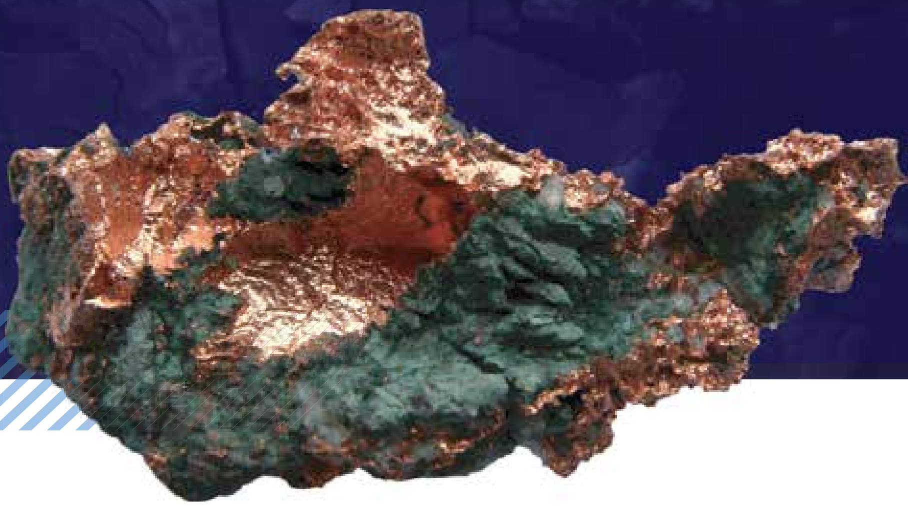
COUNCIL FOR
CRITICAL MINERALS
DEVELOPMENT
IN THE GLOBAL SOUTH

NIGERIA'S ENERGY TRANSITION MINERALS SUPPLY-DEMAND ASSESSMENT

June 2026



MINISTRY OF
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ABOUT

The global transition to clean energy is driving an unprecedented surge in demand for critical minerals—materials essential to renewable power, electric mobility, and energy storage. Countries in the Global South hold a significant share of these resources. Yet without stronger policy capability, coordination, and strategic positioning, much of the value is being captured elsewhere, reinforcing existing patterns of unequal development.

The Council for Critical Minerals Development in the Global South was established to address this gap. It is a collaborative platform that supports governments to design and implement evidence-based policies that enable critical mineral resources to drive sustainable industrialisation, economic diversification, and more equitable participation in regional and global supply chains.

The Council operates at the intersection of data, policy, and diplomacy. It combines rigorous research and analytics with direct government engagement and south-south partnerships building and exchange. This enables it to generate insight, and to translate that insight into practical policy decisions and coordinated action.

The Council for Critical Minerals Development in the Global South is co-hosted by Sustainable Energy for All (SEforALL) and the Global South Center for Clean Transportation, Institute of Transportation Studies, University of California, Davis.

ACKNOWLEDGEMENTS

The report was authored by Dr. Sarah Khan and Shivani (UC Davis) and Divyam Nagpal (SEforALL). At the outset, the authors would like to thank the strategic partnership from the Ministry of Solid Minerals Development, Government of Nigeria that made this study possible. The Govermment of Nigeria provided critical support through data provision and strategic inputs during the development phase. The authors would like to thank Africa Minerals Strategy Group; Mr. Suleiman Zakari from Core International; Dr. Aditya Ramji, Prosper Ogbonna, and Dr. Francisco Pares Olguin from the University of California, Davis; Edwin Warden, Lanre Shasore, Pavel Tereshchenko, Darryn Allan, and Sakshi Chandra from Sustainable Energy For All (SE4All) for providing strategic guidance and reviewing the report.

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Abbreviations

2W	two-wheeler
3W	three-wheeler
AMDP	Accelerated Mining Development Programme
AfCFTA	African Continental Free Trade Area
ASM	Artisanal and Small-scale Mining
BAU	Business as Usual
BESS	Battery Energy Storage System(s)
C&I	Commercial and Industrial Operations
CAGR	Compound Annual Growth Rate
CRMA	Critical Raw Materials Act
ECOWAS	Economic Community of West African States
EoI	End of Life
ESG	Environmental, Social & Governance
ETIP	Energy Transition and Implementation Plan
EV	Electric Vehicle
EVDP	National Action Plan for the Development of Electric Vehicles
HS	Harmonized System
ICE	Internal Combustion Engine
IRA	Inflation Reduction Act

LFP	Lithium-Iron-Phosphate
LIB	Lithium-Ion Batteries
MCO	Mining Cadastre Office
MMSD	Ministry of Mines and Steel Development
MoU	Memorandum of Understanding
MSMD	Ministry of Solid Minerals Development
MSP	Minerals Security Partnership
NEITI	Nigeria Extractive Industries Transparency Initiative
NGSA	Nigerian Geological Survey Agency
NMC	Nickel-Manganese-Cobalt
NZE	Net-Zero Emissions
OAL	Olisa Agbakoba Legal
OEM	Original Equipment Manufacturer
PARC	Pan-African Resource Reporting Code
PPP	Public-Private Partnership
R&D	Research and Development
RE	Renewable Energy
REE	Rare Earth Element
RMRDC	Raw Material Research and Development Council
SEforALL	Sustainable Energy for All
SMDF	Solid Minerals Development Fund
UNCTAD	UN Trade and Development
WMD	World Mining Data
WTO	World Trade Organization
YoY	Year on Year
ZEV	Zero-Emission Vehicle

UNITS USED

kg/kWh	kilogram per Kilowatt-hour
kt LCE	kilotons Lithium Carbonate Equivalent
MW	Megawatt / KW: Kilowatt / GW: Gigawatt
MWh	Megawatt-hour / kWh: Kilowatt-hour / GWh: Gigawatt-hour
MWp	megawatt-peak
PJ	Petajoules
t	tons / mt: metric tons / kt: kilotons
t/GWh	tons per gigawatt-hour

EXECUTIVE SUMMARY

Nigeria's pathway to net-zero by 2060, and its efforts to scale-up electrification of transportation and energy systems, will depend on reliable supply of critical minerals. These include lithium, cobalt, nickel, manganese, copper, rare earth elements, and other minerals essential for batteries, renewable power technologies, and grid infrastructure.

This study highlights both the scale of opportunity and the urgency of action supporting the development of enabling policies that can unlock Nigeria's clean energy potential. Nigeria has significant deposits of lithium-pegmatites, niobium, tin, iron ore with active production. While other minerals like nickel, manganese, and cobalt have occurrences, their actual reserves estimates remain largely unmapped and production is not active yet. This mineral landscape positions Nigeria as a potential hub in Africa's clean energy supply chains. However, the mining sector is constrained by policy and governance gaps, underinvestment, limited processing capacity, infrastructure bottlenecks, and informality in artisanal and small-scale mining (ASM). Without targeted reforms, the country risks missing both domestic transition and developmental goals and global export opportunities.

To estimate future demand for these technologies, two pathways informed by Nigeria's Energy Transition and Investment Plan (ETIP) and Sustainable Energy for All (SEforALL) analysis are considered in the study: (a) Business-as-Usual (BAU) scenario reflecting current policy and market trends, and (b) Net Zero Emissions by 2060 (NZE2060) scenario aligned with Nigeria's long-term climate commitments. These pathways help capture the range of possible demand trajectories under varying levels of policy ambition and technological deployment.

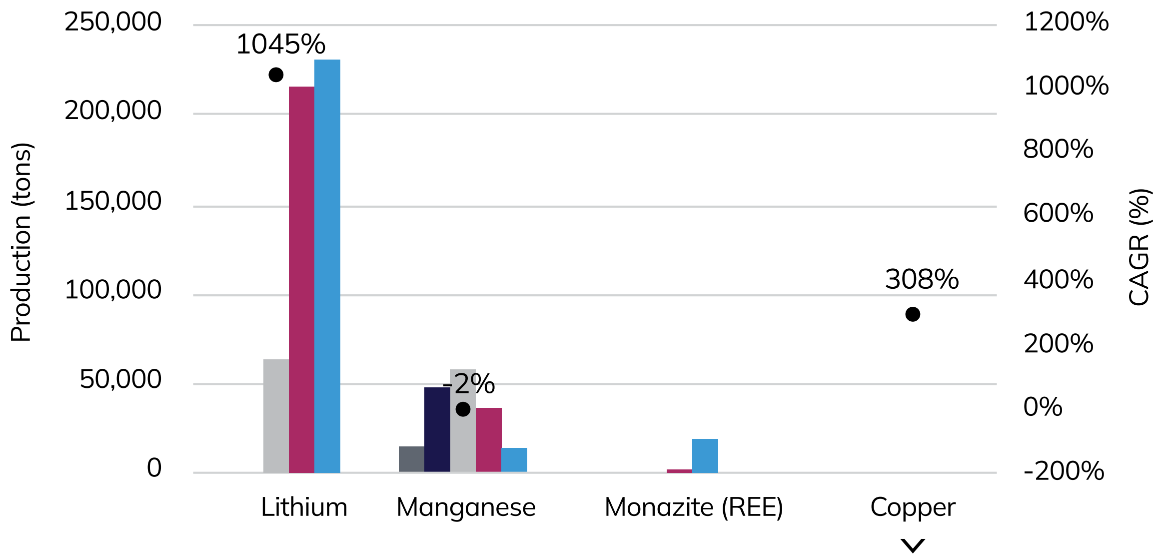
Demand for battery and solar related minerals is projected to increase sharply through 2030 and beyond, driven by the expansion of renewable energy, the adoption of electric mobility, and deployment of energy storage systems. Export demand will further intensify competition for Nigeria's resources, given global market shortages and rising investment flows into energy transition minerals. Against this backdrop, the following section sets out the key findings from this study highlighting Nigeria's projected mineral demand, recovery potential, and the strategic implications for its energy transition pathway.

KEY INSIGHTS FROM THE ANALYSIS

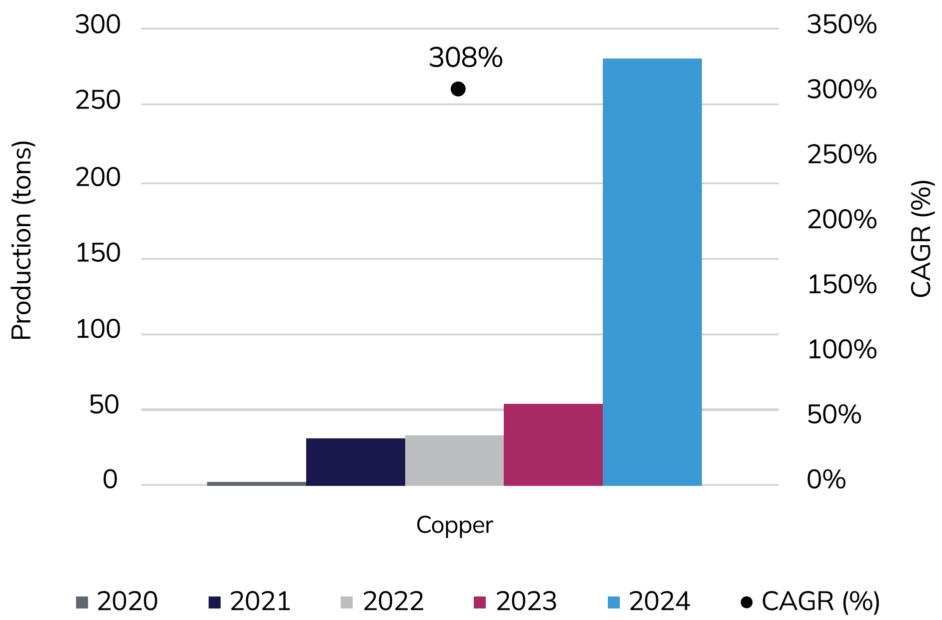
Nigeria marks high production growth signals in key minerals

Lithium, manganese, REE show high production growth signals but remain constrained by informalextraction, production inconsistency, and limited processing capacity. The country's resource potential hinges on sustained value capture that requires a shift towards formalization and strengthened governance, improved infrastructure, midstream investment, and prioritization of minerals aligning with global demand.

Production of lithium, manganese, copper & REE in Nigeria (2020-2024)



Production trend of copper in Nigeria (2020-2024)



Current resource endowment is under-developed despite its geological potential

Despite geological potential, mineral reserves and resources in Nigeria remain under-developed. While several minerals have been quantified and show industrial promise, others remain underexplored or unverified, underscoring the need for systematic geological surveys and public resource disclosure.

The country's export profile is largely dominated by crude oil and unprocessed mineral commodities

With limited domestic value-addition, Nigeria is mostly exporting crude oil and unprocessed minerals and continues to import nickel, copper, refined lithium, and other finished goods. This imbalance reflects a structural dependence on raw exports, where most of the economic value linked to refining, processing, and downstream use is captured abroad. China dominates both exports and imports in Nigeria's critical mineral trade, with limited diversification into EU or India-based offtake agreements.

Clean energy deployment will accelerate through 2060

By 2060, EV sales in Nigeria are projected to rise from the current levels of around 15 thousand - 20 thousand vehicles to about 49 thousand under BAU and nearly 100 thousand under NZE2060. This represents growth of roughly 145–227% under BAU and 400–567% under NZE2060, driven primarily by two- and three-wheelers h. Annual battery demand from new EVs will rise to around 2 GWh in BAU and 4 GWh in NZE2060. At the same time, Nigeria's vehicle market is dominated by second-hand imports—accounting for 80–85% of annual car additions—and imported used EVs alone could reach nearly 30,000 units by 2060. This means that while EV adoption will steadily expand, the timing and scale of domestic battery demand and end-of-life flows will be strongly shaped by second-hand vehicles. In parallel, stationary storage is expected to expand far more rapidly, with BESS capacity projected to reach ~89 GWh under BAU and ~2,600 GWh under NZE2060. Solar PV deployment will add further pressure, with annual capacity additions reaching 17 GW under BAU and 209 GW under NZE2060 by 2060. Together, these trends signal an unprecedented scale-up in Nigeria's clean energy deployment, underscoring the urgent need to align infrastructure, supply chains, and policy frameworks to meet future demand.

