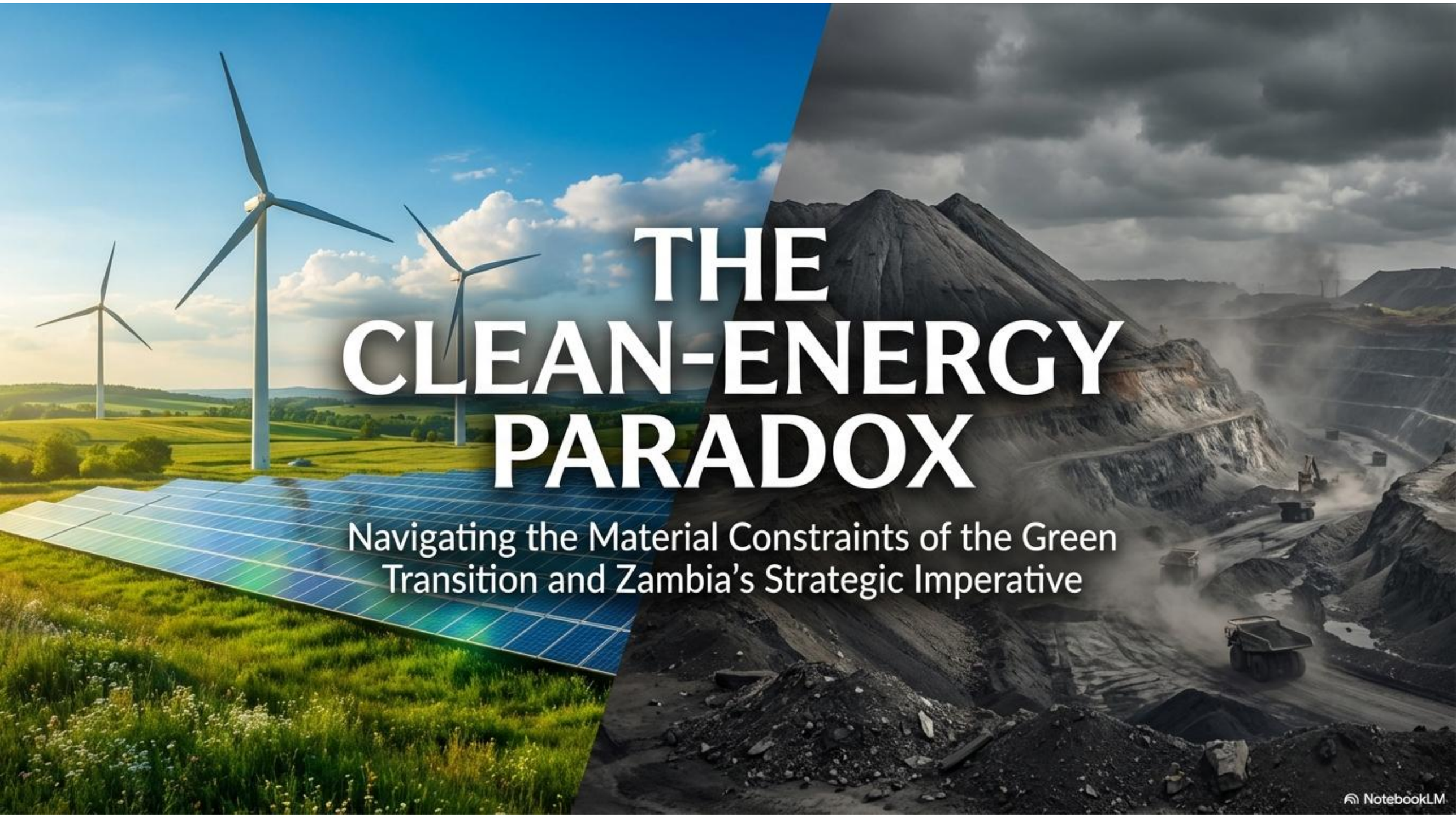
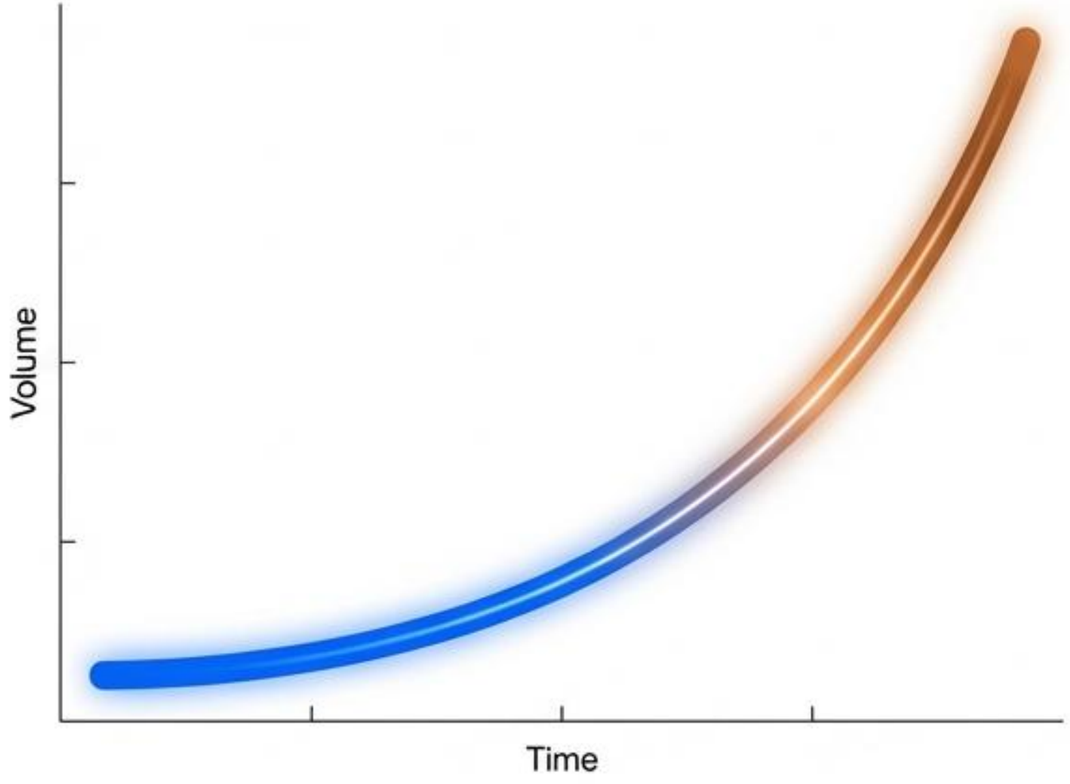
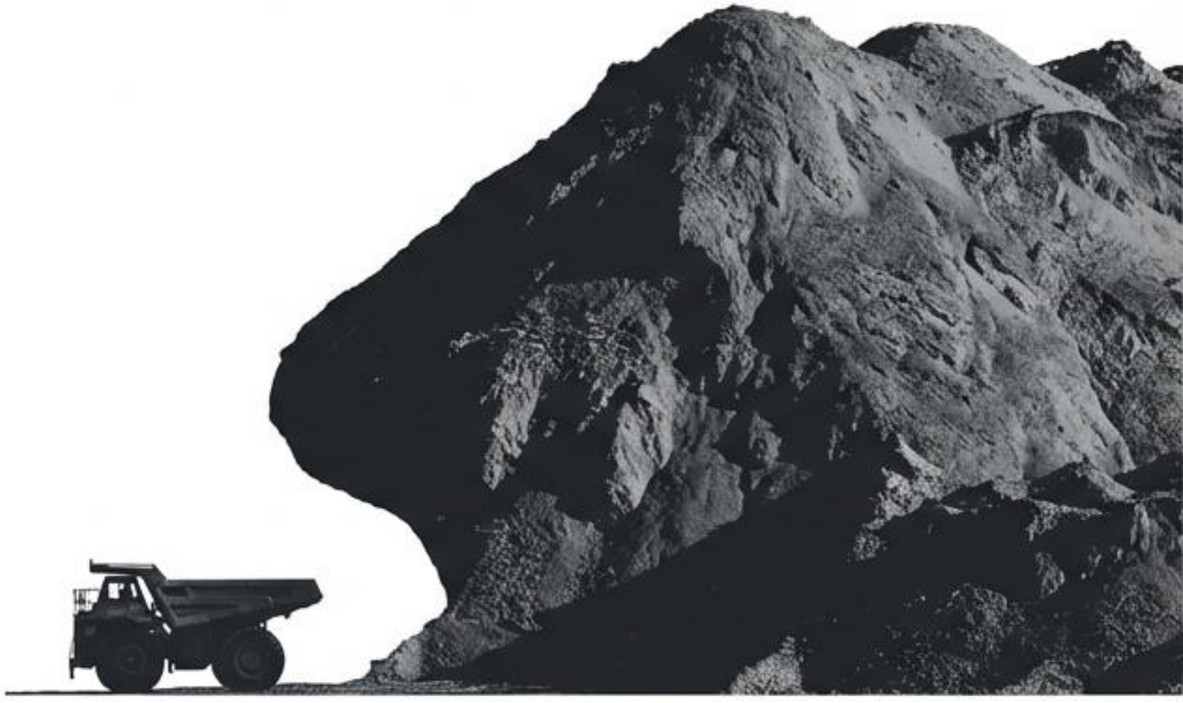

