult to make; exploration costs continue to rise, and the time required to advance a project from discovery to production often exceeds a decade. Mining investment rose just 5% in 2024 (about 2% in real terms), down from 14% in 2023 and exploration was flat, so capital is lagging forecast demand precisely when long lead times require early commitment.¹³



Table 2: Illustrative Supply Concentration of Selected Critical Minerals (HHI)

SUPPLY CONCENTRATION CREATES STRATEGIC EXPOSURE		
HHI estimates show where critical mineral supply chains exceed conventional concentration thresholds		
Critical mineral	Estimated HHI	Concentration classification
Niobium	>8 000	Extremely concentrated
Rare Earth Elements (REEs)	>4 000	Highly concentrated
Cobalt	+/- 3 000	Highly concentrated
Lithium	+/- 2 700	Highly concentrated
Nickel	2 000 - 2 500	Moderately to highly concentrated
Copper	1 000 - 2 000	Moderately concentrated

Al-Attiah Foundation, adapted from IEA, OECD, JRC, World Bank and Bucciarelli et al. (2025)



This creates a fundamental mismatch between the rapid changes in demand associated with the above-mentioned drivers and the lengthy development timelines required to establish new mines. Despite significant geological potential in regions such as Africa and the Arabian Peninsula, many mineral-rich countries remain underexplored, with geoscientific databases incomplete or insufficiently scaled to properly identify prospective mineral systems. Infrastructure constraints, including limited access to power, transport networks, ports, water resources and logistics corridors, further restrict many countries' ability to translate mineral endowment into mineral production.^{3,15,1}

Compounding these challenges, many critical minerals are not mined as primary commodities but are recovered as by-products or co-products from existing mining operations.

The Real Race: Processing, Refining and Beneficiation

While attention has traditionally focused on the location and ownership of mineral resources, the strategic challenge increasingly lies not in where minerals are mined, but where they are processed and refined.

China provides the clearest example of this dynamic. Although it does not possess a monopoly on mineral resources, it has spent decades building capacity for refining, chemical processing, battery precursor manufacturing and recycling across multiple critical mineral value chains.

As a result, China frequently exercises greater influence over supply chains through downstream processing than through control of upstream mining assets.^{18,21}

Mining alone does not guarantee participation in higher-value segments of the supply chain. Instead, local processing, refining, manufacturing and recycling capabilities are increasingly viewed as essential components of sovereign industrial capability. Resource-rich countries must move beyond exporting raw ores and leverage their critical mineral endowments as catalysts for industrialisation, value addition and economic diversification.^{4,1}

The development of downstream processing industries requires a sustained, economically viable feedstock supply at a sufficient scale to justify capital-intensive investment, reliable infrastructure, access to processing technologies, skilled labour and competitive energy costs. Beneficiation strategies are therefore, at their core, industrialisation strategies, requiring the development of integrated value chains and industrial capabilities.^{3,22}

Artisanal and Small-Scale Mining

Artisanal and small-scale mining (ASM) is playing an increasingly important role in critical mineral supply chains, particularly in developing countries. In part, this reflects the long development timelines of large-scale mining projects and the growing demand for minerals needed for the energy transition.^{17,10}

ASM contributes significantly to the production of several critical minerals and provides livelihoods for millions of people worldwide. However, an estimated 70–80% of ASM activity occurs within the informal sector, often operating illegally or within regulatory grey areas.



This presents challenges related to environmental management, occupational health and safety, traceability, taxation and market transparency.^{10,6}

As critical mineral demand continues to grow, integrating ASM into formal supply chains is likely to become a key public policy consideration.

Illicit Trade and Supply Chain Integrity

The increasing value of critical minerals has also heightened concerns regarding illicit trade and supply chain integrity. Unlike many traditional bulk commodities, certain critical minerals can be transported economically in the form of raw ores, concentrates or intermediate products. This creates opportunities for undeclared exports, smuggling and informal trade networks.¹⁸

Critical mineral supply chains are often complex and involve multiple intermediaries, processors, traders and jurisdictions. This complexity can create vulnerabilities through which material may be diverted, undeclared, blended or concealed before entering formal markets. As demand and prices increase, illicit trade is likely to become more sophisticated and involve a broader range of actors.¹⁸

Recycling and Circularity

For many critical minerals, recycling offers significant potential to alleviate future supply constraints. The IEA estimates that increased recycling could materially reduce the need for new mining by 2050. Battery recycling represents one of the fastest-growing opportunities, with recycled lithium, nickel and cobalt potentially supplying 20-30% of global demand by mid-century under supportive policy frameworks.