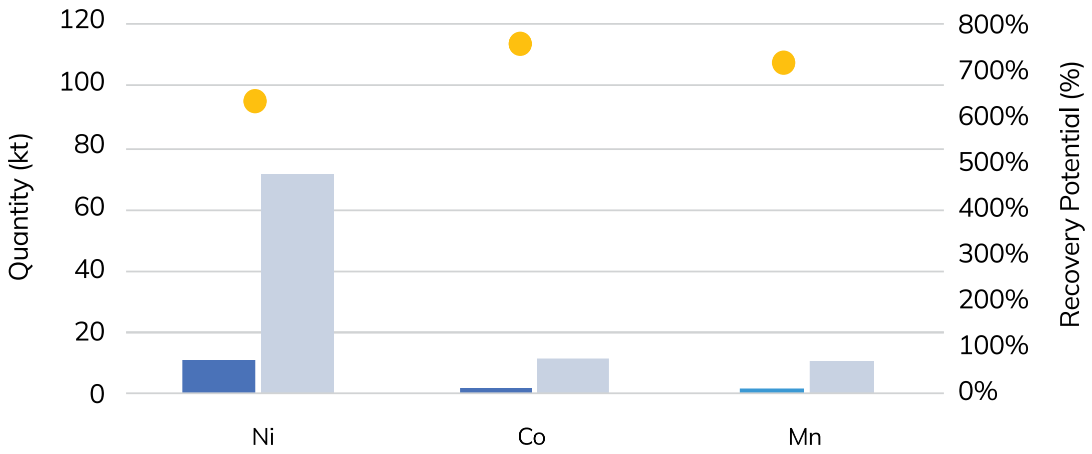
Cumulative (2025–2060) mineral demand across EVs, BESS, and PV is led by aluminum, copper, graphite, silicon, and lithium

Meeting this expansion across EVs, BESS, and solar PV will drive significant demand for graphite, copper, and aluminum, which dominate across technologies, alongside rising demand for lithium and nickel, while cobalt and manganese remain modest under the assumed LFP trajectory. Taken together, cumulative mineral demand across EVs, BESS, and PV modules between 2025 and 2060 is projected at: aluminum (4–70 mt), copper (2–42 mt), graphite (2–32 mt), lithium (0.2–2.9 mt), nickel (11–42 kt), manganese (2–6 kt), cobalt (2–6 kt), silicon (1.2–14 mt), and silver (6–71 kt). This scale of demand highlights the urgency for Nigeria to prioritise domestic value addition and secure reliable supply chains, or risk deepening dependence on imports.

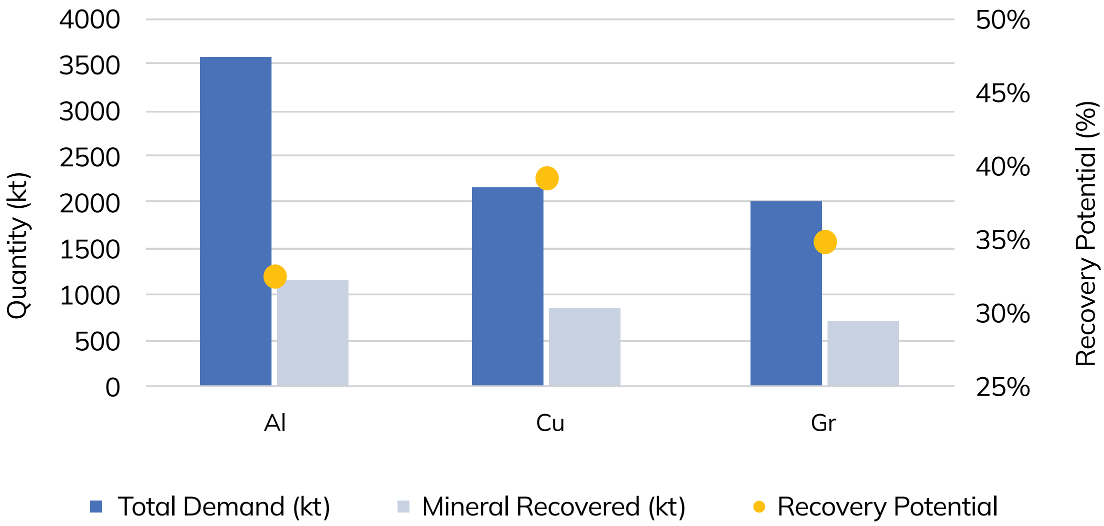
Recycling can offer partial support to high-demand minerals while creating export and industrial utilisation opportunities for other minerals

Recycling can strengthen Nigeria's long-term mineral security, but its contribution will differ significantly by mineral. Across scenarios, recycled supply is expected to offset a limited volume of cumulative demand for high demand minerals such as aluminum (11%-33%) copper (7%-39%), graphite (18%-35%), lithium (19%-36%) and silicone (7%-18%). While playing a larger role for nickel (172%-634%), cobalt (216%-753%) and manganese (2014%-717%), partly driven by end-of-life batteries from imported second-hand EVs, which reach retirement earlier after already serving part of their life in exporting markets. Although recovery volumes are higher in NZE2060 pathways, the percentage contribution from recycling is lower because mineral demand rises much faster than recovery and, due to end-of-life lags, a large share of deployed EV batteries, BESS units and solar PV systems enters the recycling stream only later. This makes it important for Nigeria to invest early in collection systems and recycling infrastructure so that capacity is ready when large end-of-life flows begin to emerge.

Mineral demand and recovery potential – nickel, cobalt and manganese (2025-2060)



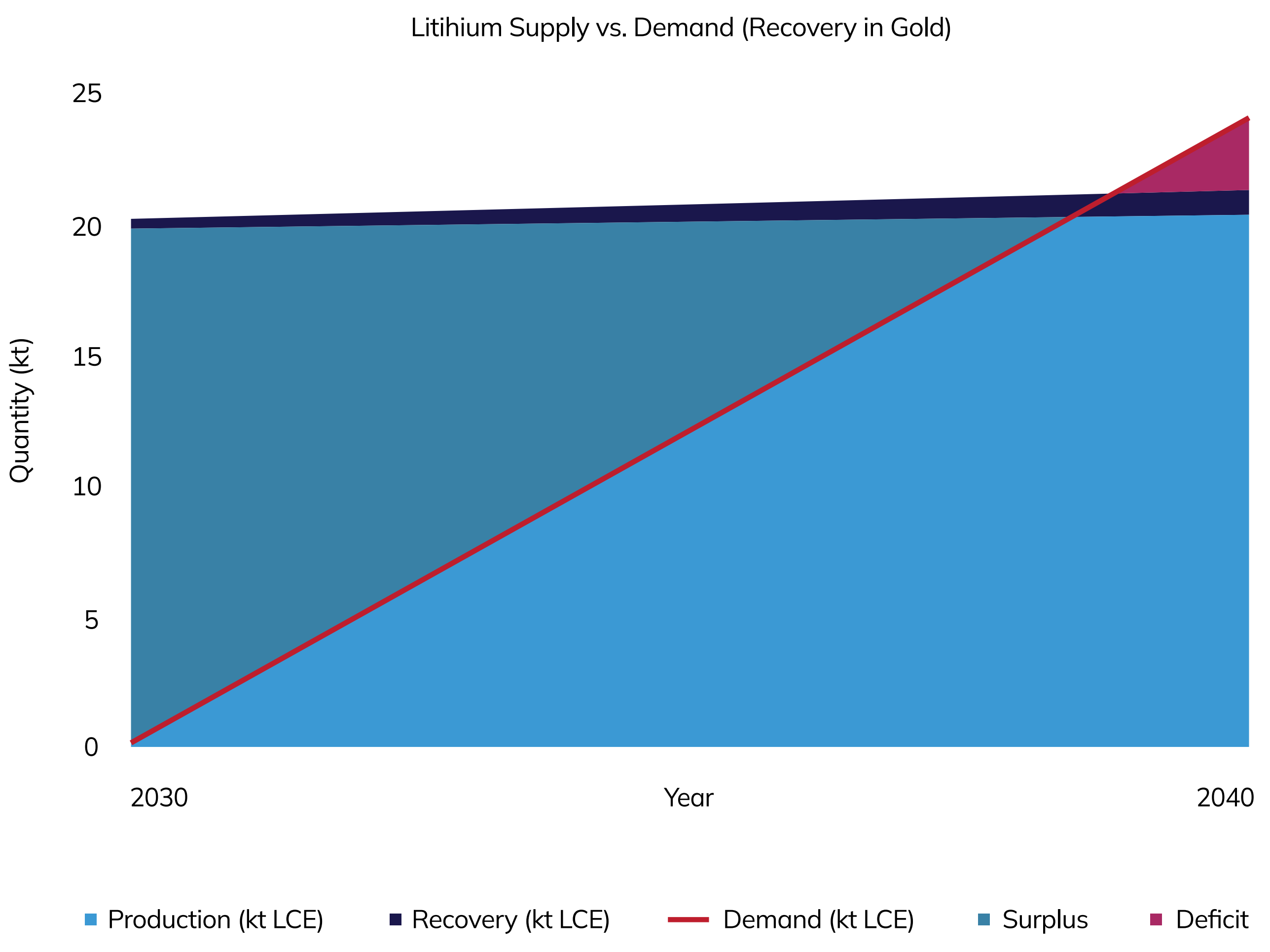
Mineral demand and recovery potential – aluminum, copper and graphite (2025-2060)



Nigeria will see lithium shortfall by 2040 but maintain a persistent manganese surplus, making lithium a supply risk and manganese an export opportunity

By 2040, lithium demand (24.2 kt LCE) will outpace its steady domestic production (20.3 kt LCE), leaving a supply gap of about 2.1 kt LCE even after recycling contributions. On the other hand, manganese output is projected to far surpass domestic clean energy demand (over 154 kiloton production vs. under 0.2 kiloton demand by 2035), creating a large export and value-addition opportunity if infrastructure and investment barriers are addressed.

Lithium supply-demand projects to 2040, including recovery



STRATEGIC PATHWAYS FOR NIGERIA'S ENERGY TRANSITION

Lithium presents a near-term domestic priority but requires deeper value-chain integration

Nigeria's lithium resources are investment-ready with production scaling in Nasarawa, Abuja, and Kaduna. While domestic demand shortfalls appear only beyond 2040, maximizing socio-economic benefits requires prioritizing processing and refining, stockpiling, local battery assembly, and structured trade agreements to secure forward linkages.

Manganese and nickel offer an export-oriented surplus with industrial linkages

Large manganese reserves and projected output exceed domestic demand, positioning Nigeria as a reliable global supplier. Similarly, nickel also shows potential for export surplus with its abundant deposits spread across Nigerian states. Strategic investment in midstream processing, certification, and transport infrastructure, coupled with beneficiation for steel, can transform manganese and nickel into both an export opportunity and a driver of local industrialization.

Copper is a medium-term strategic resource with untapped potential

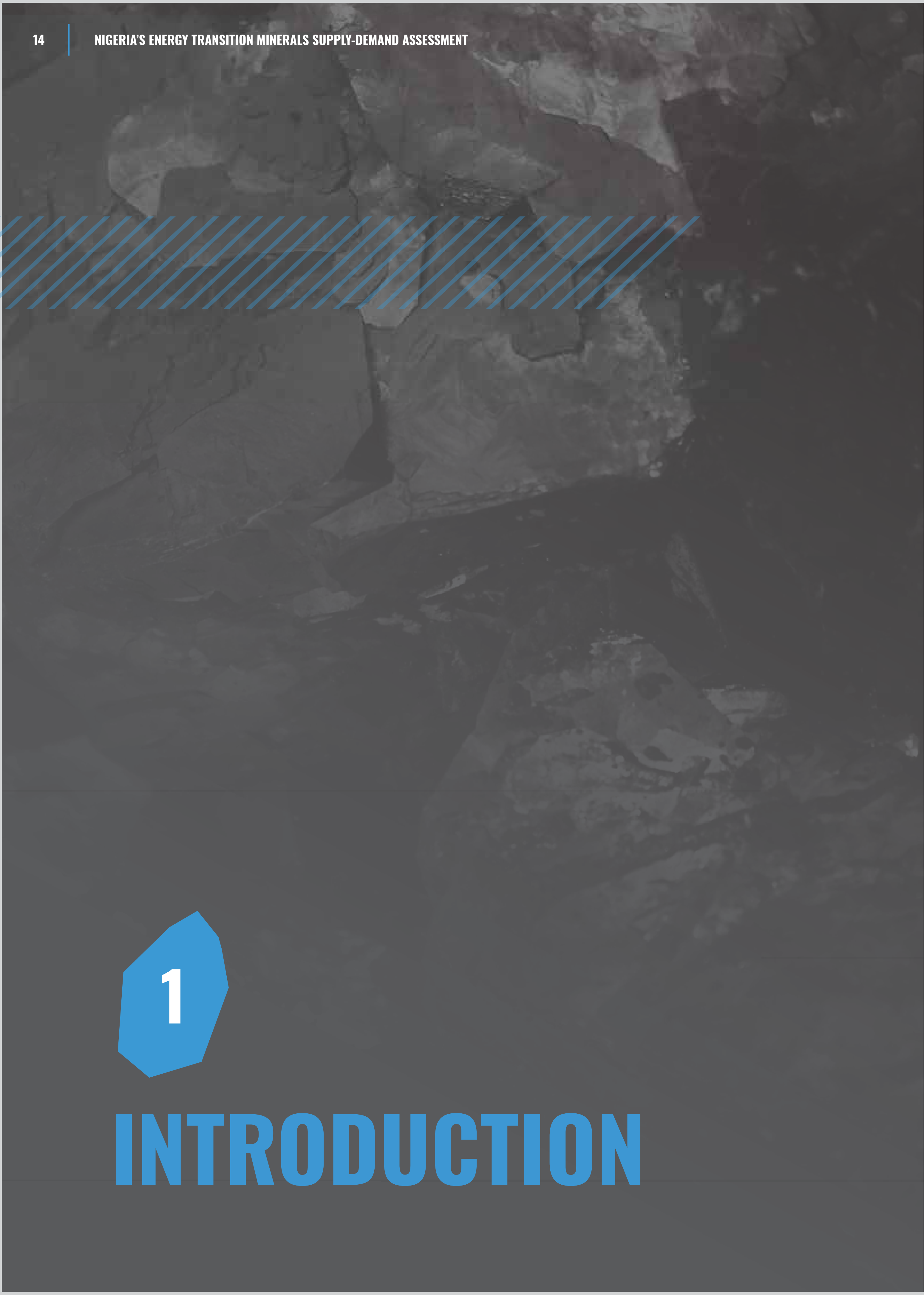
Despite identified reserves in Nasarawa, Plateau, and Zamfara, copper production remains at exploration stage. Unlocking its role in EVs and grid infrastructure requires targeted surveys, investment incentives, ESG adherence, and infrastructure upgrades to position copper as a growth driver.

Circularity and recycling can strengthen long-term mineral security

Early end-of-life batteries from second-hand EV imports and eventual PV module waste highlight the urgency of recycling frameworks. Formalized collection, repurposing and recycling infrastructure, supported by producer responsibility schemes, can transform waste streams into a secondary supply source.