THE
CLEAN-ENERGY
PARADOX
Navigating the Material Constraints of the Green Transition and Zambia's Strategic Imperative
NotebookLM

The Dual Challenge of the Energy Transition



The Demand

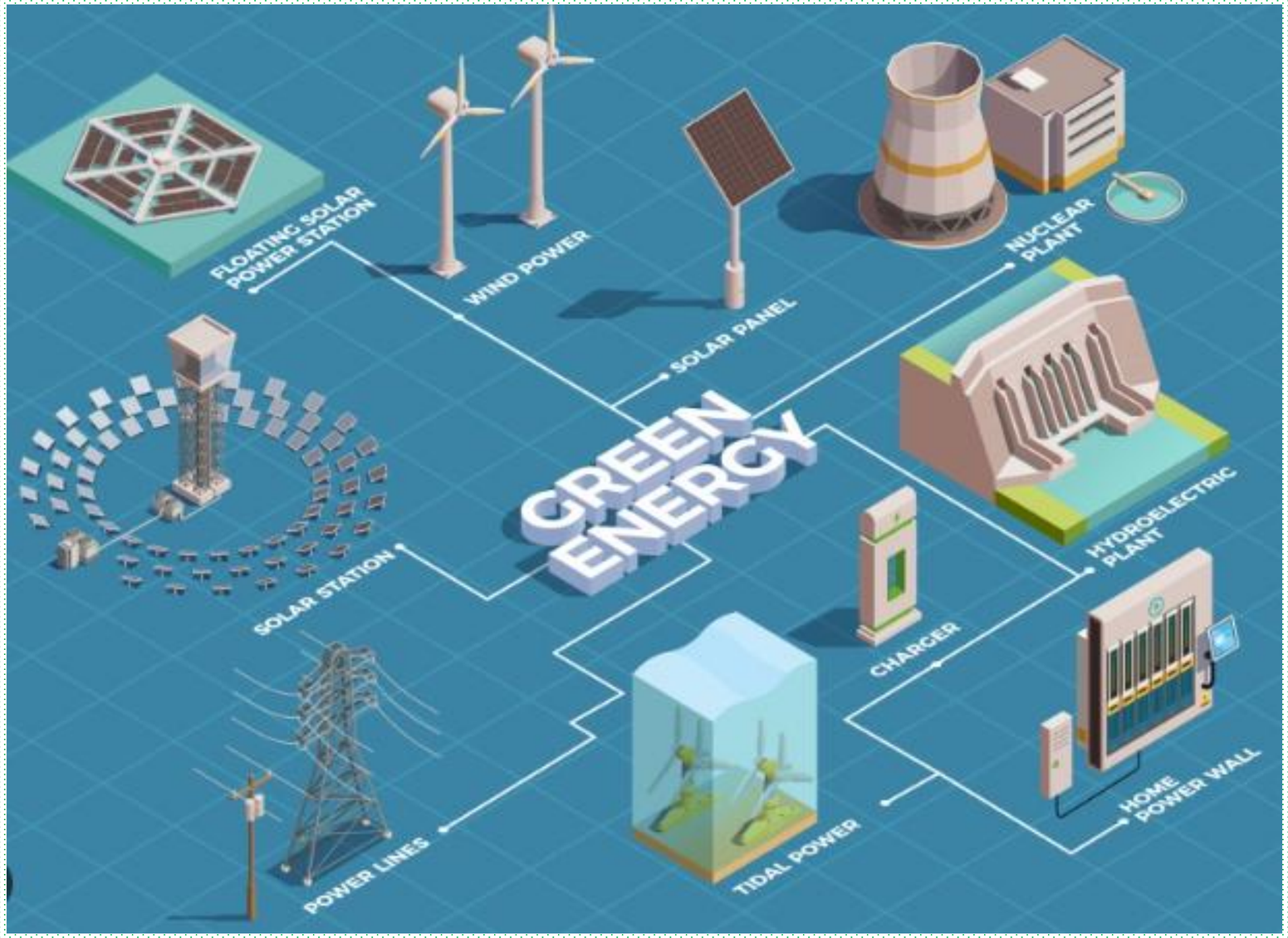
The low-carbon future demands unprecedented volumes of critical minerals.



