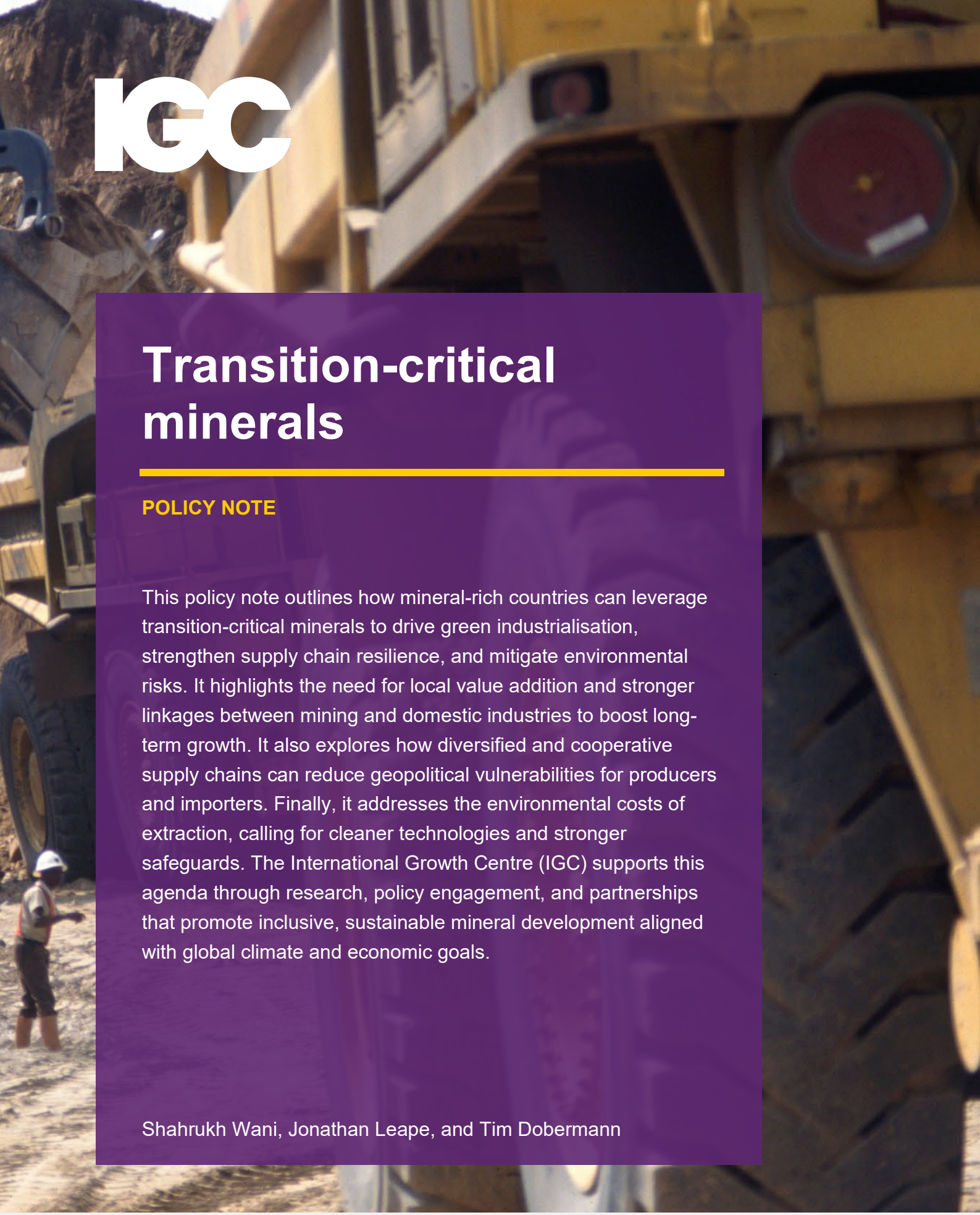

Transition-critical minerals

POLICY NOTE

This policy note outlines how mineral-rich countries can leverage transition-critical minerals to drive green industrialisation, strengthen supply chain resilience, and mitigate environmental risks. It highlights the need for local value addition and stronger linkages between mining and domestic industries to boost long-term growth. It also explores how diversified and cooperative supply chains can reduce geopolitical vulnerabilities for producers and importers. Finally, it addresses the environmental costs of extraction, calling for cleaner technologies and stronger safeguards. The International Growth Centre (IGC) supports this agenda through research, policy engagement, and partnerships that promote inclusive, sustainable mineral development aligned with global climate and economic goals.