Additional opportunities exist in electronic waste, permanent magnets, industrial scrap and the recovery of critical minerals from historical mine waste and tailings.¹²

Beyond strengthening supply security, recycling can also deliver important environmental benefits, as secondary production generally requires less energy and generates lower greenhouse gas emissions than primary production.

Despite its potential, technical challenges associated with the separation and recovery of critical minerals, increasing complexity of electronic waste streams and the capital requirements of recycling infrastructure remain significant barriers to large-scale deployment.



Table 3: Forward Policy Deadlines and Operational Impacts

FORWARD POLICY DEADLINES AND OPERATIONAL IMPACTS

Requirements, business impacts, citizen impacts

Date	Requirement	Country impact	Business impact	Citizen impact
31 Dec 2030	EU strategic raw materials benchmarks mature.	EU reduces single-supplier exposure and strengthens domestic capacity.	Procurement updates supplier audits and sourcing dashboards.	Cleaner technologies face fewer bottlenecks
31 Dec 2030	Saudi Vision 2030 diversification horizon.	Saudi Arabia scales mining as a non-oil growth pillar.	Strategy tracks investment, board sign-off and reconciliation evidence.	More skilled industrial jobs
31 Dec 2030	Qatar National Vision 2030 diversification horizon.	Qatar expands international critical mineral exposure through sovereign investment.	Finance strengthens controls over investment, risk and audit evidence.	More resilient public revenues
31 Dec 2040	Oman Vision 2040 planning horizon.	Oman aligns sector strategies and development plans with long-term diversification.	Operations stress-tests infrastructure, logistics and continuity plans.	Better long-term economic resilience

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Recycling should be viewed as a complementary component of a critical mineral strategy that can help alleviate supply pressures, improve supply security and reduce import dependence.^{18,6}

ESG Considerations

The minerals sector is generally exposed to a range of environmental, social and governance (ESG) risks that require careful management. Environmental concerns include high water and energy consumption, greenhouse gas emissions, biodiversity disturbance, land degradation, pollution and the management of tailings and mining waste. Growing scrutiny is also being directed towards certain extraction methods, including water-intensive brine operations and deep-sea mining.

The OECD Due Diligence Guidance is the recognised control framework for these risks, covering corruption and security-force conduct as well as child labour. The International Labour Organization-backed system in the Democratic Republic of Congo has supported remediation for 5,346 children, serving as a measurable benchmark (OECD, 2024).¹⁶

The critical minerals sector faces a dual challenge: accelerating mineral supply to support the energy transition while maintaining environmental and social integrity. Strong ESG performance should not be viewed solely as a compliance requirement, but as a strategic enabler of long-term competitiveness.^{3,7,1}



Much as hydrocarbons shaped the global political economy of the twentieth century, critical minerals are increasingly becoming foundational inputs for the technologies, industries, and infrastructure underpinning the global energy transition, digital economy, advanced manufacturing and defence sectors. Resource-rich countries capable of supporting secure and resilient supply chains are therefore expected to play an increasingly important role in the evolving global economy.^{1,14}

The Middle East has several structural advantages. The region possesses substantial financial resources, extensive experience in managing globally significant commodity sectors, strategic proximity to major European and Asian markets, well-developed energy and logistics infrastructure, and, in many jurisdictions, comparatively stable investment environments.

Importantly, many Gulf Cooperation Council (GCC) economies are actively pursuing economic diversification strategies to reduce dependence on hydrocarbon revenues.^{22,21,14}

Unlike established mining jurisdictions such as Australia, Chile, Indonesia or South Africa, the region's competitive advantage does not lie solely in its geological endowment. Rather, the GCC is uniquely positioned to become a major financier, processor, logistics hub and strategic coordinator of global critical-mineral value chains. The new geopolitical environment could result in Gulf states being increasingly viewed as potential reliable partners capable of connecting mineral-rich regions with downstream manufacturing centres in Europe, Asia and North America.^{6,21,8}

Geological Endowment and Downstream Potential

Although the region has historically been associated with hydrocarbons, growing evidence suggests that several GCC countries possess significant untapped mineral potential. The Arabian Shield (a Precambrian geological formation extending across Saudi Arabia and Oman) hosts substantial deposits of gold, copper, zinc, phosphates, bauxite and other industrial minerals as well as potential for a range of critical minerals including lithium (from brines associated with oilfield operations), nickel, cobalt, rare earth elements (REEs), niobium, tantalum and vanadium.⁸