The By-product

Traditional pyrometallurgy leaves behind an escalating, toxic environmental liability.

The Green Energy Technologies



https://www.miningreview.com/energy/copper-cobalt-deficits-to-drive-healthy-prices-but-only-from-2025/

Increasing Demand for Critical Metals in Clean energy Era

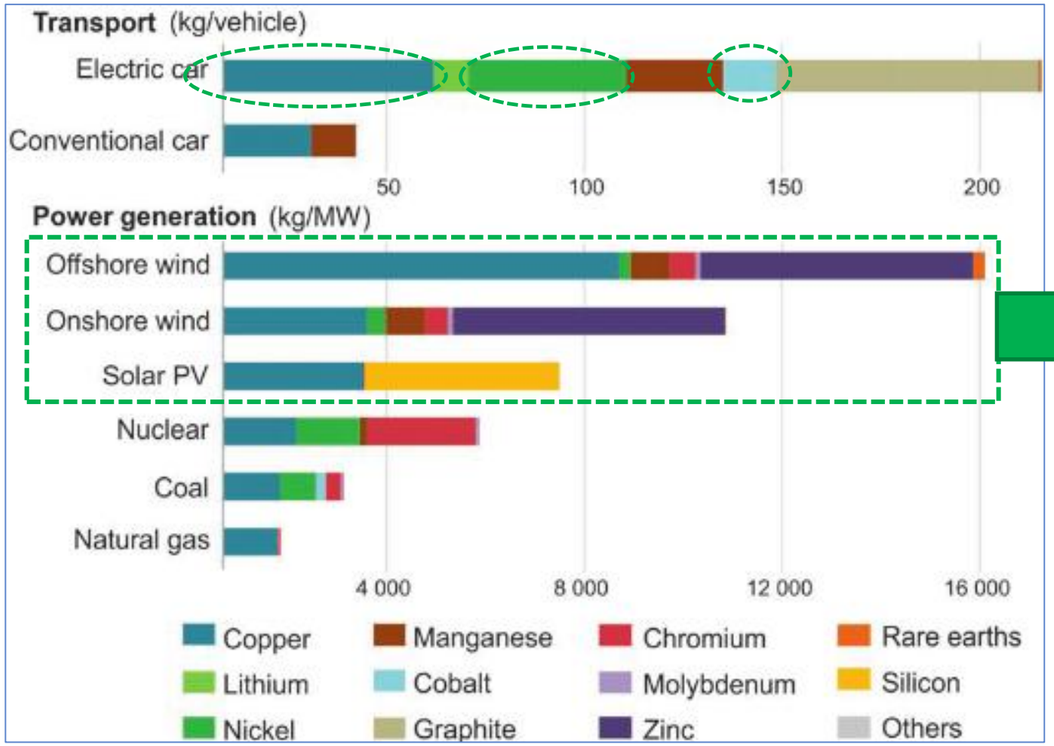


Fig 2. Metal use in selected clean energy technologies- transport & power generation (IEA, 2021)