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You can learn more about
our work on critical minerals at
theigc.org

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Introduction

The transition to clean energy depends heavily on minerals such as lithium, cobalt, nickel, and copper—each essential to technologies like electric vehicles, solar panels, and battery storage. Demand for these minerals is projected to grow rapidly over the next decades as the world decarbonises. Yet the supply landscape remains fragile: production and processing are highly geographically concentrated, investment cycles are long, and prices are prone to sharp volatility.[1] Their status as "critical" is not fixed either: demand and supply projections evolve with energy strategies, advances in recycling and substitution, and the discovery of new reserves.

These conditions expose importing countries to geopolitical and market risks while creating fiscal and institutional vulnerabilities for mineral-rich countries. This includes political economy concerns over elite capture and rent extraction. To avoid these risks, producing and importing governments must collaborate to reshape how critical mineral markets function. For producing countries, a central priority is to move beyond raw exports by developing local processing and value addition, which also helps diversify global processing capacity.

Incentivising exploration is a good place to start. Transparent, rules-based systems for auctioning new exploration rights can help attract investors. This means publishing clear, simple acceptance criteria, enforcing third-party contracts, and—critically—ensuring rapid geological prospecting and timely release of data from successful bids. Releasing exploration rights gradually can also help governments improve auction terms over time, capturing greater value while sustaining investor interest.

Achieving this requires strengthening mining governance at every stage—from discovery and licencing to construction, operations, and closure. But the agenda must go further. Many mineral sectors still operate as enclaves, with entrenched interests that are disconnected from local firms and workers. Addressing weak supplier linkages, limited domestic capacity, and infrastructure bottlenecks demands active industrial policy. Investing in public goods such as energy and transport, streamlining regulation, and providing targeted support for local suppliers on finance, skills, and technology can all help.

Mineral-importing countries have a clear interest in supporting these efforts. Moving beyond transactional trade, they can co-invest in institutional development, shared infrastructure, and regional processing hubs. These

[1] IEA (2024), Global Critical Minerals Outlook 2024, IEA, Paris https://www.iea.org/reports/global-critical-minerals-outlook-2024, Licence: CC BY 4.0

partnerships can generate shared economic gains, promoting sustainable growth and reducing emissions in the producing country while strengthening energy security and creating more resilient supply chains for importing countries.

Key questions

IGC work on critical minerals to date focuses on three key questions:

1) How can domestic economic linkages between mining and non-mining sectors in mineral-rich countries be strengthened?

To secure broader economic benefits from natural resource extraction, countries need to facilitate strong linkages between mining and non-mining sectors. Such linkages promote economic development, supporting industrialisation, exports, the green transition, and long-term growth, and helping to meet public expectations in resource-rich countries. Sub-Saharan Africa, for example, holds about 30% of the world's critical mineral reserves and while extracting these could significantly boost gross domestic product (GDP), developing local processing industries offers an even larger economic payoff—creating new trade and investment opportunities and boosting growth.

Mineral-importing countries have a strategic interest in supporting this shift. Countries that build refining and manufacturing capacity will likely be more reliable long-term partners. With more at stake—jobs, exports, tax revenue—they are less likely to disrupt supply. Greater local processing in Africa would also reduce dependence on China, which dominates global mineral refining. Integrated operations are also more resilient, and industrialising economies are typically more stable than raw exporters, prone to acting opportunistically during price spikes. Importers, meanwhile, gain more secure, diversified supply chains and new markets for services, technology, and finance. Cleaner processing closer to the mine site also supports ESG goals and compliance with domestic climate rules. Many large critical minerals processors, like Indonesian nickel, are entirely powered by coal. With measures like the EU carbon border tax (CBAM) looming, the case for greener, localised value chains is growing stronger. This is not charity—it is good strategy.