Saudi Arabia now estimates around 2.5 trillion US dollars in mineral reserves across the roughly 600,000-square-kilometre Arabian Shield, spanning rare earth elements, gold, phosphate and base metals. Against this backdrop, the region's most significant opportunity lies in the development of downstream industries associated with mineral processing, refining, manufacturing, trading, logistics and recycling. This opportunity is further underpinned by the region's access to competitively priced energy, industrial infrastructure, logistics networks, ports, special economic zones, sovereign capital and established trading hubs, which collectively provide a strong foundation for downstream industrial development.^{13,3,7,22}

The Gulf's Emerging Role in Global Critical Mineral Value Chains

The growing emphasis on critical minerals is closely aligned with broader economic transformation programmes being implemented across the region. Saudi Arabia's Vision 2030, Qatar's National Vision 2030, Oman's Vision 2040, the UAE's Operation 300bn industrial strategy, Bahrain's Economic Vision 2030 and

Kuwait's Vision 2035 all emphasise economic diversification, industrial development, investment attraction and the creation of new non-oil growth sectors. Saudi Arabia has been particularly active in this regard, positioning mining as a potential third pillar of the economy alongside hydrocarbons and petrochemicals.



Saudi Arabia's mining company, Maaden, is targeting about 110 billion US dollars of investment over the decade. The Kingdom has attracted roughly 32 billion US dollars toward a 100 billion U.S. dollar target by mid-2026 and the mining tax has been cut from 45% to 20% to attract capital.¹³

Significant investments have been directed toward exploration, mining, mineral processing and the development of integrated industrial ecosystems linked to future technologies.^{1,2,8} Maaden and the Public Investment Fund (PIF) have become increasingly active participants in global critical mineral markets. Notable examples include the acquisition of a 10% stake in Vale Base Metals and partnerships to develop rare earth processing capabilities within the Kingdom. Similarly, Abu Dhabi's International Resources Holding (IRH) has acquired a controlling stake in Mopani Copper Mines in Zambia and a majority stake in Alphamin Resources, a major tin producer operating in the Democratic Republic of Congo.²

Abu Dhabi has also expanded its role through strategic partnerships, including a US\$1.2 billion joint venture between ADQ and Orion Resource Partners to secure critical mineral supply chains. Qatar has likewise pursued international exposure through investments by the Qatar Investment Authority in companies active across battery recycling, critical mineral development and base metals mining.² This exposure complements Qatar National Vision 2030's non-hydrocarbon diversification objective.





Despite the significant opportunities associated with critical minerals, countries seeking to participate in critical mineral value chains face a range of complex challenges. As highlighted throughout the preceding sections, these challenges extend beyond the discovery of mineral resources and increasingly concern processing capacity, geopolitics, financing, technological change, workforce development and sustainability considerations.

Summary of Key Challenges:

- **Industrial and infrastructure constraints**, including limited processing capacity, inadequate infrastructure, technology gaps and skills shortages.
- **Geopolitical and supply chain risks**, arising from the concentration of production and processing in a small number of jurisdictions, resource nationalism, trade restrictions, political instability and supply disruptions.
- **Financing and investment challenges**, driven by high capital requirements, long development timelines, technical complexity and elevated project risk. Mitigation can be achieved through contracts for difference, price floors and volume guarantees.
- **Market and technological uncertainty**, including price volatility, opaque markets, evolving technologies and rapidly changing demand patterns. Over 50% of energy-related minerals now face some form of export restriction.
- **Environmental, social and governance (ESG) considerations**, including permitting requirements, environmental impacts, social licence to operate and growing sustainability expectations.

Successful critical mineral strategies require a coordinated approach spanning exploration, industrial policy, infrastructure, finance, skills development, ESG performance and international cooperation. Before implementing targeted interventions, governments should first establish a clear understanding of their resource endowment, strategic priorities, supply chain vulnerabilities and competitive advantages. This can be achieved through the following actions:

- Conduct national or regional critical mineral risk and readiness assessments to identify strategic minerals, supply vulnerabilities, competitive advantages and priority value chains.
- Develop and regularly update critical minerals lists, supported by detailed supply, demand, trade and geological data.
- Strengthen national geoscience programmes, geological mapping and mineral databases to support exploration and investment decision-making.
- Undertake value chain assessments to identify where the greatest opportunities for local participation, beneficiation and industrial development exist.
- Engage industry, investors, academia and civil society to identify barriers, opportunities and implementation priorities.

Once these foundational elements are in place, governments can implement a range of policy and strategic interventions to strengthen participation across critical mineral value chains. The recommendations presented below are neither exhaustive nor mutually exclusive and should be viewed as complementary components of a broader critical minerals' strategy:

- Accelerate exploration and project development through incentives, streamlined permitting and support for junior exploration companies.
- Promote downstream processing, refining, manufacturing and recycling through targeted industrial policies, technology transfer and strategic partnerships.
- Invest in enabling infrastructure, including power generation, electricity networks, transport corridors, ports, logistics systems, water infrastructure and digital connectivity.
- Establish de-risking mechanisms such as contracts-for-difference, price floors, volume guarantees and standards-based incentives, recognising the roughly 50% capital-cost premium on diversification projects (IEA, 2025).