Infrastructure, ESG benchmarks, and ASM formalization are foundational enablers

Persistent infrastructure bottlenecks, lack of traceability, and dominance of ASM constrain competitiveness. Nigeria must align a unified minerals strategy with industrial policy, strengthen governance and certification systems, and formalize ASM through cooperatives and finance access to integrate into global clean energy supply chains.



1

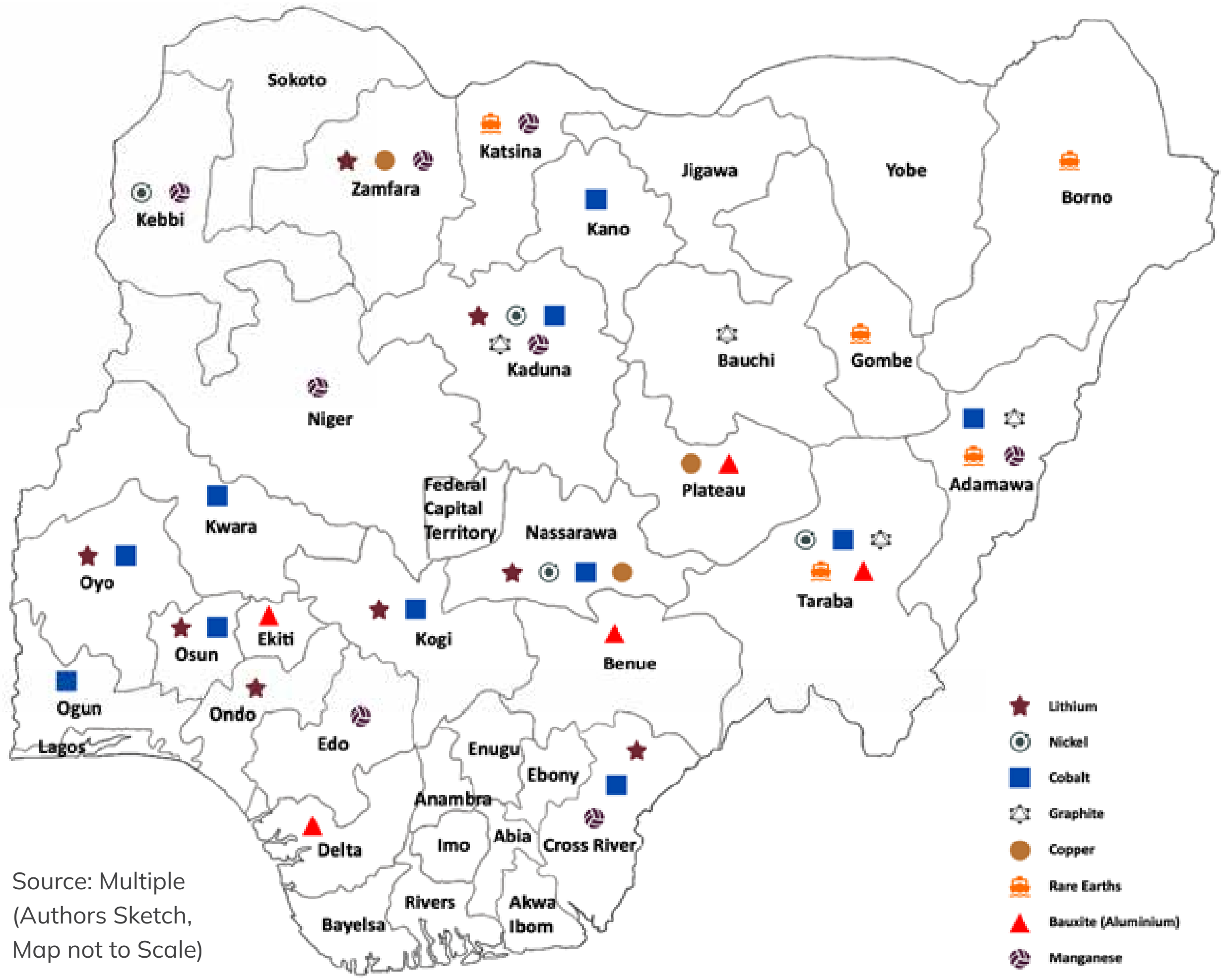
INTRODUCTION

INTRODUCTION

Nigeria is increasingly recognized as a country with a strategic role to play in critical energy transition minerals supply chains. It is among the largest markets for renewable energy (RE) and electric mobility technology adoption in Sub-Saharan Africa. Furthermore, deposits of minerals such as lithium, nickel, manganese, cobalt, copper and others, critical in the production of electric vehicles (EVs), solar modules and energy storage systems, are reported across Nigeria's geological zones (Figure 1) [1], [2], [3], [4]. In 2023, the Ministry of Solid Minerals Development (MSMD) reported that Nigeria hosts 44 minerals in over 500 locations in all 36 States and Federal Capital Territory [5]. While mineral endowment is abundant, active production remains limited to a handful of resources, primarily in lithium, tin, tantalum, zinc and copper, and largely driven by artisanal and small-scale mining (ASM) [6], [7]. Minerals like nickel, manganese and graphite remain at the exploration stage or largely undeveloped, despite evidence of viable deposits [8]. Processing and value addition have traditionally been minimal; however, the government has recently taken steps to reduce imports of raw minerals and attract investments in local beneficiation infrastructure.

FIGURE 1

Critical minerals occurrence in Nigeria



Source: Multiple (Authors Sketch, Map not to Scale)

The 2016 Roadmap for the Growth and Development of the Nigerian Mining Industry by the Ministry of Mines and Steel Development (MMSD) lists seven strategic minerals: iron ore, gold, coal, limestone, barytes, bitumen and lead/zinc [9]. However, this list is outdated in the context of current energy transition goals and does not reflect the global demand for clean energy-related critical minerals.[1] As of September 2023, Nigeria's unexplored critical mineral deposit was valued at USD 700 billion [10]. Ongoing reforms include a proposed amendment to the Mines and Minerals Act that aims to designate strategic minerals, enforce environmental, social and governance (ESG) compliance, and require beneficial ownership disclosures. Nigeria has also proposed granting new mining licenses to companies that include plans for local processing [11]. As of 2025, Nigeria has yet to publish an updated critical or strategic minerals strategy, or revise its official list of priority minerals [12]. These gaps underscore the need for a formal policy update to align Nigeria's mineral governance framework with emerging global clean energy value chains.

In this context, this report presents an assessment of Nigeria's energy transition minerals[2] landscape. Using two scenarios: Business as Usual(BAU) and Net-Zero Emissions (NZE), we assess how much of these minerals are required to meet the projected demand of solar PV modules and batteries for stationary and electric mobility applications through 2060 under two pathways informed by Nigeria's Energy Transition and Implementation Plan (ETIP) and developed by the Government of Nigeria in partnership with Sustainable Energy for All (SEforALL) [13]. On the supply side, we examine the current production levels, resource potential and how much of the projected demand can be met by Nigeria's domestic supply. This analysis provides a baseline for understanding the country's readiness to secure minerals supply for its own energy transition, opportunities for midstream and downstream industry development and identifies gaps and strategic priorities in the critical minerals value chain.

This report has been developed by the Global South Center for Clean Transportation, Institute of Transportation Studies, UC Davis under the auspices of the Council for Critical Minerals Development in the Global South.

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[1] The 2016 roadmap prioritizes minerals that boost domestic interests such as infrastructure development, energy access and job creation. These choices align with the country's economic needs and are still relevant to national development. While Nigeria has outlined its own mineral agenda, it remains anchored to a decade-old list and risks missing emerging opportunities in global critical mineral supply chains. Updating the roadmap would position Nigeria to benefit fully from future trade, technology and investments linked to the energy transition.

[2] For the purposes of this study, the following energy transition minerals are considered: lithium, manganese, copper and graphite.

2

NIGERIA'S MINERAL ENDOWMENT

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Nigeria has a population of approximately 227 million people (2023) [14], making it the most populous country in Africa. Nigeria operates as a federal presidential republic [15], comprising 36 states and the Federal Capital Territory (Abuja). Nigeria is the fourth-largest economy in Africa, with a nominal GDP (current USD) of approximately USD 188 billion in 2024, after South Africa, Egypt and Algeria [16]. The Mining & Quarrying sector comprising crude petroleum and natural gas, coal mining, metal ores and quarrying, and other minerals sub-activities contributed nearly 8 percent to the overall GDP in the third quarter of 2024 [17]. Specifically, metal ores, quarrying and other non-fossil-fuel based minerals accounted for less than 1 percent of total GDP. The Ministry of Solid Minerals Development (MSMD) is laying a strong emphasis on raising the contribution of the mining sector to the country's GDP, leveraging its non-oil mineral resources. leveraging its non-oil mineral resources.

2.1. MINERALS PRODUCTION TRENDS

This analysis draws on the production data by the Mines Inspectorate Department of the Ministry of Solid Minerals Development (MSMD) to examine trends in Nigeria's production of critical energy transition minerals between 2020 and 2024. Table 1 lists the minerals considered for the analysis. Over this period, mineral output shows a mix of rapid growth, declines and inconsistent patterns that reflect Nigeria's undercapitalized mining sector.

Among metallic minerals, iron ore production, increased at 90 percent Compound Annual Growth Rate (CAGR), from 3,413 tons in 2020 to 44,513 tons in 2024. This rise may be attributed to a combination of factors: reporting or classification changes, policy or enforcement changes such as government reforms pushing informal production into official records, or project-level developments and new local processing activity that motivate ramp-up in production. There is an increasing production trend in manganese between 2020 to 2022, followed by a decrease, overall reflecting a negative CAGR. In contrast, the World Mining Data (2019-2023) reported manganese experienced a high growth, increasing from 1,000 tons in 2019 to over 22,000 tons in 2021 before falling to 16,300 tons in 2023, reflecting an overall CAGR of 101 percent [18].

TABLE 1

Nigeria's mineral production, tons (2020-2024)

Group	Type of Mineral / Ore	2020 (t)	2021 (t)	2022 (t)	2023 (t)	2024 (t)	CAGR (2020-2024)
Metallic Minerals	Columbite Ore	9,838	1,151	3,227	3,965	1,834	-34%
	Coltan	33	33	27	15	6	-35%
	Copper	1	30	32	53	277	308%
	Iron Ore	3,413	1,543	2,630	18,419	44,581	90%
	Ilmenite	-	-	17,142	17,609	57,639	-
	Lead/Zinc Ore	149,750	87,048	117,590	63,120	117,259	-6%
	Lead/Zinc Concentrate	-	-	-	-	10,176	-
	Lithium*	-	153	63,724	216,123	230,164	1045%
	Tantalite* (Crude)	-	38	91	19,361	1,869	267%
	Tin Ore (Cassiterite)	2,078	24,873	12,569	48,688	61,626	133%
	Tin Concentrate	-	-	-	-	4,781	-
	Manganese	15,000	47,673	58,315	36,030	14,000	-2%
	Rutile	-	-	-	2,023	-	-
Non-metallic (Industrial) Minerals	Wolframite*	-	46	18	51	4,411	359%
	Nickel Ore	10	-	-	-	-	-
	Beryllium (Beryl)	-	-	-	299	960	-
	Laterite	5,615,936	6,583,894	6,288,495	4,694,809	18,462,932	35%
	Monazite	-	-	50	2,220	19,431	-

Source: MSMD (n.d.)

Note: Rounded figures. TiO_2: titanium dioxide, Ce: Cerium, La: Lanthanum, Nd: Neodymium, Th: Thorium

*Lithium, Tantalum, and Tungsten CAGR is calculated between 2021-2024.

Copper production, while it started from negligible levels in 2020 has grown by over 300 percent CAGR, indicating nascent but fast-rising activity. While no activity was recorded for titanium (ilmenite) for 2020 and 2021, the production jumped from 17,000 tons to over 57,000 tons between 2023 and 2024, marking a 227 percent annual increase, likely driven by new discoveries or exploited deposits. Niobium and tantalum-bearing ores (columbite, coltan, and tantalite) recorded declines after intermittent peaks, maybe reflecting the artisanal extraction or lack of structured markets, indicating potential for niche market development if formalized. Tungsten (wolframite) production though remained small in comparison to other minerals, but exhibited exponential growth, highlighting volatility in small-scale extraction.

Lithium production increased from 153 tons in 2021 to 230 thousand tons in 2024, at 1045 percent CAGR (2021-2024) (Figure 2), pointing to a rapid response to demand from various sectors, including global EV battery production. This growth is accompanied by the reported rise in royalties from NGN 113 million (USD 0.18 million) in 2023 to NGN 400 million (USD 0.27 million)[3] in 2024. Lead and zinc production remained high but volatile with negative CAGR between 2020 and 2024, whereas tin showed a high production growth (133 percent CAGR) during the same period.

For non-metallic (industrial) minerals, laterite stands out with reported volumes soaring to over 18 million tons in 2024 (35 percent CAGR). This highlights both its use as a proxy for bauxite and nickel bearing ores, and its role in the domestic construction industry. Beryllium, absent from earlier years, emerged as a significant mineral in 2023, reaching close to 1,000 tons in 2024, indicating new exploitation.

Monazite, a key source of rare earth elements (REE), shows a sharp increase from negligible levels in 2022 to over 19,000 tons in 2024. Nigeria has an underutilized potential on REE, and its production trend suggests unexploited deposits. Global REE supply chains are highly constrained and dominated by countries like China (which controls nearly 69 percent of REE production and around 90 percent of refining, according to 2023 estimates), Australia, and the United States [20]. According to the United States Geological Survey, Nigeria accounted for 2 percent of the total global REE production in 2023, increasing to 3.3 percent in 2024. The country is a new entrant to the world's top 10 REE producing-nations [21]. Its underdeveloped REE reserves could represent a strategic opportunity, if mapped and responsibly developed with investment and regulatory clarity [22]. The government signed a memorandum of understanding with France in 2024 as a step to develop Nigeria's critical minerals sector including REE [23].

Overall, Nigeria's critical mineral supply landscape is marked by high-growth signals in key transition minerals such as lithium, manganese, copper, REE, and tin, but remains constrained by artisanal extraction, production inconsistency and limited processing capacity. While data suggest significant resource potential, sustained value capture will require a shift toward formalization, improved infrastructure, midstream investment and the strategic prioritization of minerals aligned with global demand trajectories [24]. There is an opportunity for Nigeria to build upstream-to-midstream value chains for some key minerals (e.g., lithium, manganese, REE), where both growth potential and demand alignment exist.

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[3] World Bank official exchange rate data was used for exchange with 2023 average of NGN 645/USD and 2024 average of NGN 1,479/USD [19].