Most resource-rich developing countries face real constraints in making this transition. To begin with, mining in Africa has typically functioned as an enclave sector with limited connections to local suppliers or processors. In addition, gaps in financing, skills, technology, and infrastructure among local firms limit the growth of upstream and downstream industries around the mining sector. A recent IGC survey of over 1,000 firms in Kitwe in the Zambian Copperbelt found

that firms interested in entering the mining supply chain face multiple barriers, including low demand, competition, lack of networks, and corruption. High upfront capital investments and strong vested interests amplify market failures by reducing competition and transparency.

IGC research: How do local firms participate in the global mining value chain?[2]

The integration of local suppliers into Zambia's mining sector is critical for economic development, yet the scale and depth of these backward linkages remain underexplored. A recent IGC study focused on Kitwe, a key mining hub in the Copperbelt, examining the extent to which local firms participate in the global mining value chain and the barriers they face.

Building on IGC's longstanding partnership with the Zambian Revenue Authority, the authors used ten years of VAT transaction and import data, which they combined with a survey of 1,055 firms in Kitwe. They found that mine suppliers—firms selling to mining companies—constitute 35% of local businesses. These firms are larger, older, and more likely to be formally registered. However, they rely heavily on imports, reflecting limited domestic procurement. Their demand for goods and services fluctuates with the international copper price, underscoring their exposure to global commodity cycles.

Despite a strong interest in entering the mining supply chain, many local firms struggle with low demand, competition, lack of networks, and corruption. Policies promoting supplier development through financing, training, and stricter enforcement of local content requirements could strengthen these linkages. However, deeper integration into mining supply chains must be balanced with efforts to diversify the economy to reduce vulnerability to global price shocks.

Resource-rich countries face a choice. They can continue treating mining as a low-value sector, they can impose blunt protectionist measures—like Indonesia, which banned raw nickel exports and rapidly expanded local processing[3]—or they can take a broader approach, combining investment in core public goods with policies that encourage local value addition. The first option offers little economic value. The second can stimulate industrialisation but risks deterring investors, entrenching rent extraction, and might not work where minerals are not significantly concentrated in a single country because of price competition from suppliers with fewer trade barriers.

A better path is an active industrial policy that balances local value-addition and content policies—requirements for mining firms to buy from local suppliers, hire

[2] Benshaul-Tolonen, Anja and Fernandez Musso, Paula, Mine Suppliers: Understanding backward linkages in Kitwe, Zambia.
[3] Lovering, D. and Tirtosudarmo, A., (2024). Resource nationalism and downstreaming: The geopolitics of critical minerals value chains. Atlantic Council.

locals, and stimulate technology transfer—with creating the institutional and infrastructural environment that makes investment in local value-addition more attractive and feasible. Policies that can help foster such an enabling environment include investments into key public goods (such as transport and energy), simplifying regulations, ensuring transparent governance, and investing in underlying drivers of firm growth, such as improved management practices and access to finance.[4]

A more ambitious approach includes adopting an explicitly **green industrial policy** that focuses not only on increasing the production of critical minerals to fuel cleaner technologies (such as electric vehicles) but also on encouraging the use of cleaner technologies in the process of mining itself. This can include direct measures, such as promoting the use of solar energy in mining and processing, as well as policies that encourage greener practices in traditional extraction. The economic case for using industrial policy to promote green growth is strong. Market failures—such as the under-pricing of carbon and the spillovers from technological innovation—justify government intervention to support green technologies.[5] Recent international actions, especially the EU Carbon Border Adjustment Mechanism (CBAM), strongly reinforce the case for action.

Experience from China's solar photovoltaic (PV) industry shows that state-led support, combined with trade integration, can help green industries scale rapidly.[6][7] The effectiveness of such policies, however, depends on their design.[8] Time-bound incentives can attract investment into mineral processing and manufacturing without creating long-term dependence on subsidies. Performance-based support, as seen in South Korea's industrialisation drive, helps ensure that public funds go to firms that deliver results and allows governments to phase out assistance to underperformers.[9]

Regional partnerships can reinforce these efforts. Developing shared processing hubs can allow countries to achieve economies of scale and strengthen their position in global supply chains. A current example is the push in Southern Africa to build a battery manufacturing hub, where countries are