- Strengthen research, innovation, digitalisation, artificial intelligence and advanced manufacturing capabilities to improve competitiveness and support technological upgrading.
- Develop the skilled workforce required to support the sector through investment in technical education, vocational training, research institutions and industry-led skills programmes.
- Expand recycling, circular economy initiatives and resource efficiency programmes to reduce pressure on primary mineral production.
- Strengthen ESG frameworks, responsible sourcing standards and supply chain traceability systems
- Establish systems to monitor supply risks, trade flows, market concentration, foreign investment, illicit trade and emerging geopolitical vulnerabilities.
- Pursue strategic international partnerships (while recognising that partnerships alone do not guarantee supply security and should complement domestic capability development).
- Ensure that policy interventions remain adaptive and are regularly reviewed as technologies, markets and geopolitical realities evolve.



Critical minerals are rapidly evolving from conventional commodities into strategic assets, driven by the growing demands of electrification, digitalisation, advanced manufacturing and decarbonisation. At the same time, supply chains remain constrained by geographic concentration, lengthy development timelines and limited processing capacity.

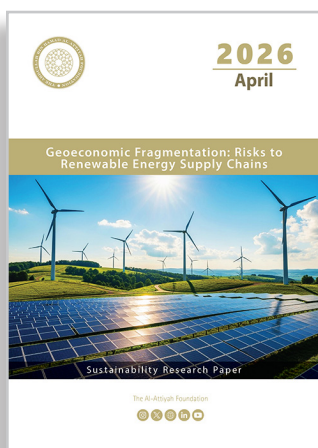
Critical minerals provide a platform for industrialisation, localisation, economic diversification, technological development and regional cooperation. However, transforming mineral endowment into sustainable economic value requires more than resource extraction alone.

Success will depend on the development of downstream industries, enabling infrastructure, a skilled workforce, strong institutions and effective governance frameworks.

Ultimately, securing resilient and sustainable critical mineral supply chains will require mutually beneficial partnerships between producing and consuming nations. In this increasingly competitive environment, the future winners will be those that can successfully combine resource development, processing capacity, industrial capability, finance, innovation and strategic partnerships into competitive and resilient value chains.

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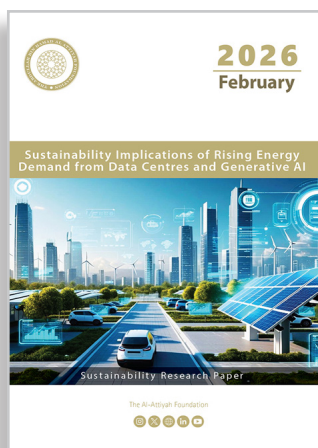
April – 2026

Goeconomic Fragmentation: Risks to Renewable Energy Supply Chains

Goeconomic fragmentation – the progressive realignment of trade, investment and technology flows along strategic rather than purely economic lines – has, in recent years, moved from a scenario to a standing feature of the energy transition.



(QR.CO.DE)



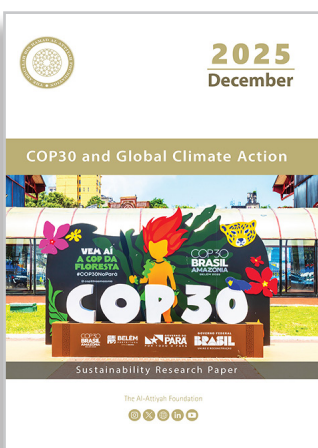
February– 2026

Sustainability Implications of Rising Energy Demand from Data Centres and Generative AI

Global data centre electricity demand has roughly doubled since 2020 and the International Energy Agency (IEA) has projected it will more than double again by 2030, driven primarily by generative Artificial Intelligence (AI) model-building and deployment activities.



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December – 2025

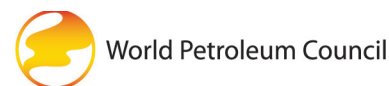
COP30 and global climate action

The 2025 United Nations Climate Change Conference (COP30) in Belém concluded with outcomes that underscored a structural shift in climate governance: non-state actors such as cities, businesses, and civil society brought forward implementation pipelines while national government commitments lagged.



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Our partners collaborate with The Al-Attiyah Foundation on various projects and research within the themes of energy and sustainable development.





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