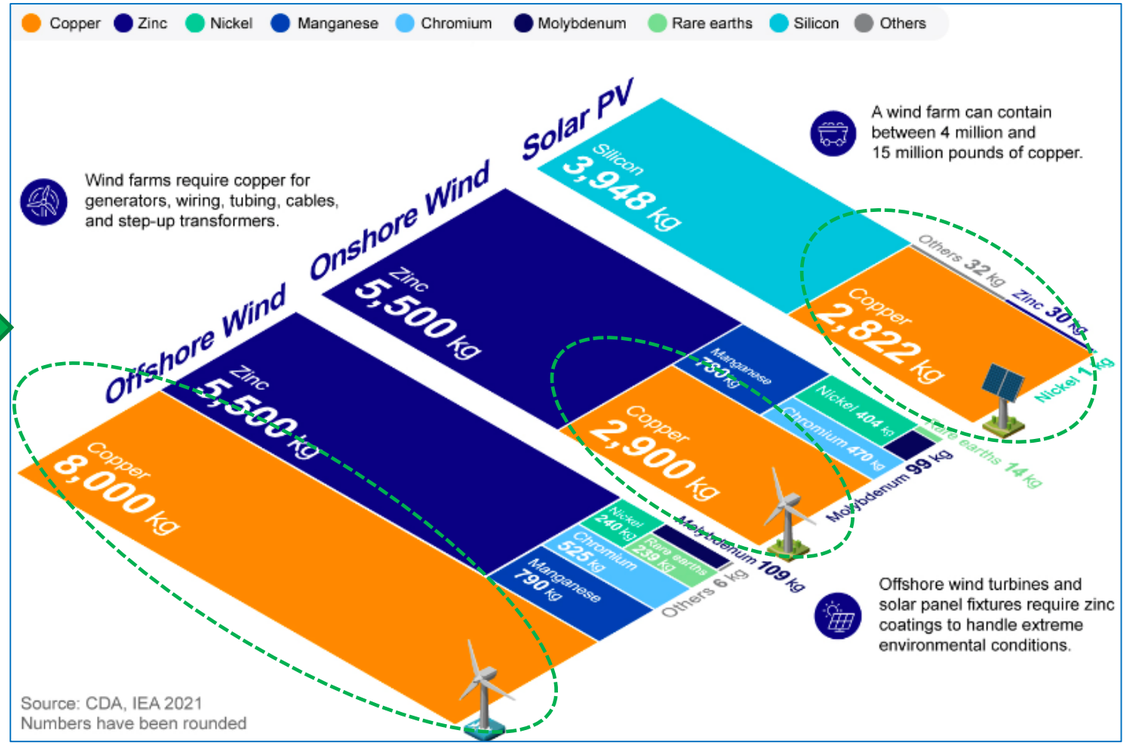
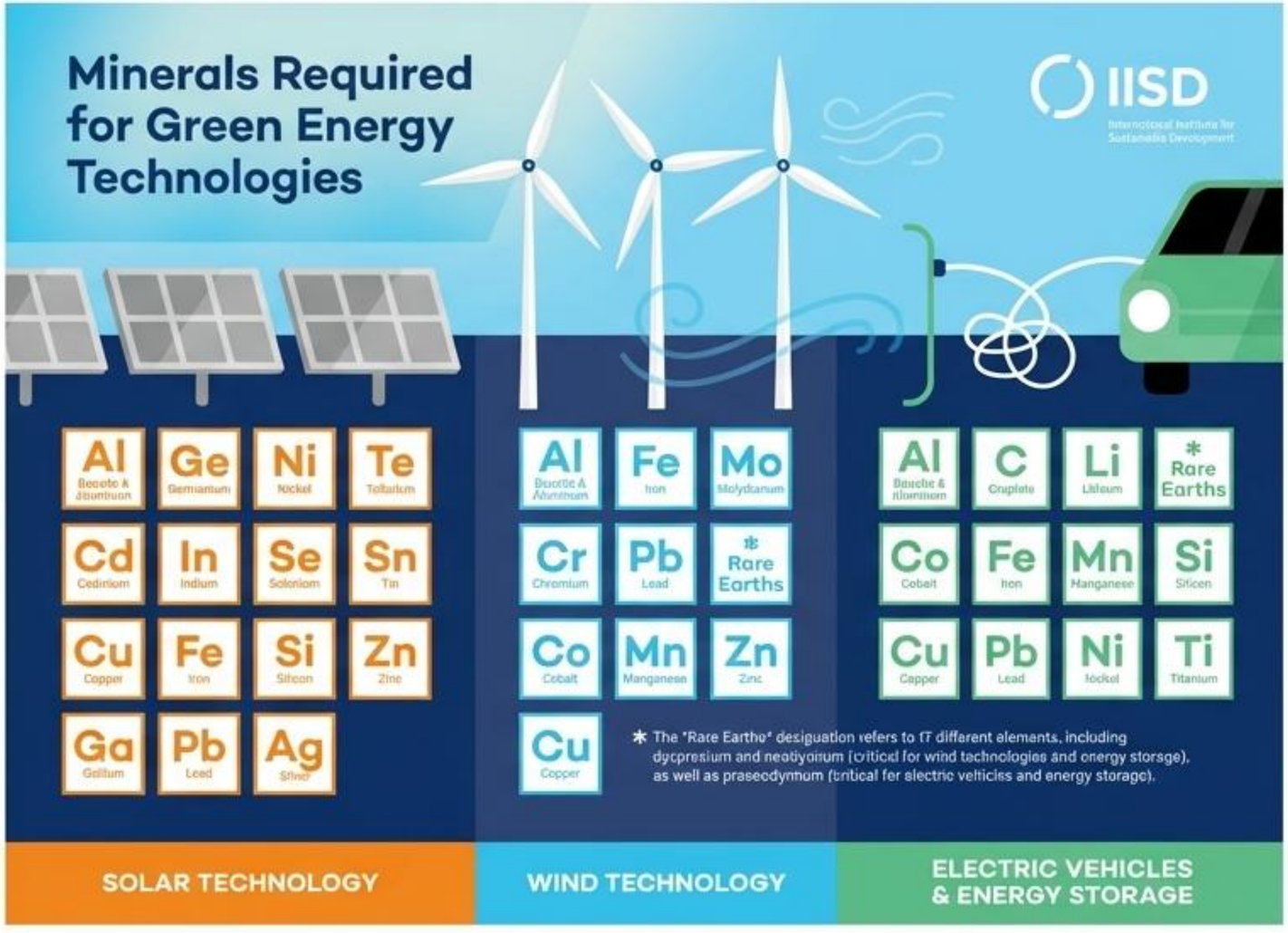


Fig 3. Metal content in clean energy technologies (kg/megawatts) (IEA, 2021)

- ❖ Electric vehicle: 53 kg Cu and 13 kg Co per vehicle (10% global population = 43 million tons Cu)
- ❖ Offshore wind has highest uses, with Cu content of 8,000 kg/megawatt of energy

✓Processing smelting slag can increase supply of Cu & Co for clean energy

Green technologies require an exponential leap in critical mineral inputs.



The Material Reality

Electric Vehicles vs. Conventional

6x

EVs require **6x** the mineral inputs (53 kg Copper and 13 kg Cobalt p). 10% global EV adoption equals **43 million tons of Copper** demand.

Onshore Wind vs. Gas Plant

9x

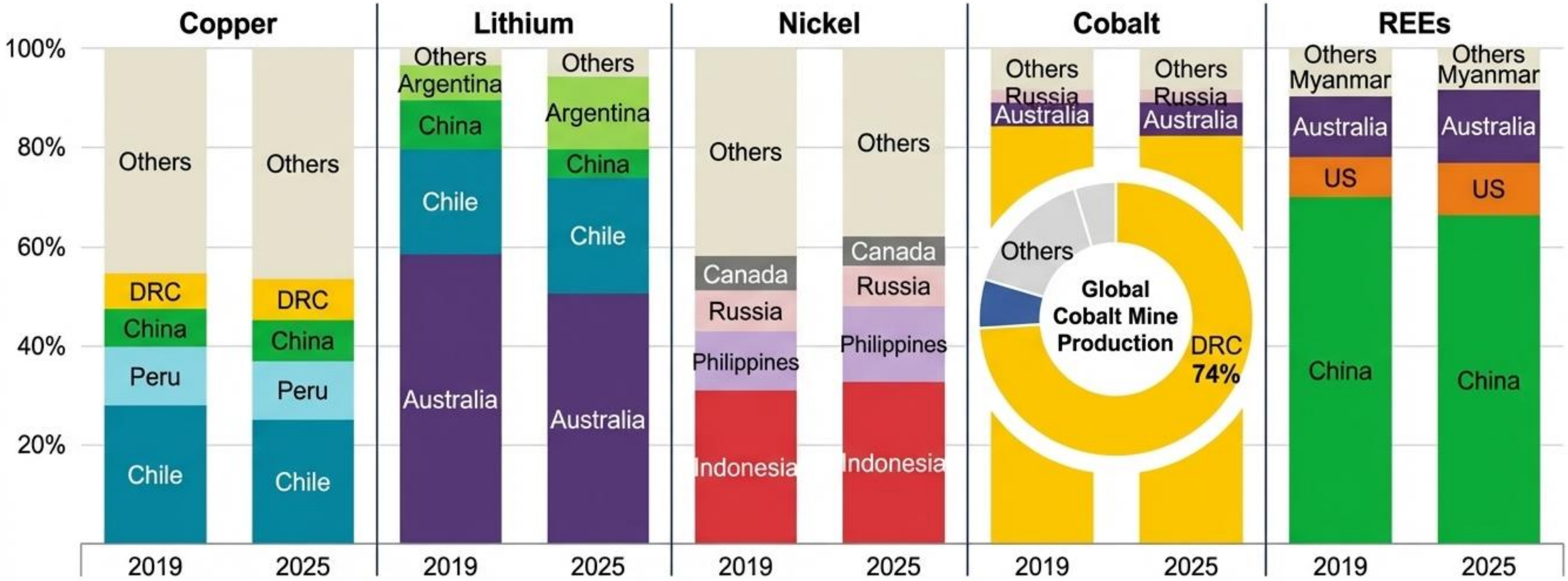
Wind requires **9x** the mineral resources.