Several other critical minerals used for clean energy technologies, such as nickel (with recorded negligible production in 2020), cobalt, graphite, etc. are not captured in the official production datasets. However, the absence of production data does not necessarily indicate that these minerals are geologically absent, as Nigeria is known to hold deposits of several of these minerals. This distinction is important: for minerals that are not geologically present, Nigeria will need to rely on imports, but for those with proven reserves, the priority should be to address data gaps and unlock production. This will be important for developing a coherent national strategy and attracting investment in the sector.

FIGURE 2 (A)

Production of lithium, manganese, copper & REE in Nigeria (2020-2024)

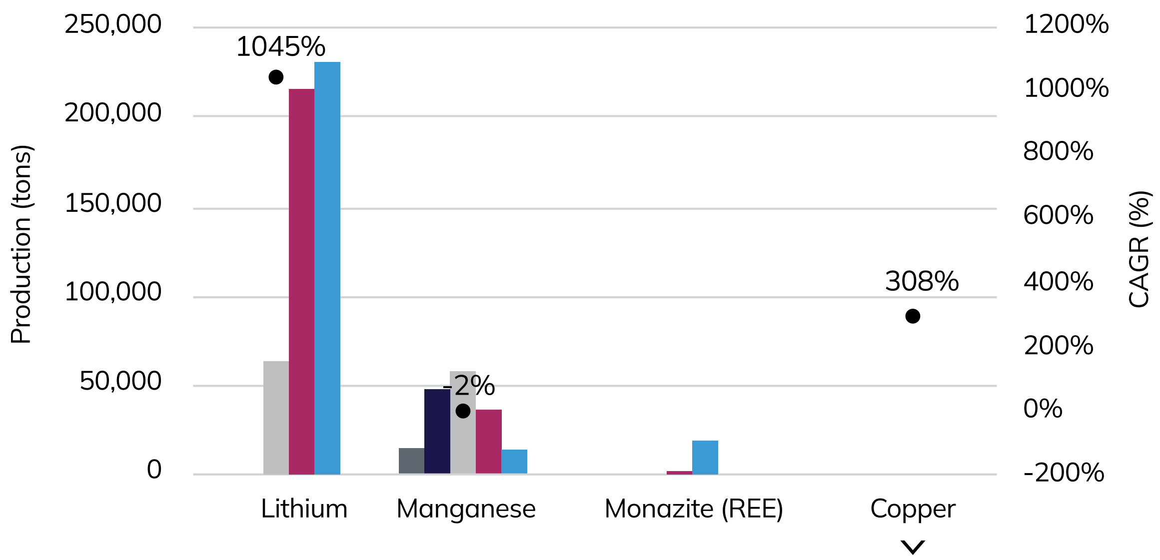
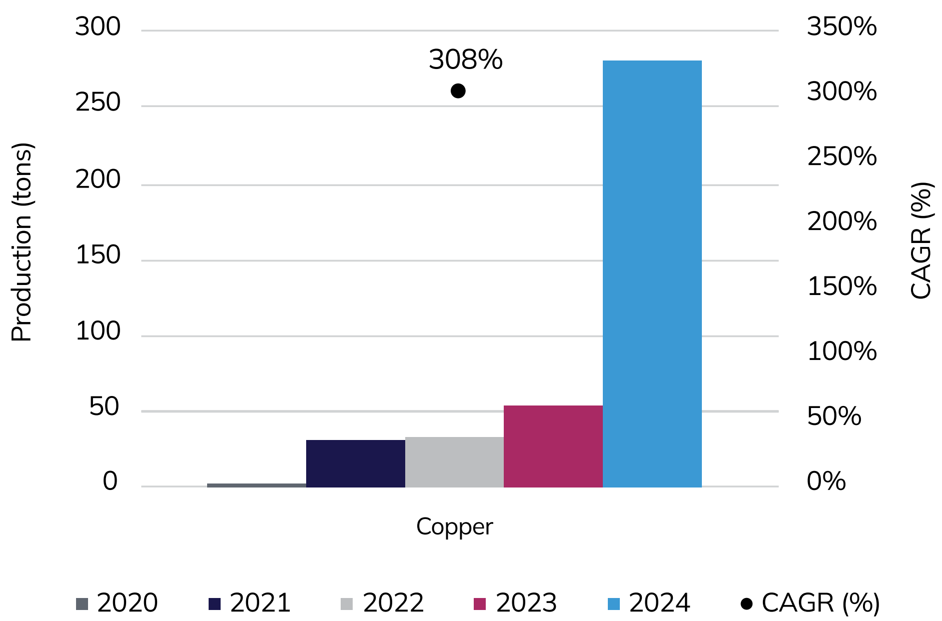


FIGURE 2 (B)

Production trend of copper in Nigeria (2020-2024)



Source: MSMD (n.d.)   Note: Lithium CAGR is calculated for 2021 and 2024.

2.2. STATUS OF RESERVES AND RESOURCE ESTIMATION

Nigeria's current mineral reserve and resource estimation remains under-developed, despite the country's geological potential [25]. Most known deposits of critical minerals exist only at inferred or indicated levels, with minimal regulated mining. According to the Nigerian Geological Survey Agency (NGSA), large portions of the country's mineral terrain remain unmapped or surveyed only with outdated techniques. This lack of up-to-date and digitized geological data restricts private investment, limits strategic planning and undermines the feasibility of downstream value addition. While artisanal and small-scale mining (ASM) has revealed promising occurrences, particularly for lithium, tin and REEs, these sites lack verified grades, volumes and spatial continuity. As a result, Nigeria's critical mineral development is often speculative. Strengthening Nigeria's understanding of its mineral base is a critical first step toward leveraging its endowment for clean energy value chains.

While Nigeria has institutions such as the NGSA, data often remain undigitized or undisclosed. MSMD has taken steps to improve its geological data infrastructure, including ongoing collaborations with development partners such as the World Bank [26]. However, without a credible reserve baseline, Nigeria cannot confidently attract long-term capital, negotiate offtake agreements or plan for industrial processing. The status of reserve and resource estimations varies considerably across different commodities (Annexure 1). Key highlights include:

1. Surveys conducted by the NGSA find high-grade varieties of **lithium** (spodumene and lepidolite), particularly in Kwara and Oyo states. The occurrence is in association with some rare earth metals, including cassiterite and columbite-tantalite. States with known lithium deposits include Kwara, Nassarawa, Kogi, Ekiti, Kaduna, and Oyo Osun. Economic viability of deposits in Cross River, Bauchi, Niger, Edo and Taraba is yet to be determined [27].

2. **Nickel** resources, estimated at 5 million metric tons and found across Kaduna, Kebbi, Nasarawa, and Taraba, remain at the exploration and development stage. Despite the announcement of a nickel processing facility in Kaduna, Nigeria continues to import the mineral for its industry's needs.

3. **Cobalt** occurrences are widespread, spanning over ten states. Prominent examples include deposits in Adamawa and Kaduna, areas where the government has actively licensed blocks for exploration. Geologically, the cobalt typically appears in sulphide form, most commonly as the mineral cobaltite. Crucially, it is almost always found as a byproduct of nickel and copper deposits. This means that the economic feasibility of mining Nigeria's cobalt is directly tied to the simultaneous development of its larger nickel and copper resources, such as the major nickel find in Kaduna. Therefore, while the potential is confirmed and exploration is underway, the path to commercial cobalt production in Nigeria is intrinsically linked to the broader progress of its base metal mining industry.

4 **Graphite** deposits, while reported in Bauchi, Kaduna, Adamawa, and Taraba, are largely underexplored, signalling the need for further efforts on bridging the information gaps.

5 **Copper** ore reserves are estimated at over 10 million tons with high-grade deposits in Azara and Akiri in Nasarawa State, along with occurrences in Plateau, and Zamfara.

6 **Manganese** is more widely distributed, with an estimated 5 million metric tons of deposits across Niger, Edo, Adamawa, Kebbi, Cross River, Kaduna, Zamfara, and Katsina.

7 **Bauxite (Aluminum)** deposits are found in Plateau, Taraba, Delta, Ekiti, and Benue states. The Mambilla Plateau is noted for its low-silica bauxite deposits. It has an estimated total reserve of approximately 1,000 kt [28].

8 **Monazite** is a significant **rare earth** mineral found in several states across the country, notably Plateau (Jos Plateau), Kaduna, Niger, Bauchi, Katsina, Adamawa, Oyo, Cross River, and others. Nigerian monazite contains a wealth of rare earth elements (REEs) such as cerium, lanthanum, neodymium, europium, terbium, ytterbium, and lutetium, and is often associated with other valuable minerals like columbite, tantalite, zircon, ilmenite, rutile, quartz, and feldspar.

The occurrence of these critical minerals suggests many of them are currently either under geophysical investigation or geochemical assessment. This emerging data landscape reflects a mixed picture: while several minerals have been quantified and show industrial promise, others remain underexplored or unverified, underlining the need for systematic geological surveys and public resource disclosure.

2.3. TRADE: IMPORT AND EXPORT OF MINERAL COMMODITIES

Trade plays a pivotal role in shaping Nigeria's mineral resources landscape as well as broader structural transformation ambitions.

Nigeria's export profile remains dominated by crude oil and unprocessed mineral commodities, with limited value addition. In the first quarter of 2025, crude oil and liquefied natural gas dominated Nigeria's exports, accounting for over 73 percent of total export value. Key export destinations included France, India, the Netherlands, Spain and the United States, accounting for 46 percent of the total value of Nigeria's exports. On the import side, Nigeria sources most of its goods – including refined petroleum products (gas oil, motor spirit, crude oils) cane sugar and durum wheat – from China, India, the Netherlands, the United Arab Emirates and the United States.

Nigeria continues to import key industrial and technological minerals, such as nickel, copper and refined lithium, as well as finished goods. Nigeria is in fact a net-importer of renewable energy (RE) technologies, having imported solar PV modules to the tune of approximately USD 120 million and nearly USD 160 million in 2022 and 2024, respectively. In the first quarter of 2025 alone, it imported modules valued at over USD 82 million. For lithium-ion batteries, imports reached nearly USD 150 million in 2022 and close to USD 200 million in 2023. China was the primary trading partner for both technologies, accounting for over 90 percent of the import value.

This trade pattern reflects both structural constraints and missed opportunities for upstream-to-midstream value capture. A closer examination of mineral-related imports and exports provides insight into Nigeria's current positioning in global critical mineral supply chains and highlights areas for strategic policy intervention.

This section draws on official international trade statistics from the UN Comtrade Database to assess Nigeria's import and export activity for selected critical minerals and mineral-based products relevant to clean energy technologies.[4] The analysis covers the years from 2019 to 2024; and a list of Harmonized System (HS) codes considered for the analysis is attached in Annexure 2. Various applications and industrial uses for these minerals are included in Annexure 3.

2.3.1. Lithium

Nigeria's lithium sector has seen significant development in recent years with a focus on expanding production leveraging reserves as well as introducing regulatory measures to formalize mining and encourage local processing and refining. Alongside domestic production insights, trade data can assist us in better understanding how lithium ores and concentrates, as well as refined products, are integrated into global supply chains.

The UN Trade and Development (UNCTAD) Technical Note on Critical Minerals (2023) [29] uses HS 253090 to track global trade in lithium raw materials such as spodumene and similar ores fall under this broader category, while refined lithium compounds such as lithium carbonate (HS 283691) and lithium hydroxide (HS 282520) have their own specific codes. The HS code 253090 is a broad category used for raw or unprocessed mineral materials that do not fall under more specific classifications (mineral substances not specified in Chapter 25).[5]

[4] Under section 2.3.1 and 2.3.2, the trade has been analyzed using exports and imports with Nigeria reported by partner countries because of a consistent pattern of asymmetric trade visibility across Nigeria's trade profile. It is important to note that in UN Comtrade, imports are recorded CIF (cost insurance and freight) while exports are FOB (free on board). This may represent a 10 to 20 percent difference.

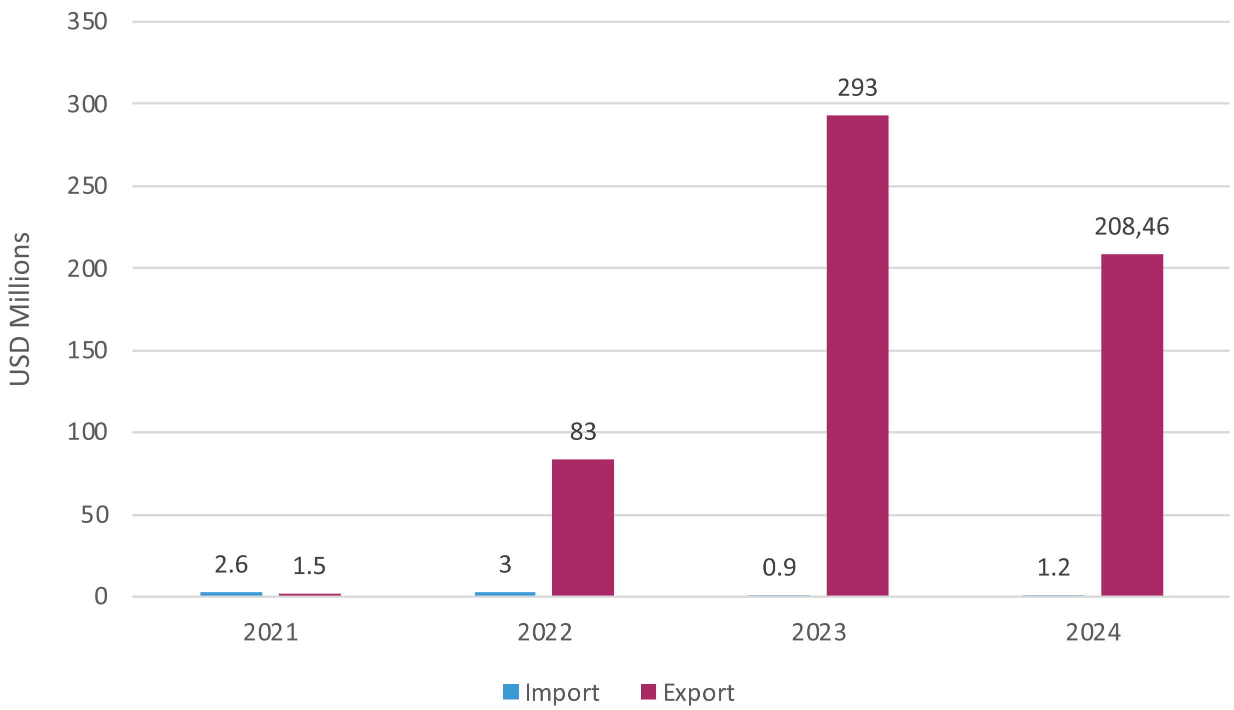
[5] This includes a wide range of unprocessed minerals, such as natural graphite (unrefined form), feldspar, quartzite, other earth minerals and stones with industrial applications, and certain by-products of mining used in cement, agriculture or metallurgy. Other raw material substances included are spodumene ore, lepidolite, petalite and other lithium-bearing minerals before they undergo chemical processing. Since there is no dedicated HS code for lithium ores or concentrates, these materials are grouped under this generic heading. As a result, lithium trade at the raw material stage is often underreported or difficult to isolate without country-level disaggregated data. To improve transparency, Australia introduced a new national-level statistical code in 2021 under its Australian Harmonized Export Commodity Classification (AHECC), code 25309011 for lithium concentrates, specifically capturing spodumene exports, providing additional insights into commodity trade.

