

An Assessment of Environmental Challenges and Opportunities for Minerals in the Energy Transition

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Abstract

The rapid change to clean energy systems is generating a swift movement in mineral demand, as a result this creates a variety of interplay of environmental challenges and opportunities for energy minerals. This research evaluates the opportunities and environmental challenges for lithium, cobalt, rare earth elements and copper as energy minerals. Findings indicated that mineral demand for clean technologies will increase by 400% by 2040, with lithium demand alone going over 1 000%. This rapid increase is projected to produce over 50 million metric tons of mining waste annually and increase energy-related water consumption by 35% potentially resulting in water scarcity. Environmental challenges include geopolitical supply chain vulnerabilities, insufficient lifecycle governance frameworks and socio-ecological conflicts in biodiversity hotspots. Opportunities that have emerged with the energy transition are technological innovation in low-impact extraction methods, circular economy advancement through urban mining, strategic mineral diversification and multilateral cooperation on environmental certification standards. The convergence of quantitative pressure points and qualitative governance gaps underscores that mineral extraction for the energy transition is not environmentally neutral. Strategic investment in recycling infrastructure could reduce primary demand by 25-40% by 2050. This assessment concludes that realizing the net-zero agenda requires parallel investment in both clean energy deployment and the ecological integrity of mineral supply chains. As a result this process positions environmental stewardship as foundational to energy transition objectives.

Keywords

Circular economy, clean energy, critical minerals, environmental justice, energy transition, lifecycle assessment, mining governance, recycling, supply chain vulnerability, sustainable extraction