Offshore Wind

The most material-intensive, requiring **8,000 kg** of Copper per megawatt of energy.

Takeaway: Global demand for Copper and Cobalt is projected to increase by **350%** by 2050 to meet these targets.

Primary extraction is heavily concentrated, exposing the transition to severe geopolitical risk.



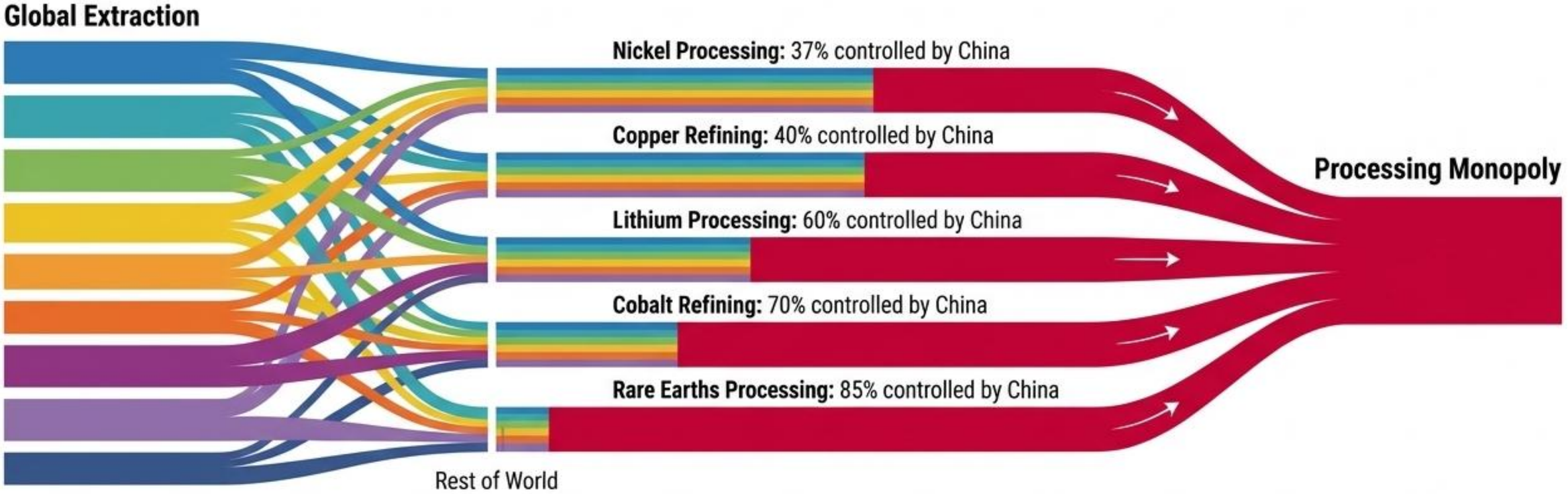
Cobalt
The Democratic Republic of Congo (DRC) commands a staggering **74%** of global cobalt mine production. Global demand for Co will reach **66 million tons** by 2040.

Lithium
Heavily dominated by **Australia**.

Rare Earth Elements (REEs)
Overwhelmingly dominated by **China**.

Insight: This monopolistic supply structure is inherently unsustainable and highly vulnerable to trade restrictions and price volatility.

Downstream processing funnels diverse global resources through a single geographical chokepoint.



Strategic Implication: Downstream concentration grants disproportionate influence over the cost, availability, and timing of global clean-energy deployment.

Declining ore grades mean primary extraction is becoming dirtier, deeper, and more carbon-intensive.

High-grade, near-surface deposits are progressively depleted globally.