[4] International Monetary Fund (IMF). (2024). "Digging for Opportunity: Harnessing Sub-Saharan Africa's Wealth in Critical Minerals." In Regional Economic Outlook: Sub-Saharan Africa—A Tepid and Pricey Recovery. Washington, DC, April
[5] Rodrik, D. (2014). Green industrial policy. Oxford Review of Economic Policy, 30(3), pp.469–491.
[6] Groba, F. & Cao, J. (2015). Chinese Renewable Energy Policy and Its Impact on Solar PV Manufacturing. Climate Policy, 15(1), pp.30–57.
[7] Banares-Sanchez, I., Burgess, R., Laszlo, D., Simpson, P., Van Reenen, J., & Wang, Y. (2023, July 18). Ray of hope? China and the rise of solar energy
[8] David Atkin, Amit Khandelwal, Laura Boudreau, Rafael Dix-Carneiro, Isabela Manelici, Pamela Medina, Brian McCaig, Ameet Morjaria, Luigi Pascali, Heitor Pellegrina, Bob Rijkers & Meredith Startz, "International Trade" VoxDevLit, 4(2), February 2025
[9] Lane, N. (2023). Manufacturing Revolutions: Industrial Policy and Industrialisation in South Korea. Quarterly Journal of Economics.

attempting to coordinate policy to support their efforts to move beyond raw material exports and integrate into high-value industries.

The IGC is drawing on its research and policy expertise and networks to:

- Undertake research to help countries improve policies that attract foreign direct investment into refining and manufacturing, coupled with initiatives to build the capacity of local suppliers such as through training, technology transfer, and access to credit.
- Facilitate discussions on creating multi-country mineral processing and trade hubs (such as the Lobito Corridor), allowing resource-rich nations to build economies of scale and open new minerals for global market.
- Document international experience to identify successful models of resource-based industrialisation (for instance, lessons from countries that developed local mineral processing, like Indonesia and Chile) and how those could be adapted in new contexts.

2) What is the environmental impact of mining critical minerals and how can it be mitigated?

Minerals essential for clean energy technologies can cause significant environmental harm at the extraction stage—from habitat destruction to pollution and climate impact—unless strong safeguards are in place. Large-scale mining inevitably disrupts land and ecosystems. Clearing vegetation and topsoil can lead to deforestation and biodiversity loss, while excavation and waste piles alter landscapes.[10] Poorly managed operations pollute air and water: toxic tailings and mine runoff may contaminate rivers and groundwater with heavy metals, and dust from blasting and transport can degrade air quality.[11] Recently, an acid spill at a Chinese-owned mine has contaminated a major river in Zambia, leading to an environmental and livelihood disaster.[12] Many critical minerals also have a high carbon and energy footprint. Their extraction and processing often require more energy per unit than conventional metals, leading to substantial greenhouse gas emissions. Refining battery metals such as lithium and nickel is particularly energy-intensive, relying on vast amounts of electricity or fuel and adding to CO_2 emissions.[13]

Unchecked environmental damage from mining threatens sustainable development and climate goals. Locally, pollution and land degradation harm communities and weaken long-term economic prospects. Water contamination or depletion can disrupt farming and fishing, undermining food security, while air pollution and hazardous waste endanger public health. Those living near mines—often the most vulnerable—bear the brunt of these damages,

[10] IEA (2021). The Role of Critical Minerals in Clean Energy Transitions – Chapter: Sustainable and Responsible Development of Minerals
[11] Ibid.
[12] A river 'died' overnight in Zambia after an acidic waste spill at a Chinese-owned mine https://apnews.com/article/mining-pollution-china-zambia-environment-93ee91d1156471aaf9a7ebd6f51333c1
[13] G7/WB (2024). RISE Partnership Update – Supporting Africa's Green Minerals

deepening poverty and inequality.[14] Social unrest can follow if livelihoods are lost or health crises emerge, destabilising regions. At a national level, emissions and deforestation linked to mining can make it harder for countries to meet climate commitments. Unchecked environmental harm could disrupt mineral supplies themselves. If degradation or social resistance forces governments to halt projects or tighten regulations, supply shocks could ripple through global clean energy industries.

Mining supply chains are also vulnerable to climate-related shocks. Many resource-rich developing countries face extreme weather events, water scarcity, and rising temperatures, all of which threaten mining and processing operations.[15] Climate impacts, such as declining agricultural productivity, may also drive migration to mining regions.[16] This will place pressure on infrastructure and public services but also create an opportunity to accelerate structural transformation. Policies must anticipate these challenges by integrating climate adaptation into mining strategies. This includes climate-resilient transport networks and mining technologies that mitigate environmental risks, particularly in flood- and drought-prone regions.