Lithium ores and concentrates (unprocessed) (HS 253090)

Nigeria's trade in lithium ores and concentrates, represented through reporting of HS 253090 from partner countries, has expanded substantially. The value of exports from Nigeria grew from USD 1.5 million in 2021 to nearly USD 300 million in 2023, falling to almost USD 210 million in 2024 (Figure 3). China is the largest trading partner; it accounted for over 99 percent of Nigeria's exports in 2023 and 2024. The value of imports into Nigeria saw a declining trend from USD 2.6 million in 2021 to USD 1.2 million in 2024. The country-reported data indicate a growing share of export of Nigeria's lithium and participation in global value chains, although there is a need for strengthened trade monitoring, accurate customs coding and improved cross-border data reconciliation with Nigeria's domestic trade data as the critical mineral sector evolves.

FIGURE 3

Lithium ores and concentrates import and export (2021-2024)



Source: UN Comtrade

Lithium carbonate (HS 283691) and lithium hydroxide (HS 282520)

The first lithium processing plant in Nigeria in Nasarawa State was commissioned in 2024, and there are several others in the pipeline including in Kaduna State. The processed outputs in the form of lithium carbonate or lithium hydroxide from the plants are not yet reflected in the trade data, although it is expected that lithium ore exports will decrease due to the government's decisions to encourage local processing (to achieve greater value addition) and trade in processed goods.

The lack of domestic lithium processing infrastructure is evident in trade data over the past few years. The export and import of both commodities have been limited and were only sparsely reported between 2021 and 2024. Significant recent transactions have been with China, India and the United Arab Emirates but trade was not sufficiently sustained for meaningful conclusions on trends to be drawn.

2.3.2. Manganese

Trade in manganese is captured from manganese ores and concentrates (HS 260200) manganese dioxide (HS 282010), and manganese oxide (282090). Manganese is a critical input for battery cathodes in lithium-ion battery chemistries often used as battery precursors or as alloying agents for producing high-strength steel.

Manganese ores and concentrates (HS 260200)

Nigerian exports of manganese ores and concentrates exceeded USD 16 million between 2020 and 2023. The figures range from nearly USD 3 million in 2020, increasing to about USD 5 million both in 2021 and 2022 but decreasing to USD 3.4 million in 2023. China is the largest importer of Nigeria's manganese ore, accounting for over 95 percent of the trade. Nigerian imports of ores as reported by partner countries, on the other hand, remain minimal.

Manganese dioxide (HS 282010) and other oxides (HS 282090)

Nigeria lacks the manganese processing and refining infrastructure to produce oxides used in battery chemistries and in other sectors, including steel. Minimal exports are reported for manganese dioxide and other oxides from Nigeria, indicating limited domestic production and/or consumption in local industries. In fact, imports of manganese oxides are reported; these may be used in the agriculture, chemical and manufacturing, and metallurgy industries.

2.3.3. Copper

Trade in copper is captured through ores and concentrates (HS 260300). While trade in ores and concentrates has been minimal, Nigeria has consistently exported copper worth over USD 2.9 million between 2019 and 2024. Key partners include China, with additional exports recorded to Germany and Belgium. This indicates that copper is being exported largely in raw form. While official records indicate minimal domestic production, the export volumes (cumulative 1,618 metric tons between 2019-2024) point to much of the activity is taking place through ASM, which is not reflected in production statistics, and the raw ore is leaving the country without significant domestic processing.

2.3.4. Implications for Trade

Available evidence indicates Nigeria captures only a small fraction of overall value in its mineral trade. Most of Nigeria's mineral exports are in raw or unprocessed form, with minimal domestic value addition. For instance, the Nigeria Extractive Industries Transparency Initiative's (NEITI's) 2021 Solid Minerals Industry Audit recorded that the solid minerals sector contributed only 0.63 percent to Nigeria's GDP and just 2.62 percent to federal government revenue, despite significant export volumes [30], [31]. This imbalance reflects a structural dependence on raw exports, where most of the economic value linked to refining, processing and downstream use is captured abroad.

Nigeria's critical mineral trade is highly concentrated, with China dominating as a key trade partner. As Nigeria continues to take steps to limit exports of raw minerals and attract investments in local beneficiation, a critical minerals trade and development strategy is necessary. Recently, the Nigeria Senate passed the Raw Material Research and Development Council (RMRDC) Act Amendment Bill (2025) mandating that raw materials are not exported without undergoing at least 30 percent value addition. It is also finalising an Electric Vehicle Transition and Green Mobility Bill that is expect to introduce requirements for all EVs sold in Nigeria to have 30% of their components locally sourced by 2030. These offer strategic pathways towards safeguarding jobs, endorsing local manufacturing, and reducing dependency on imported raw materials [32], [33]. To build a more strategic trade power, Nigeria must regulate its exports, develop midstream capacity and negotiate from a position of value leveraging the African Continental Free Trade Area (AfCFTA) and the Economic Community of West African States (ECOWAS) for Regional Market Access [34], [35], [36], [37], [38].

Beyond domestic beneficiation, Nigeria has an opportunity to adopt a continental lens. Africa has considerable reserves of critical minerals but lacks downstream battery processing capacity, indicating scope for strategic investment in midstream projects like battery plants. South Africa's recent 1 billion-rand (USD 54 million) incentive for EV and battery production [39], Rwanda's European Investment Bank (EIB)-backed push in CRM development [40], and Democratic Republic of Congo (DRC)-Zambia Lobito Corridor for cross-border cooperation, development of nickel, manganese and cobalt (NMC) battery precursors [41], and minerals sourcing are examples of how regional/international collaborations could unlock mutual benefits in the critical minerals-to-battery value chain. For Nigeria, a similar approach could mean positioning itself as a hub that links West African mineral producers with regional processing and battery manufacturing capacity. This would help diversify Nigeria's industrial base and embed it firmly in the Africa-wide minerals value chain.

Currently, Nigeria is shaping its critical minerals diplomacy through several Memoranda of Understanding (MoU) and technical engagements (Table 2) with a number of countries, including China, France, Qatar, Saudi Arabia, South Africa, Turkey, the United Arab Emirates and the United Kingdom. Nigeria also played a leadership role in the establishment of the Africa Minerals Strategy Group unveiled at the Future Minerals Forum in January 2024. These efforts are complemented by strong domestic policies requiring beneficiation and secure licensing to build processing and trade capabilities.

Furthermore, the AfCFTA provides entry points for Nigeria to align with environmental, social and governance- (ESG-)compliant supply chains and regional market access. The MSMD uses the Pan-African Resource Reporting Code (PARC) as the guiding framework for the Accelerated Mining Development Programme (AMDP), ensuring that mineral evaluation and certification adhere to continent-wide standards of transparency, accountability and investor confidence.

Furthermore, Nigeria's electronic Mining Candastre Plus (eMC+) system has been recognized as a model for excellence and transparency to be potentially utilized as a blueprint for a unified regional mining cadastre platform across the ECOWAS region.

TABLE 2

International agreements related to Nigeria's critical minerals (2024-2025)

Partner/ Collaboration	Type of Agreement	Data Signed	Focus Area	Notes
France [23]	Bilateral MoU	December 2024	Lithium, copper, cobalt, nickel, REEs; joint research, training, processing projects	Includes public-private co-financing; signed during Nigeria-France Business Forum
South Africa [42]	Bilateral MoU	April 2025	Geological mapping, mineral processing, tech transfer, training, data sharing	Part of Bi-National Commission; collaboration with South Africa's Council for Geoscience
Qatar [43]	Broad Bilateral Agreement	March 2024	Lithium and other solid minerals cooperation	Includes broader investment cooperation beyond minerals

2.4. INFRASTRUCTURE AND ESG FRAMEWORK

Nigeria's mineral wealth is undermined by persistent infrastructure deficits. A major constraint for mining operators in Nigeria is the lack of essential infrastructure, especially reliable access to electricity and accessible roads to mineral-rich areas. National estimates from 2017 indicate that Nigeria depends on over 8,000 MW of distributed diesel generation, with diesel generators covering 40-48 percent of electricity demand and costing households and businesses roughly NGN 3.5 trillion (~USD 11.45 billion)[6] annually [45]. A 2023 World Trade Organization (WTO) study noted Nigerian exporters pay 30-40 percent more in freight than to other countries in the region, attributable to infrastructure negligence, customs delays and port inefficiencies [46].

While these challenges persist, ongoing power sector reforms and the privatization of the national electricity utility are expected to attract private investment and expand generation, transmission and distribution capacity. As the power situation improves, current supply shortages are likely to ease. In the interim, mining investors can bridge the energy gap by partnering with independent power producers to ensure captive energy supply. On the transport front, the federal government is leveraging public-private partnerships (PPPs) and fiscal incentives such as the Road Infrastructure Development and Refurbishment Investment Tax Credit Scheme to improve road access to mining sites. Additionally, the rehabilitation of national rail lines is underway and is expected to enhance the movement of minerals from mine to port, supporting more efficient and cost-effective logistics [7].

As global battery and energy transition markets tighten traceability and sustainability standards, Nigeria risks exclusion. Original equipment manufacturers (OEMs) and other manufacturers in the European Union (EU), Japan, South Korea, and the United States now require that critical minerals be sourced in compliance with stringent environmental, social and governance (ESG) standards, in coherence with frameworks such as the OECD Due Diligence Guidance for Responsible Mineral Supply Chains, the EU's Critical Raw Materials Act (CRMA), the US Inflation Reduction Act (IRA), and Minerals Security Partnership (MSP) criteria. Currently, Nigeria lacks formal traceability systems, environmental baselines or alignment with any of these frameworks. While Nigeria has established strong governance mechanisms through the Nigeria Extractive Industries Transparency Initiative (NEITI), which provides publicly audited data across the entire value chain—including licensing, onwerhsip, production, revenue and environmental reporting among others, little efforts have been put in place to translate these reporting into robust mine to market chain-of-custody and ESG certification required by global OEMs. The dominance of unregulated ASM also means most Nigerian minerals do not meet traceable or ESG-certified thresholds. Without reforms, these minerals will be locked out of global clean-tech value chains.

Artisanal and small-scale miners are central to Nigeria's critical mineral production, but they operate largely outside formal systems. Mining often occurs without geological assessments, formal licenses or environmental safeguards, and is frequently linked to conflict dynamics, child labour risks and unsafe working conditions. Despite this, ASM remains the only active production mechanism for many minerals, including lithium and niobium. Nigeria must invest in formalization through cooperatives, training, finance access and certification schemes that can link verified ASM output to traceable licences, owners, revenue payments, environmental obligations and export pathways. Without this integration, informality will continue to undermine both value capture and reputational access to regulated markets.

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[6] Using the 2017 official average exchange rate of about NGN 305.8 per USD (World Bank and corroborated by CBN inter-bank average ₦305.81/US$), NGN 3.5 trillion is nearly equivalent to USD 11.45 billion [19], [44].

2.4.1. Institutional, Legal, Policy and Fiscal Framework

Nigeria's critical minerals governance is coordinated by the MSMD, which is responsible for sector policy, regulation and the issuance of mining licenses. The Mining Cadastre Office (MCO), under the MSMD, plays a central role in administering mineral titles and ensuring regulatory compliance. The Nigerian Geological Survey Agency (NGSA) is tasked with conducting geological surveys and maintaining data on mineral occurrences. In parallel, the Nigerian Institute of Mining and Geosciences acts as a centre of excellence for professional training and research and development (R&D) related to the sector. To catalyze investments in the sector, the Government of Nigeria has established the Solid Minerals Development Fund (SMDF), a sovereign fund that provides financing across the entire lifecycle of mining projects including exploration, development and production. On governance, the Nigeria Extractive Industries Transparency Initiative (NEITI) is mandated to ensure transparency and good governance across the entire extractive value chain. Furthermore, the Raw Material Research and Development Council (RMRDC) focuses on promoting local beneficiation and value addition, reflecting a core policy goal.

Nigeria's legal, policy, and fiscal framework for solid minerals is undergoing significant reform, directly shaping the enablers for green industrialisation. The Nigerian Minerals and Mining Act 2007 (NMMA) remains the primary statute, a pending revision has yet to pass, but the current administration has pursued reform through executive policy, most notably a 2024 directive conditioning all new mining licences on demonstrated in-country processing capacity and a mandate requiring at least 30% local beneficiation before raw mineral export. These measures have catalysed over $800 million in processing investment and a six-fold increase in sector revenue between 2023 and 2024, though their durability is constrained by the absence of statutory backing. The Nigeria Tax Act 2025 (effective January 2026) introduces a 5% per annum Economic Development Tax Credit on qualifying capital expenditure and standardised ad valorem royalties of 7.5–15%, though royalty rates remain undifferentiated by processing stage, removing a key fiscal lever for incentivising midstream refining over concentrate export. On governance, the eMC+ digital cadastre now supports beneficial ownership disclosure, and 388 mineral buying centres established in 2024 represent Nigeria's recent attempt at tracing artisanal mining.

The Olisa Agbakoba Legal (OAL) essay, The Case for Critical Minerals Legal and Policy Reform in Nigeria, highlights institutional fragmentation and overlapping mandates among agencies as a major constraint, calling for streamlined coordination and legal reforms [12]. It emphasizes the urgent need to align Nigeria's governance structures with international traceability and ESG standards such as the OECD Due Diligence Guidance and advocates for reforms that include beneficial ownership disclosures, the designation of strategic minerals and stronger oversight mechanisms. However, to date, there is no clearly established inter-ministerial body coordinating these efforts, nor has Nigeria formally adopted a unified critical or strategic minerals strategy.