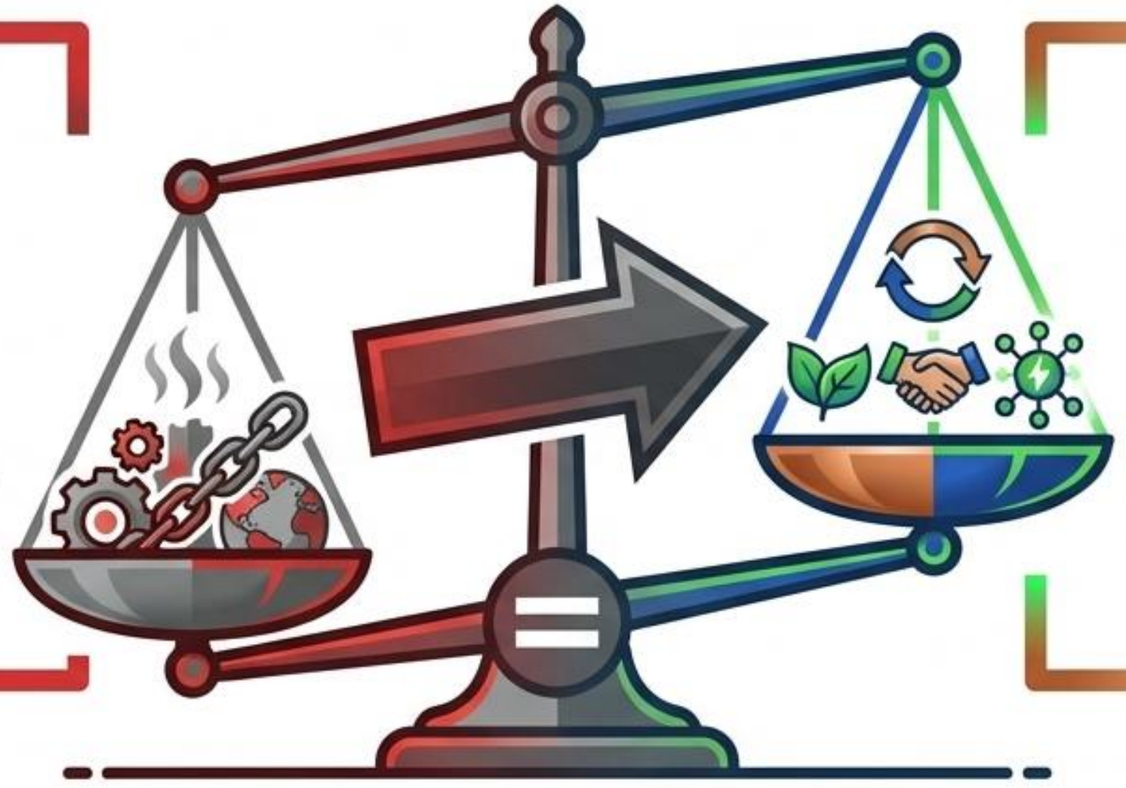
Producing the same amount of **refined metal** now requires extracting and processing exponentially larger volumes of earth.

The Ultimate Paradox:
For energy-intensive metals like Copper and Nickel, this declining quality partially offsets the emission reductions gained by deploying clean energy.

We cannot achieve clean energy using inherently unsustainable material supply chains.

The Clean Energy Paradox

Extraction Monopolies + Processing Chokepoints + Declining Grades

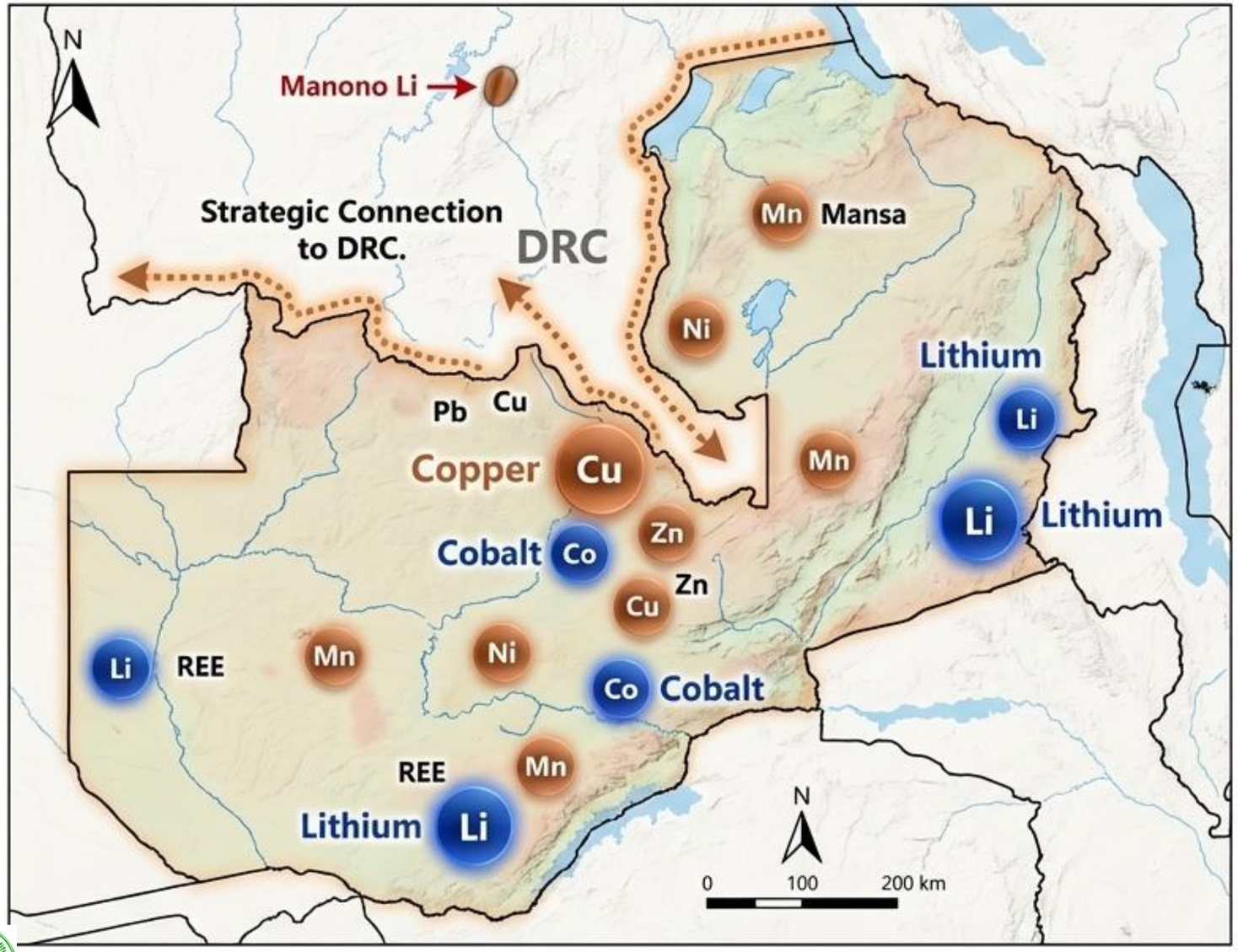


The Strategic Imperative

Circular Economy + ESG Principles + Regional Hubs

Core Argument: To truly classify these metals as 'clean energy metals,' we must look beyond primary mining. We must integrate alternative sources, enforce transparent supply-chain governance, and radically adopt circular economy principles.

Zambia possesses the geological endowment to serve as a strategic linchpin for global supply chains.



The Zambian Advantage

Copper and Cobalt

Copper

7th largest producer globally, hosting 1,000 million tonnes of Cu reserves.