Addressing these challenges requires proactive policies and industry support to minimise the environmental impact of critical mineral mining. Governments and businesses must enforce adequate environmental standards at every stage of the mining process, including environmental impact assessments, regulations on waste disposal and water use, and land restoration after closure.

Policies here can also reduce emissions in mineral extraction and processing. One example is policies to shift from fossil fuel-based energy to an energy mix that includes greater use of renewables. Zambia, for example, has vast solar potential that could help power its copper mining industry, lowering costs. Co-locating solar farms with mining operations, as seen in First Quantum Minerals' plan for a 430 MW solar and wind project at Kansanshi, shows how clean energy can directly support resource industries.[17] Similar plans and discussions are underway in Indonesia, where its critical mineral sector is entirely fuelled by coal power. Other key measures include improving equipment efficiency and electrifying mining vehicles.

The IGC can support governments and investors (including DFI's such as British International Investment) in implementing these strategies by expanding the evidence base on mining's environmental impact, facilitating innovation and knowledge transfer on best practices—such as modern tailings management to

[14] World Bank (2019). Climate-Smart Mining: Minerals for Climate Action
[15] Acevedo, S., Mrkaic, M., Novta, N., Poplawski-Ribeiro, M., Pugacheva, E., & Topalova, P. (2017). The Effects of Weather Shocks on Economic Activity: How Can Low-Income Countries Cope? World Economic Outlook.
[16] Kala, N., Balboni, C., & Bhogale, S. (2023). Climate Adaptation. VoxDevLit, 7(1), June 2023.
[17] Saggese, A., Shawa, B. and Wani, S. (2024). Positioning Zambia for a Copper-Plus Future. International Growth Centre. Available at: https://www.theigc.org/publications/positioning-zambia-copper-plus-future

prevent leaks or financing mechanisms for renewable energy investments—and working with policymakers to test incentives, such as tax breaks, that might encourage cleaner mining practices.

IGC research: Mapping, measuring and mitigating exposure to toxic metals in copper mining areas in Zambia.

The IGC is presently examining the environmental and public health risks of copper mining in Zambia, a key global supplier of transition-critical minerals. As demand for copper rises with the green energy transition, concerns grow over pollution from mining activities, including contamination of air, water, and soil by heavy metals such as arsenic, lead, and cadmium. IGC research seeks to quantify these environmental impacts, assess community perceptions, and test the effectiveness of an information campaign to reduce exposure risks.

The IGC study follows a three-pronged approach:

1. Researchers collect soil, water, and air samples at varying distances from mining sites in the Copperbelt and Northwestern provinces. A staggered grid sampling method ensures comprehensive data, with laboratory analysis determining the extent of heavy metal contamination.
2. A structured household survey and focus group discussions assess local knowledge, attitudes, and behaviours related to mining pollution and health risks.
3. Households near mines are randomly assigned to receive either neutral information or targeted messaging about pollution risks and mitigation strategies, particularly for protecting children. The study tracks changes in knowledge and self-reported protective behaviours over time.

Findings will inform regulations on mining pollution control, community health interventions, and sustainable mining policies. By highlighting the severity of environmental hazards, the study provides evidence for stricter monitoring and mitigation strategies, such as improved waste management, safer water access, and awareness campaigns. If effective, the intervention model could be scaled up to other mining regions, helping align Zambia's mineral production with sustainable development and public health objectives.

3) How can supply chain resilience be strengthened for both export-focused and import-focused countries?

Strengthening supply chain resilience means reducing the risk of interruption (due to conflict, pandemics, trade disputes, natural disasters, or other crises) so that both exporting and importing countries can plan with more certainty. In recent years, as demand for these minerals has surged, their supply chains have become complex and global – often, a mineral is mined in one country, processed in another, and then used in manufacturing in a third. This geographic span makes the supply chain vulnerable to external shocks and bottlenecks. The risk of policy-induced shocks has increased dramatically under

the new US administration, which is using tariffs and the threat of tariffs as the central instrument of economic policy.

