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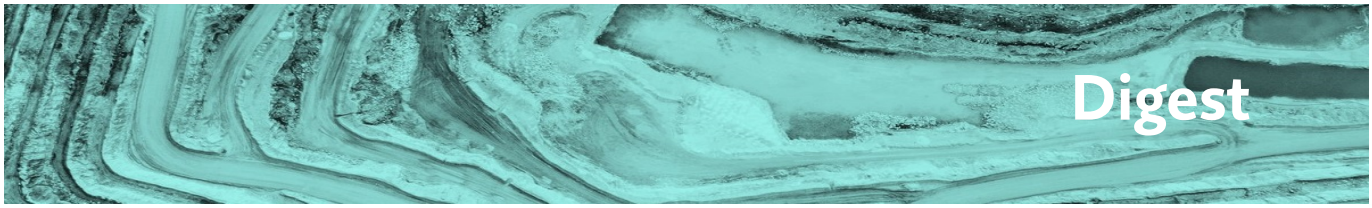

Clean energy's material dependencies

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The transition to clean energy is a story of material transformation. Enormous amounts of refined minerals and rare earths are required for tomorrow's economy: batteries for electric vehicles (lithium, cobalt, manganese, graphite), solar panels (minor metals), wind turbines (rare earth magnets) and new power lines (copper). Global demand is increasing rapidly.
While the previous economic literature has largely focused on supply-side risks, such as domestic conflicts or the global political economy, a new strand of literature focuses on the effects of the boom in demand, too.

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Hugh Miller et al. (2023), in "The Stumbling Block in 'the Race of our Lives': Transition-Critical Materials, Financial Risks and the NGFS Climate Scenarios," examine the implied material demand from low-carbon technologies under two climate scenarios (see Figure 1). Their methodology identifies transition-critical materials (TCMs) based both on demand-induced pressures and supply-side risks, including geographical concentration, country risk profiles and water stress. The authors find that the implied material demand increases the risk of bottlenecks, especially in a delayed transition. The paper argues that resulting price volatility could create financial risks, calling for central bank action.

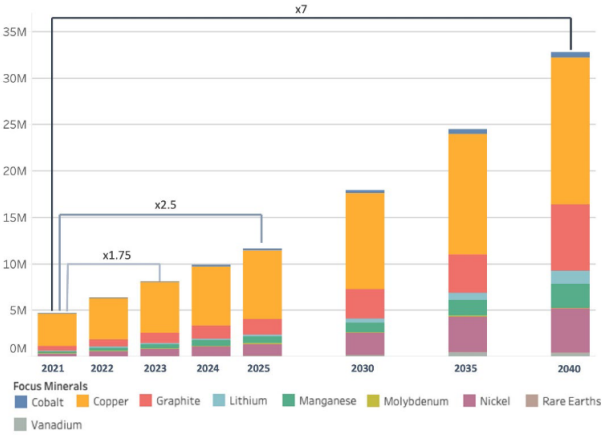
The research builds on previous findings by **Lukas Boer et al.** (2021) on "Energy Transition Metals." Using a structural VAR approach, the authors model the impact metal-specific demand shocks (based on scenarios) on the prices for copper, nickel, cobalt and lithium. Under a net-zero scenario, metal prices would reach peak prices for an unprecedented, sustained period. A shock increasing prices by 10 percent would increase the same-year output of copper by 3.5 percent, nickel by 7.1 percent, cobalt by 3.2 percent and lithium by 16.9 percent.

Prices have already soared. Lithium was, at its 2022 peak, 13 times more expensive than in the beginning of 2021. These signals seem to incentivize production, but often at the cost of severe ecological impacts. China just announced a halt to lithium mining at its top production hub amid a probe of environmental misconduct. Considerable demand variability depends on future climate policies and technological developments. But mineral extraction is set to reshape the global economy - and energy security strategies.

The **The International Energy Agency**'s 2021 Energy Outlook chapter on, "The Role of Critical Minerals in Clean Energy Transitions," zooms in on the policy challenges arising from the unequal distribution of the sought-after materials. Energy security protocol has to adapt from monitoring oil prices to the new vulnerabilities raised by minerals supply. China has cornered the processing industry for most materials, while extraction suffers from concentration in some politically unstable countries (see Figure 2). Ramping up efforts elsewhere will be difficult. IEA analysis suggests that it takes an average 16 years from discovery to first production in mineral mining. Declining resource quality, exposure to climate risks and water stress will add further complications. Better recycling and higher efficiency can alleviate some pressure.

Hugo Lapeyronie and Etienne Espagne (2023), in Energy transition minerals and the SDGs. A systematic review," investigate the links between mineral mining and their threat to social and environmental dimensions of the 2030 Sustainable Development Goals. Extraction is associated with environmental degradations, but reliable information for top producer countries such as China are scarce. Novel remote sensing approaches to monitor impacts are likely to change that. The authors also highlight that countries rich in low-grade metals may not capture the mining boom's benefits.

Figure 1. Demand for TCMs (in Mt) implied by the NGFS 'Net Zero by 2050' scenario



Note: The demand for TCMs induced by the NGFS 'Net Zero by 2050' Scenario increases from 4.7Mt in 2021 to 32.8Mt in 2040. Total demand is multiplied by 2.5 between 2021 and 2025, and by 7 between 2021 and 2040. The demand for copper largely drives this trend, followed by other TCMs such as graphite, nickel and lithium.

Figure 1: Demand for transition-critical minerals estimated by Miller et al. (2023)

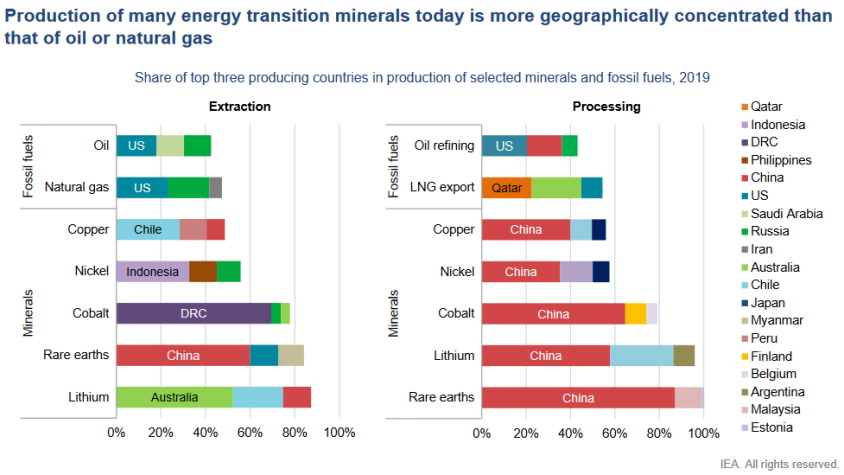


Figure 2: IEA (2021) estimates of the concentration in mineral extraction and processing

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