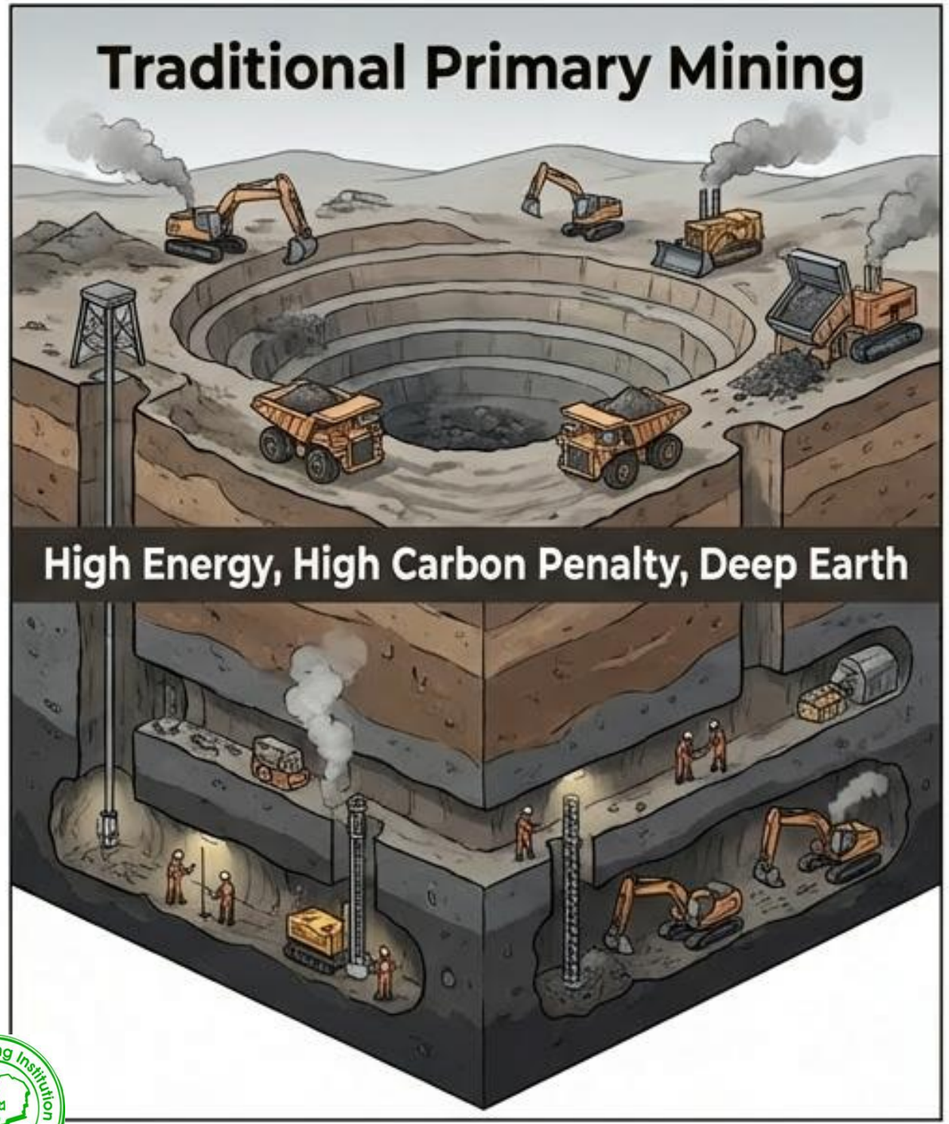
Diversification

Abundant new discoveries of Lithium, Manganese, and Rare Earth Elements (REEs).

Strategic Location

Direct access to the DRC (which holds 74% of Cobalt), positioning Zambia as a natural processing partner.

Reframing waste as wealth: Zambia's circular economy alternative to primary extraction.