Critical mineral supply chains are fragile due to a mix of geographic concentration, infrastructure weaknesses, and political and market volatility. Many minerals are produced and processed in just a few countries, leaving both producers and importers vulnerable. In Africa, miners often rely on a narrow set of buyers and transport routes, with raw minerals frequently exported to a dominant market—usually China—without diversification, exposing them to price crashes or shifts in demand. Landlocked producers such as Zambia face additional risks from long, fragile transport corridors where poor maintenance and domestic instability—such as conflict, labour strikes, or sudden policy shifts like export bans—can disrupt supply.

Mineral importing economies like the UK face the reverse problem: over-reliance on a few suppliers means any disruption in a major producer threatens entire industries, while trade restrictions or resource nationalism—such as export quotas or taxes—can further limit access. Opaque supply chains and illicit practices, including unregulated artisanal mining and smuggling, add further uncertainty, potentially leading to shortages or reputational and legal risks.[18]

Building resilience in critical mineral supply chains requires a strategic and cooperative approach, where research and policy support from the IGC can make a difference. While geological constraints mean that the sources of key minerals cannot be easily diversified—over 70% of the world's cobalt is in the Democratic Republic of Congo—there is more scope to diversify processing. Currently, most refining and value addition happens in China with Chinese firms playing an important role in logistics and trucking, concentrating control over supply chains.

Shifting some of this processing capacity to Africa, potentially in partnership with Chinese firms, would enhance global resilience. While few, if any, developing countries can develop end-to-end value chains, a more geographically distributed refining network would improve supply security and market stability.

International cooperation is essential to achieving this aim. Rather than acting in isolation, mineral-producing and importing nations can form more proactive partnerships to ensure fair and open supply chains. This could involve harmonising quality, environmental, and labour standards, making it easier to

[18] G7/WB (2024). RISE Partnership Update – Supporting Africa's Green Minerals

source responsibly from multiple locations. Information-sharing and trade agreements can also support more resilient markets.

The IGC aims to support these efforts by convening stakeholders, providing evidence-driven policy analysis, and exploring mechanisms such as investment guarantees and other risk mitigation measures to encourage diversified supply. Strengthening governance in producer countries is another critical factor: reducing corruption and illicit trade, improving regulatory oversight and ensuring fair revenue management can make supply chains more stable and predictable, giving importers greater confidence. The IGC's capacity-building initiatives – such as the Zambia Evidence Lab – aim to support governments in such efforts, ensuring they have the data to make informed decisions.

IGC policy support: Building a copper-plus future for Zambia

Zambia's vast copper reserves position it at the centre of the global energy transition, as demand for minerals essential to low-emission technologies rises. However, sustained economic benefits will require looking beyond extraction towards a 'copper-plus' strategy—one that integrates value addition, supply chain expansion, and renewable energy. At the request of President Hakainde Hichilema, the IGC has provided high-level framing for how Zambia can build a more resilient and diversified economy by capitalising on its resource wealth while mitigating risks from price volatility and overreliance on raw exports.

Mining remains the backbone of Zambia's economy, contributing 80% of export earnings, yet much of the value is captured abroad. Despite significant production, the country exports mostly raw copper, with limited local processing and manufacturing. Declining ore grades, fluctuating commodity prices, and an unstable policy environment create uncertainty for investors. To counteract these challenges, Zambia must strengthen its position in the global value chain by investing in refining, smelting, and manufacturing activities linked to copper and other critical minerals such as cobalt. Development finance from institutions like British International Investment (BII) can play an important role to this end.

Energy constraints are a major barrier to industrial expansion. Mining consumes over half of Zambia's electricity, yet power supply remains unreliable, dominated by hydropower, which is vulnerable to climate variability. Increasing solar energy capacity could help stabilise electricity access, reduce production costs, and enhance competitiveness. Strategic investments in grid infrastructure, transmission, and independent power generation would help attract private investment and support a broader industrial base. A well-structured industrial policy is key to transitioning from resource extraction to broader economic development. This includes improving the regulatory framework to provide stability for investors, streamlining business registration, and enforcing predictable tax policies. The study emphasises the need for targeted infrastructure investments, particularly in transport and energy, to reduce operational bottlenecks and improve connectivity for mining-related industries.