3

MINERALS DEMAND ASSESSMENT FOR ENERGY TRANSITION TECHNOLOGIES

MINERALS DEMAND ASSESSMENT FOR ENERGY TRANSITION TECHNOLOGIES

Nigeria is at a pivotal stage in its clean energy transition, with rising momentum around electric vehicles (EVs), solar PV systems and energy storage technologies. These sectors are gaining traction in response to both policy shifts and market drivers. For instance, enabling policies and the removal of fuel subsidies have significantly accelerated the uptake of solar PV, with Nigeria adding at least 63.5 MWp in 2024 alone, bringing total reported installed capacity to over 386 MWp and positioning it among the top five solar markets in Africa [47]. The actual figures are expected to be significantly higher when household and other decentralized installations are considered captured through solar PV module imports. At the same time, the EV sector, though nascent, is expanding, with an estimated 15,000-20,000 EVs expected to be on the roads by 2025 and a national target to deploy 13 million EVs by 2050 [48]. In parallel, Africa's energy storage capacity rose from 150 MWh in 2023 to over 1,600 MWh in 2024, driven by falling battery costs and the need for stationary storage and grid stability [49].

This growing uptake highlights the urgent need for a structured analysis to identify opportunities for building local value chains for energy transition technologies to reduce import dependency, create local jobs and advance industrialization goals. Understanding the scale, pace and spatial distribution of future demand for EVs, solar PV and storage solutions will be critical for informing Nigeria's minerals development, investment priorities and infrastructure rollout. This assessment aims to quantify potential growth trajectories, identify opportunities and support the development of enabling policies that can unlock Nigeria's clean energy potential. To estimate future demand for these technologies, we consider two pathways informed by Nigeria's Energy Transition and Investment Plan (ETIP) and Sustainable Energy for All (SEforALL) analysis [13]: a Business-as-Usual (BAU) scenario reflecting current policy and market trends, and a Net-Zero Emissions by 2060 (NZE 2060) scenario aligned with Nigeria's long-term climate commitments. These pathways help capture the range of possible demand trajectories under varying levels of policy ambition and technological deployment.

3.1 ELECTRIC VEHICLES

3.1.1 Overview

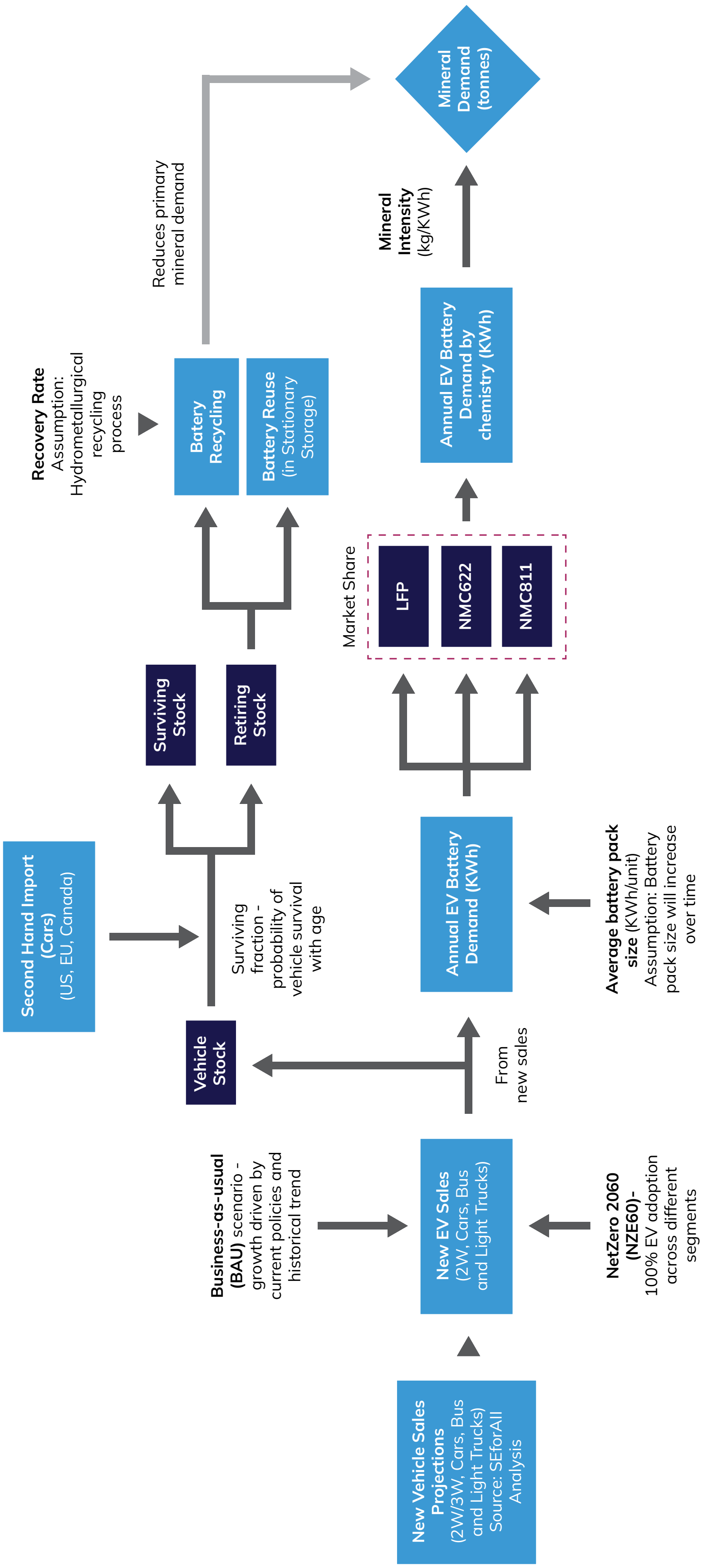
Nigeria has taken several strategic steps toward decarbonizing its transport sector in line with its 2060 net-zero emissions target. In 2024, the country signed the Zero-Emission Vehicles (ZEV) Declaration at the International Transport Forum, committing to 100 percent zero-emission sales for new cars and vans by 2040. This aligns with Nigeria's ETIP, launched in 2022 and updated in 2024, which sets ambitious targets for EV adoption – 60 percent of the market by 2050 and 100 percent by 2060 [50]. A key policy tool supporting these targets is the National Action Plan for the Development of Electric Vehicles (EVDP) [48], which aims to reduce reliance on imports by ensuring that at least 30 percent of EVs are produced locally by 2032. [48], The current EV market landscape features a mix of local and international manufacturers, with innovation largely concentrated in two- and three-wheelers (2W and 3W) as well as electric buses—segments seen as early adopters due to their high urban utilization and cost-saving potential.

3.1.2 Methodology

The assessment of critical mineral demand from EV batteries is based on a stepwise modelling approach that links annual EV sales to battery requirements across vehicle segments, which are then converted into corresponding mineral demand. The approach includes estimating annual EV sales under two scenarios—BAU and NZE 2060—and subsequently translating those into mineral requirements using chemistry-specific material intensity factors. The overall methodological flow is illustrated below (Figure 4). While not covered in this report, permanent-magnet synchronous motors used in EVs are also a demand centre for critical minerals, including copper and rare earth elements (REEs) (upwards of 1 kg per motor) such as neodymium, praseodymium, dysprosium and terbium (IEA 2021).

FIGURE 4

Methodological flow for estimating mineral demand from EVs



For this analysis, we consider five vehicle segments: 2W/3W, cars, buses, and light- and heavy-duty trucks, which are likely to be the priority segments for EV uptake. The shares of EV sales for each segment are applied to total projected new vehicle sales to estimate the number of EVs sold annually. The assumed sales shares are presented in Table 3.

TABLE 3

Shares of EV sales across vehicle segments

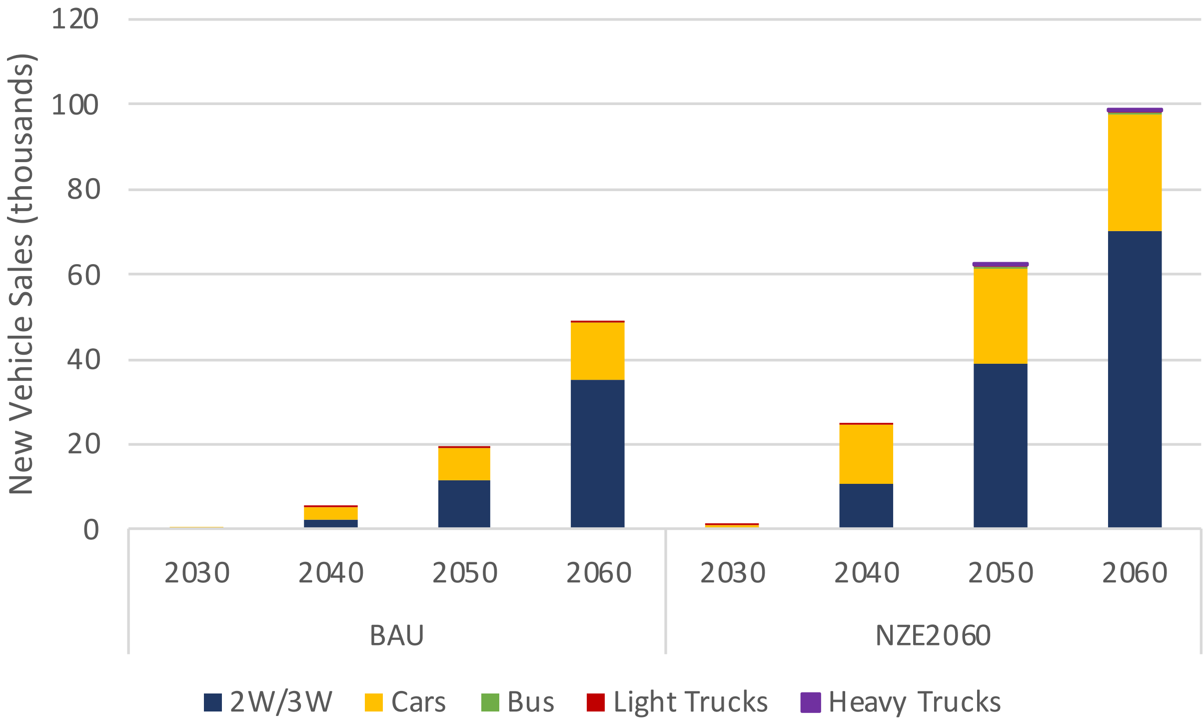
Vehicle segment	2045		2060	
	BAU	NZE 2060	BAU	NZE 2060
2W/3W	20%	100%	50%	100%
Cars	25%	100%	50%	100%
Buses	13%	64%	30%	100%
Light-duty trucks	25%	100%	30%	100%
Heavy-duty trucks	0%	15%	0%	70%*

* In the NZE 2060 scenario, heavy-duty trucks are expected to transition to 30% hydrogen fuel cell technology by 2060.

Using these sales share trajectories and Nigeria's projected new vehicle sales by segment, we have estimated annual EV sales from 2025 to 2060. Figure 5 below presents the resulting EV uptake across segments. In 2060, new EV sales are projected to reach over 49,000 vehicles under the BAU scenario and 98,554 vehicles under the NZE 2060 scenario, driven primarily by growth in the 2W/3W and car segments.

FIGURE 5

Projected new EV sales by vehicle segment (2030–2060)



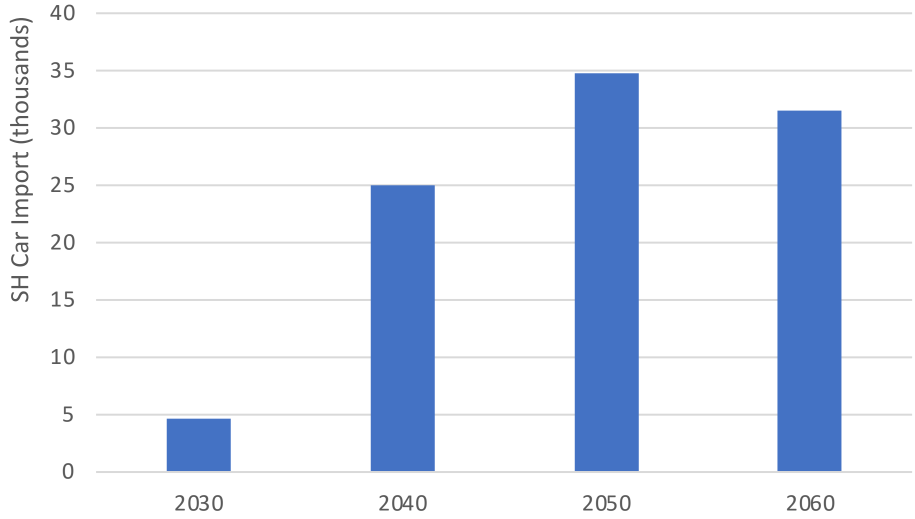
Source: Author's Analysis

It is important to note that Nigeria's vehicle market is overwhelmingly dominated by second-hand imports, particularly in the case of cars, which account for approximately 80–85 percent of all additions annually [51]. These vehicles, commonly referred to as 'tokunbo', are predominantly imported from Canada, the EU (notably Belgium and Germany) and the United States. According to trade data by the International Transport Forum (2020), the US accounts for 52 percent of Nigeria's total used vehicle imports, followed by the EU at 37 percent and Canada at 12 percent [52]. This heavy reliance on imported used vehicles is primarily driven by affordability constraints, limited domestic production of new vehicles and consumer preference for lower-cost alternatives. In addition, policy measures—such as a 12-year age limit on imported vehicles [53]—also shape the composition and flow of vehicle imports. For the purpose of this study, we have accounted for the second-hand vehicle market (Annexure 3), particularly the import flow from Canada, the EU and the US, while estimating total car sales. Figure 6 illustrates projected trends in the import of second-hand e-cars.[7] While mineral demand projections are based solely on new vehicle sales, second-hand imported vehicles are expected to play a significant role in future recycling output, contributing to the availability of secondary raw materials.

[7] Due to limited data availability, projections are based on US export data from 2015–2024. The US share in Nigeria's total second-hand vehicle imports is derived from ITF and assumed to remain constant throughout the analysis period.

FIGURE 6

Projected secondhand e-cars import (2030–2060)



Source: Author's Analysis

Building on the EV sales projections, we estimate the total battery capacity required for new EVs based on the average battery pack size for each vehicle segment. As EV adoption accelerates toward 2060, battery demand is expected to rise substantially across all segments. With ongoing technological advancements, the average battery pack size is expected to increase to meet both consumer requirements for improved driving range and vehicle performance. Segment-specific pack size assumptions are applied to annual EV sales to calculate the yearly demand for battery capacity (Table 4).