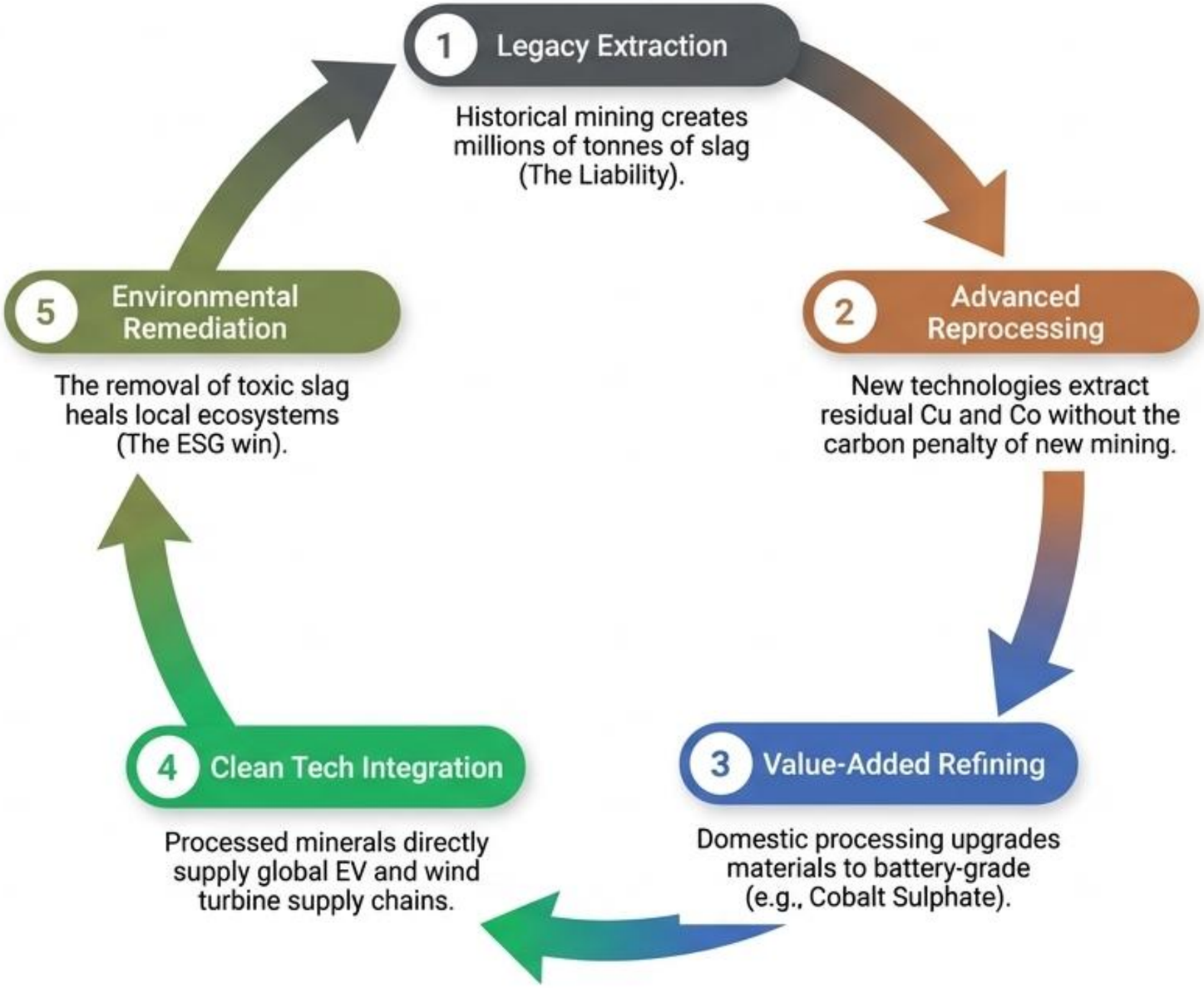


60 MILLION
TONNES OF SLAG
Currently sitting as waste, but rich in Copper and Cobalt.

500 MILLION
TONNES OF TAILINGS
Containing critical minerals ready for recovery.

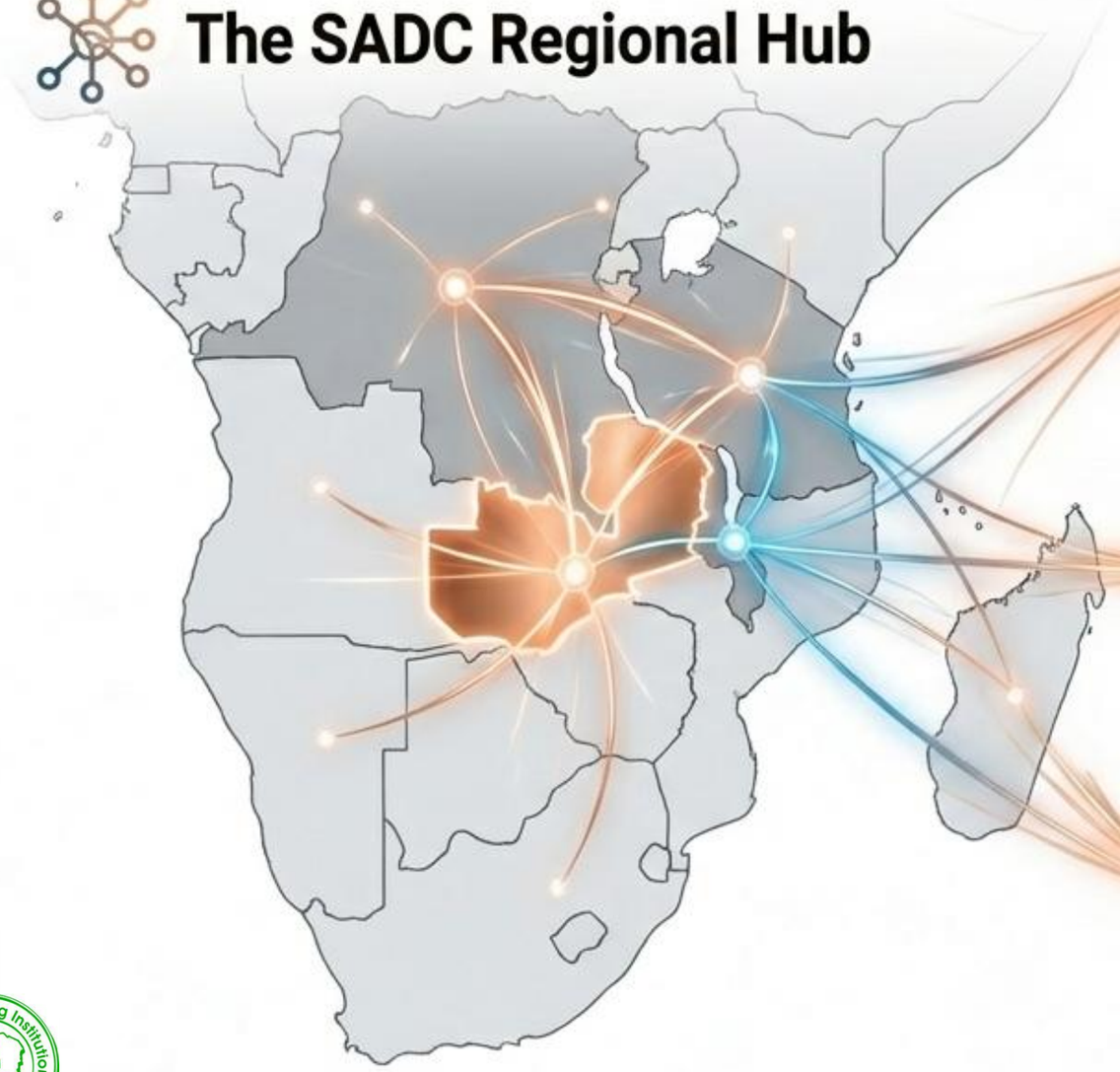
The Impact: Processing smelting slag can massively increase the supply of Cu & Co for clean energy while bypassing the high-emissions profile of primary, low-grade ore mining. It actively rehabilitates the environment while feeding the green transition.

Closing the loop: How Zambian slag reprocessing feeds green tech manufacturing



Shifting the processing chokepoint through regional integration and domestic value-addition.

The SADC Regional Hub



Strategic Moves

Beyond Exporting Ore

The Zambia National Critical Minerals Strategy mandates a shift from raw material export to domestic value addition.

Africa's First

Commissioning Africa's first cobalt sulphate refinery to anchor higher-value processing domestically.

Regional Synergy

Leveraging the African Continental Free Trade Area (AfCFTA) to process minerals from the DRC, Malawi, and Tanzania, creating a resilient, diversified alternative to Asian monopolies.

The Net-Positive Reality: Circular practices guarantee the environmental triumph of the clean-energy transition.

Final Takeaway: The mineral intensity of green energy is undeniable, but it results in a 10x reduction reduction in lifecycle emissions. By leveraging Zambia's critical minerals, embracing circular slag reprocessing, and enforcing ESG standards, we do not just mitigate the paradox—we solve it.

Questions