TABLE 4

Battery pack size assumptions (kWh)

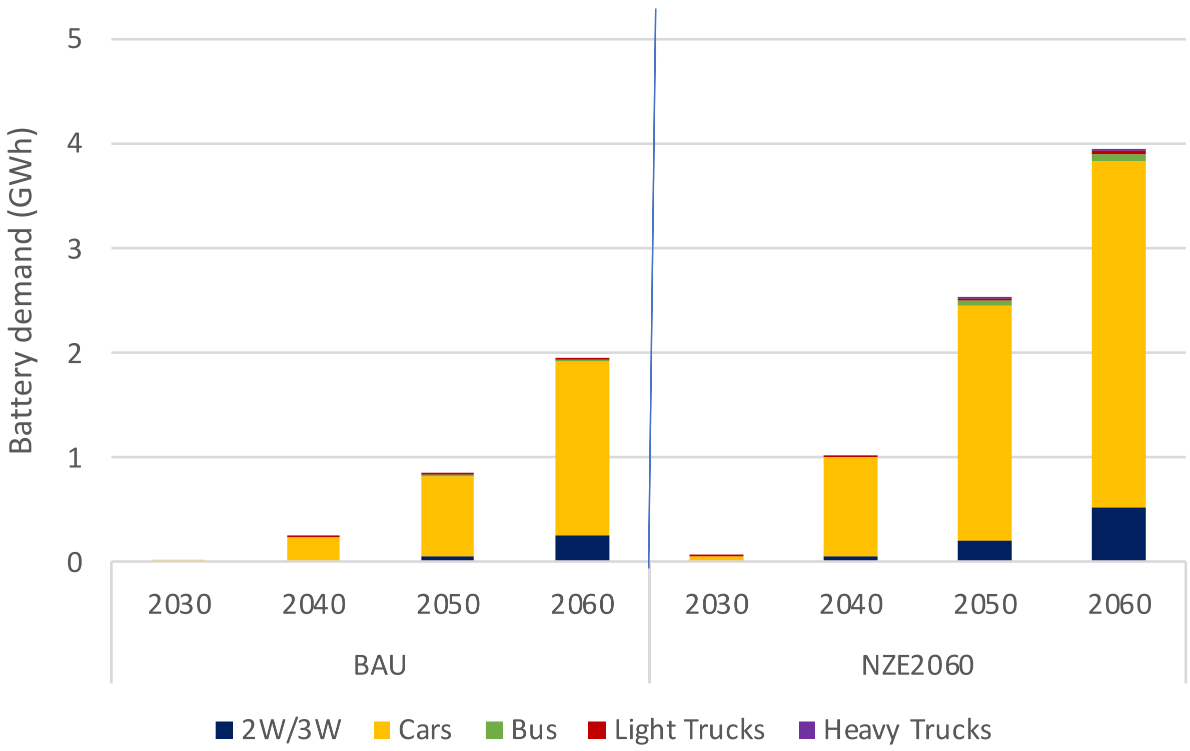
Vehicles Segments	2035	2040	2050	2060
2W/3W	5	5	5.5	7.5
Cars	65	70	100	120
Buses	225	225	250	300
Light-duty trucks	30	35	40	45
Heavy-duty trucks	288	298	380	450

For lifecycle assumptions, we consider battery life to follow the service life of the vehicle, with end of life (EoL) determined on the basis of the vehicle survival function. This means that batteries exit the stock only when vehicles reach their end of service, at which point they may be available for recycling or repurposing (e.g., stationary energy storage).

The estimated battery demand (Figure 7) reflects the growth in total battery capacity required to support new EV deployment from 2025 to 2060 under both the BAU and NZE 2060 scenarios.

FIGURE 7

Annual li-ion battery requirement for EVs



Source: Author's Analysis

By 2060, annual battery demand from new EV sales is projected to reach 2 GWh under the BAU scenario and 4 GWh under the NZE 2060 scenario. This demand is largely driven by cars, reflecting both their high sales volumes and larger assumed battery pack sizes.

The quantity of minerals required for battery production is calculated using mineral intensity values specific to different lithium-ion battery (LIB) chemistries. This study assumes that LIB will account for 100 percent of the EV battery market across all segments during the projection period. While emerging chemistries such as sodium-ion and solid-state batteries may gain market share in the longer term, they are not considered in this analysis due to current uncertainties around commercialization and deployment timelines.

We consider three key chemistries: lithium-iron-phosphate (LFP), nickel manganese cobalt 622 (NMC 622) and nickel manganese cobalt 811 (NMC 811). As of today, LFP already dominates the EV battery market, particularly in cost-sensitive economies. This trend is expected to strengthen over time due to LFP's lower cost, better thermal stability and reduced reliance on critical minerals such as cobalt and nickel. Reflecting these market dynamics, our analysis assumes a progressively increasing share of LFP, reaching 100 percent across most of the vehicle segments by 2060.

Based on these chemistry assumptions, we estimate demand for critical minerals —lithium, nickel, cobalt, manganese, aluminum, copper and graphite —used in LIB batteries. The mineral demand is computed by applying chemistry-specific intensity (expressed in kg/kWh) to the total annual battery capacity required. These intensity values represent the amount of each critical mineral embedded in one kilowatt-hour of battery storage. The mineral intensity values used in this analysis are provided in Table 5.

TABLE 5

Mineral Intensity (kg/KWh)

Minerals	Intensity (kg/kWh)		
	LFP	**NMC 622**	**NMC 811**
Li	0.09	0.1	0.1
Ni	-	0.5	0.7
Co	-	0.2	0.1
Mn	-	0.2	0.1
Al	0.7	0.6	0.6
Cu	0.6	0.4	0.4
Gr	1.0	0.9	0.9

Source: Authors' compilation from multiple sources

In addition to estimating mineral demand from new battery deployment, this analysis also evaluates the potential for mineral recovery through battery recycling, based on the expected volume of batteries reaching EoL.

To estimate the annual retiring volume of EV batteries from new sales, we apply an age-wise survival function to the EV stock by segment, using Weibull distribution. Due to the lack of EV-specific survival data, the model uses the shape and scale parameters derived from internal combustion engine (ICE) vehicle stock modelling, as presented by Guttikunda (2024) [54], with adjustments to the characteristic service life to reflect typical EV usage (Annexure 4). In the absence of country-specific data, we assume that vehicle survival characteristics in Nigeria are comparable to those in India and therefore apply the same parameters.

In addition to new sales, the model also accounts for battery retirements from second-hand EV imports. To estimate the retiring volume from this segment, we assume that vehicles operate for five years in their country of origin before being imported into Nigeria. Upon entry, these vehicles are incorporated into the EV stock and follow the survival function starting from year five of their lifespan. As a result, second-hand EVs are expected to retire earlier than new vehicles, contributing to the battery EoL stream sooner. This earlier retirement has important implications for the timing and volume of available recyclable battery materials and highlights the role of the second-hand vehicle market in shaping recycling potential.

Battery retirement is assumed to occur when capacity drops below 70–80 percent of its original rating. Retired batteries are categorized into two potential streams: recycling and repurposing. In this analysis, for 2W/3W batteries, 90 percent of retired battery volume is assumed to be recycled initially, declining to 70 percent by 2060, as the share directed toward repurposing increases over time. For other vehicle segments, 40 percent of retired battery volume is assumed to be recycled initially and 60 percent repurposed. By 2060, this shifts to 20 percent recycling and 80 percent repurposing, reflecting the greater suitability of larger battery packs for second-life stationary storage applications. Batteries directed toward secondary applications are assumed to eventually enter the recycling stream after the end of their second-life use (accounted under BESS recycling in this study), implying a delay in mineral recovery rather than a loss of recoverable materials.

Mineral recovery from LIB waste is facilitated through various recycling processes. For the purposes of this analysis, we have focused on hydrometallurgical recycling techniques due to their efficacy in extracting lithium. The assumed recovery rates for minerals from different battery chemistries are given in Table 6 [55]. Based on current technology and industry practices, recovery efficiency is expected to improve progressively, reaching 98–100 percent by 2060 for all minerals under an advanced recycling ecosystem.

TABLE 6

Mineral recovery rates

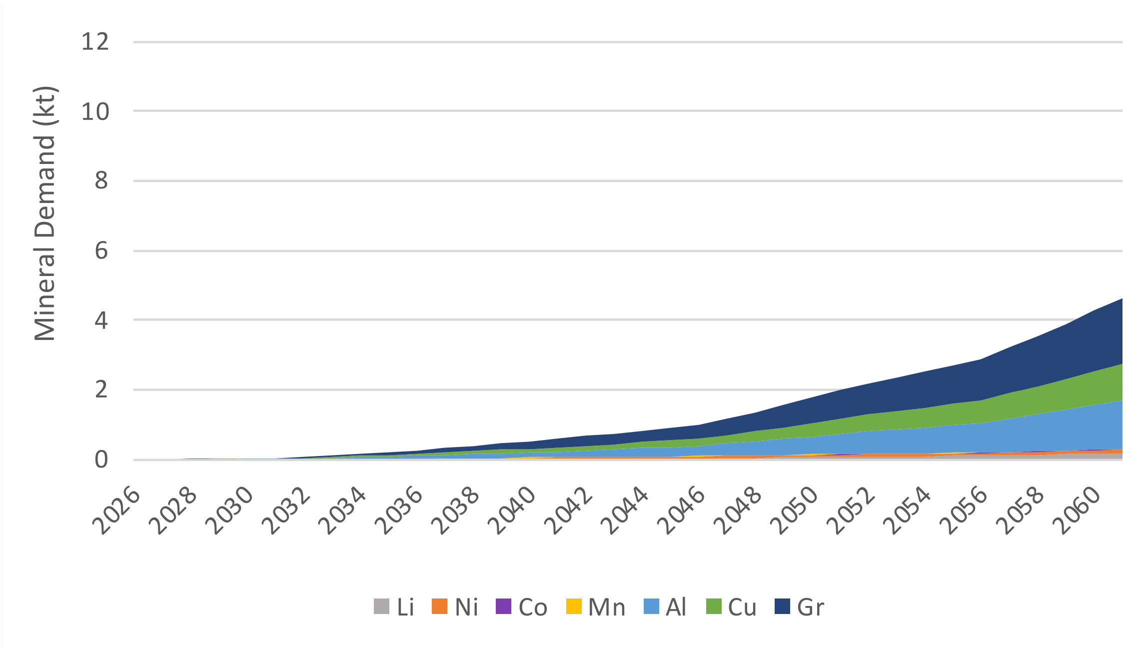
Minerals	Current Recovery Rate (%)		
	LFP	NMC 622	NMC 811
Li	81%	94%	94%
Ni	-	97%	97%
Co	-	100%	100%
Mn	-	100%	100%
Al	100%	100%	100%
Cu	100%	100%	100%
Gr	83%	83%	83%

3.1.3 Mineral Requirements for EV Batteries

Building on the EV sales projections, this section quantifies the associated demand for key minerals used in batteries across scenarios. Figure 8 and Figure 9 show the annual mineral requirements for EV batteries in the BAU & NZE 2060 scenarios. This highlights the steep rise in demand for graphite, copper and aluminum, reflecting their dominant roles across battery chemistries and pack architectures. Demand for lithium and nickel also increases steadily, while cobalt and manganese requirements remain relatively modest due to the shift towards advanced NMC and LFP chemistry, which minimizes their use. The cumulative demand for these minerals is presented in Table 7.

FIGURE 8

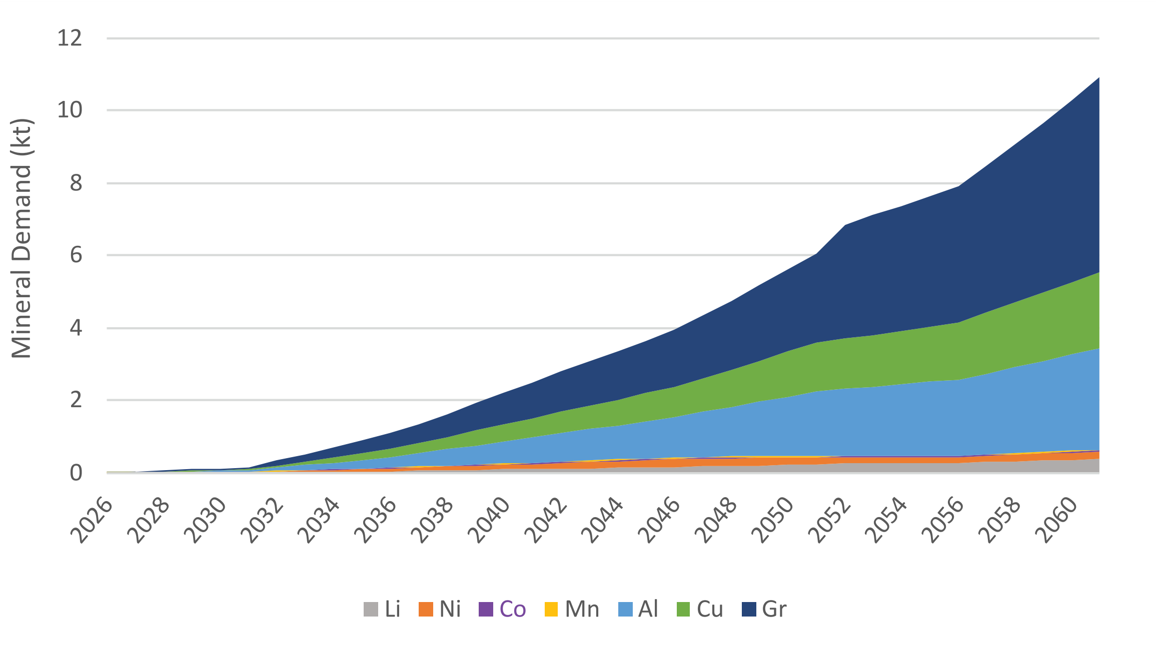
Projected annual mineral demand from EV batteries (BAU)



Source: Author's Analysis

FIGURE 9

Projected annual mineral demand from EV batteries (NZE 2060)



Source: Author's Analysis

TABLE 7

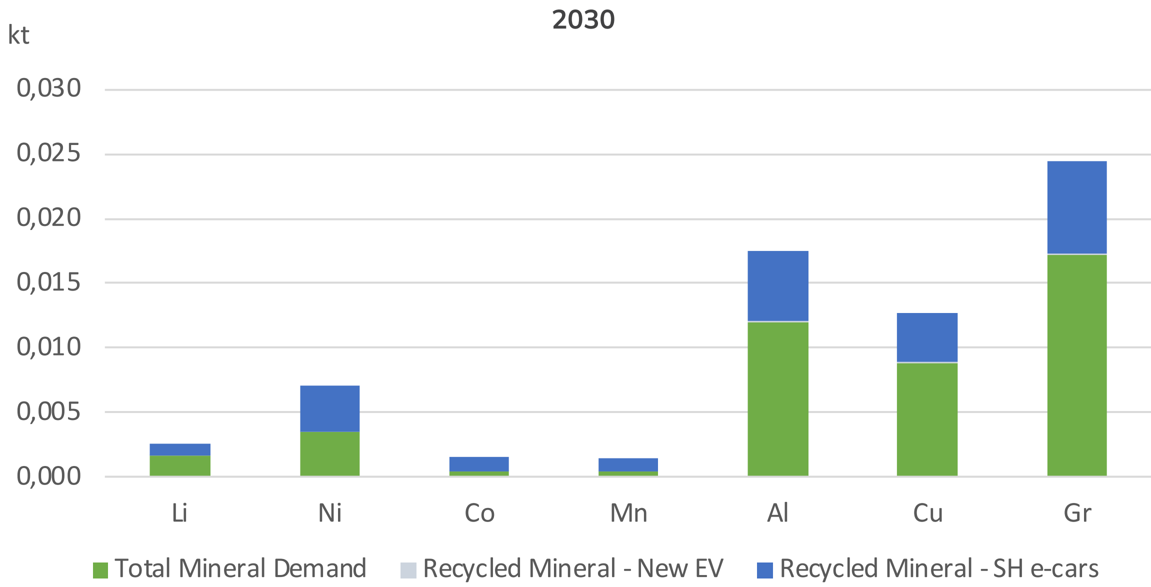
Cumulative mineral demand from EV batteries, 2025–2060 (kt)

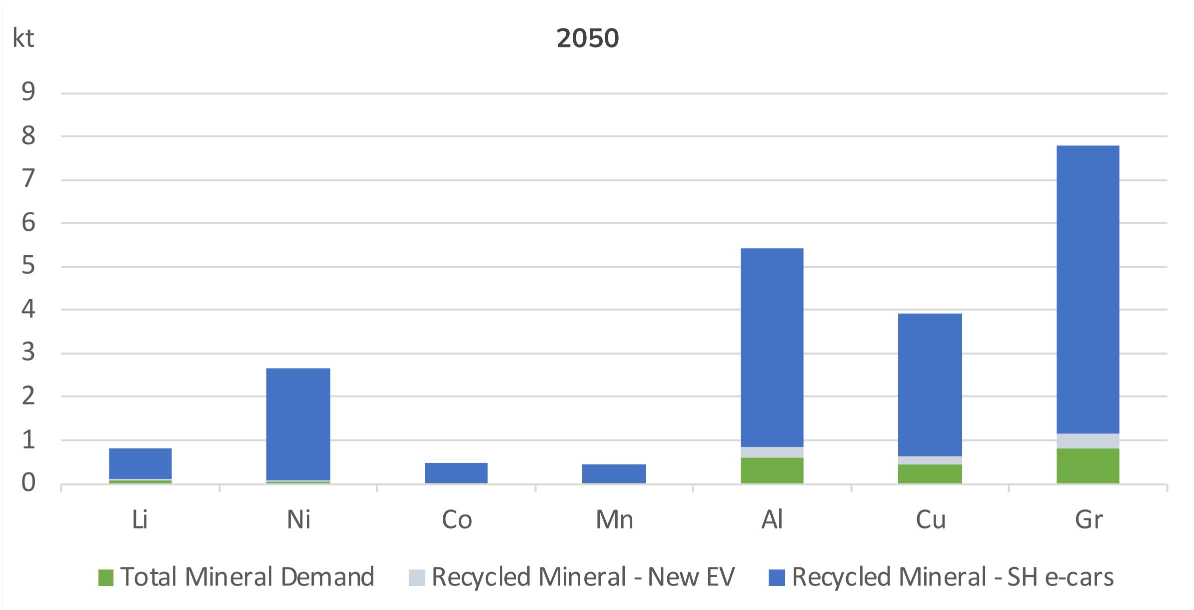
Minerals	Cumulative Demand (kt)	
	BAU	NZE 2060
Li	1.8	5
Ni	1.5	4.6
Co	0.19	0.6
Mn	0.2	0.5
Al	13.96	38.4
Cu	10.49	28.83
Gr	19.36	63.26

The cumulative demand estimates highlight the scale of critical mineral requirements over time. However, not all this demand needs to be met through primary extraction. A significant share can be offset through material recovery from EoL batteries, especially in the later years of the transition (post-2040) as the EVs begin to retire. Figure 10 presents projected annual demand and recycled minerals from EV batteries under a high-recycling scenario for the BAU case.

FIGURE 10

Annual demand and recycled minerals from EV batteries for 2030 (top) and 2050 (bottom)





Source: Author's Analysis

In the near term, recycled mineral availability remains below annual demand for most of the minerals. By 2030, total recycled supply reaches around 54% of lithium demand, 46% of aluminum demand, 44% of copper demand and 43% of graphite demand. For nickel, recycled supply is almost equal to annual demand, while cobalt and manganese already exceed annual demand by around 2.4 times.

In the long term, recycled mineral availability increases significantly and exceeds annual demand across all minerals. By 2050, recycled lithium reaches around 9.5 times annual demand, nickel 44 times, cobalt and manganese around 64 times, aluminum 8.2 times, copper 7.8 times and graphite 8.5 times. This increase is mainly driven by the retirement of second-hand e-cars. Since these vehicles are assumed to enter Nigeria after already serving part of their useful life in exporting markets, they reach end-of-life earlier than newly sold EVs and contribute to mineral recovery sooner. The effect is particularly strong for nickel, cobalt and manganese because second-hand imports are assumed to come largely from the US, EU and Canada, where larger battery packs and NMC-based chemistries are more common. Since mineral demand is tied to new vehicle sales, while recycled supply includes both new EV retirements and imported second-hand e-cars reaching end-of-life, recycling becomes a major source of future mineral availability.

This implies that higher recycled mineral availability from second-hand e-cars should not be interpreted as a reason to favor older vehicle imports. Weakly regulated used-vehicle trade can result in importing countries receiving older, lower-quality, less safe and more polluting vehicles. In this assessment, the higher recycling potential is therefore treated as an outcome of the assumed import pathway, not as a policy preference for older vehicle imports.

3.2 BATTERY ENERGY STORAGE SYSTEMS

3.2.1 Overview

Battery energy storage systems (BESS) are rapidly emerging as a cornerstone of Nigeria's energy transition strategy. According to the IEA, 69.8% of Nigeria's population had access to electricity in 2023 [56], reflecting continued progress in electrification, although reliable power supply remains a major challenge. Frequent grid outages have made distributed solar and hybrid systems vital for residential and commercial users. Batteries are a key enabling technology, ensuring power reliability for mini-grids, commercial-industrial (C&I) operations, and increasingly, utility-scale applications. Nigeria's ETIP outlines an ambitious pathway to achieve universal energy access by 2030 and reach net-zero emissions by 2060, with renewables expected to contribute over 90 percent of electricity generation by 2050 [50]. Under this plan, battery storage is essential for integrating variable renewables, improving grid stability and displacing diesel generation in off-grid and weak-grid areas.[50].

Current deployments span a wide spectrum: from hundreds of solar mini-grids with LFP-based BESS under 1 MWh [57], to large-scale hybrid C&I systems with 2–5 MWh batteries, to emerging utility-scale projects exceeding 4 MWh [58], [59]. The dominant chemistry is LFP, reflecting global trends toward safer and longer-lasting storage technologies. Developers, such as JinkoSolar, Daystar, and Sterling & Wilson, are increasingly deploying LFP-based systems across residential, C&I and grid-tied applications.

Understanding the scale and nature of Nigeria's future BESS needs requires a structured modelling approach. The following section outlines the methodology used to estimate mineral demand from battery storage under the two scenarios. By integrating data from annual capacity addition, storage targets and technology assumptions, our model aims to provide a robust forecast of Nigeria's mineral demand from battery storage requirements through 2030 and beyond.

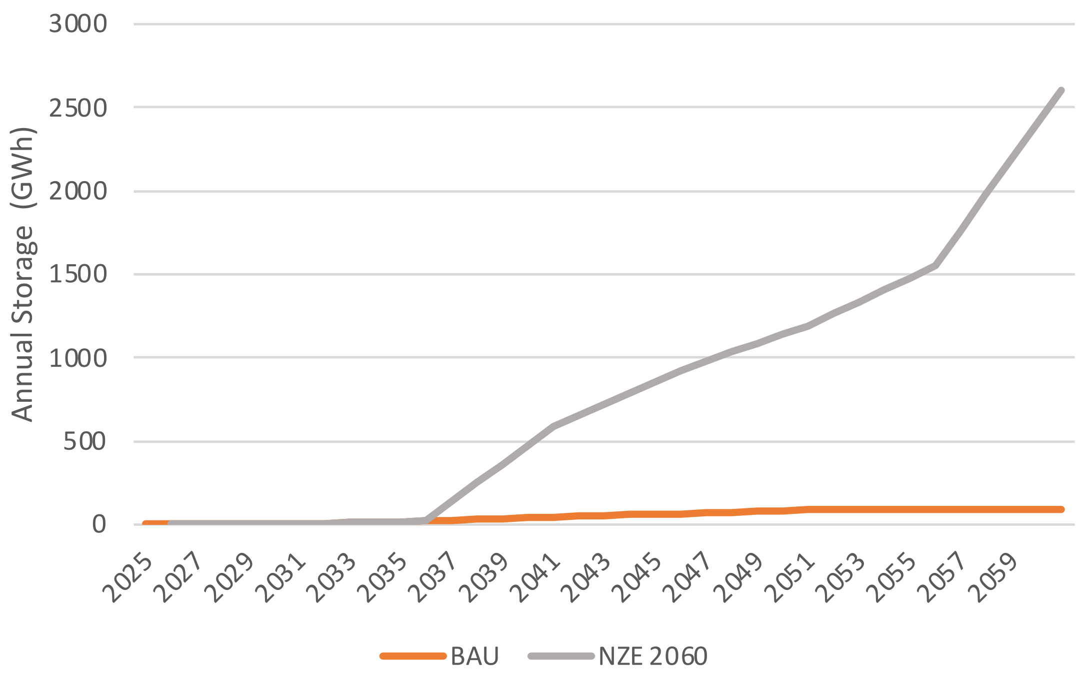
3.2.2 Methodology

This study estimates the demand for BESS required to support Nigeria's renewable electricity expansion and assesses the resulting implications for critical mineral requirements. The analysis draws on projections from SEforALL, which provide annual estimates of renewable electricity capacity additions and associated BESS requirements under two scenarios for the period 2025–2060.

The annual storage capacity additions for the two scenarios are presented in Figure 11, illustrating the projected year-on-year increase in BESS capacity from 2025 to 2060. Under the BAU scenario, annual storage capacity is expected to reach approximately 89 GWh by 2060. In contrast, the NZE 2060 scenario anticipates a substantially higher expansion, with annual storage capacity reaching around 2,604 GWh.

FIGURE 11

Annual storage capacity requirement (GWh)



Source: SEforALL projections [13]

In addition to the core SEforALL scenarios, we introduce two additional cases to assess the role of second-life EV batteries in offsetting new battery demand:

Case A – All New Batteries: Assumes that 100 percent of the required BESS capacity is met through newly manufactured or imported batteries.

Case B – Integration of Reused EV Batteries: Assumes that part of the required storage capacity is met by repurposing retired EV batteries that are still functional and not immediately recycled.

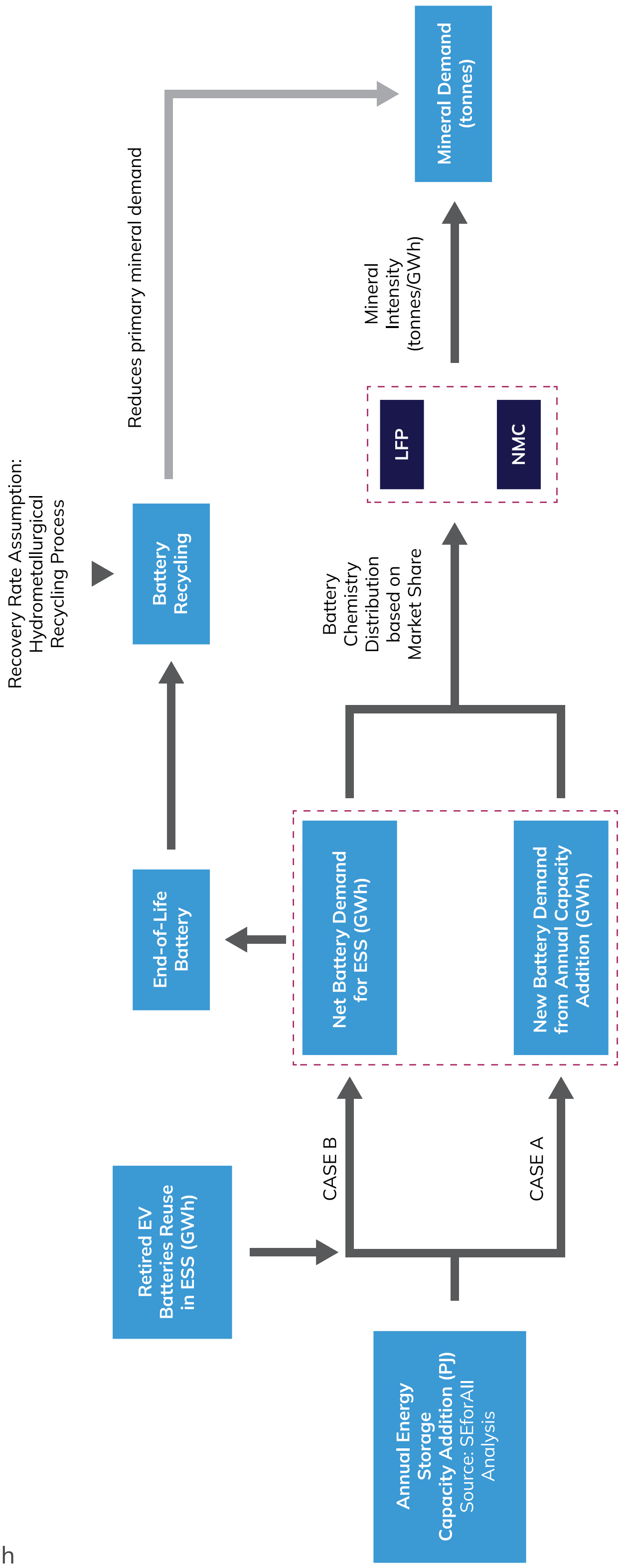
Under case B, the net annual battery requirement is calculated as the difference between the projected annual BESS capacity requirement (in GWh) and the available second-life battery capacity. Retired EV batteries are assumed to be reused in energy storage applications for a limited second-life duration of four years, after which they are considered no longer viable for stationary storage and are replaced by new batteries. As a result, the net battery demand in case B also includes the additional capacity needed to replace expiring second-life batteries after their four-year service period.[8]

The overall methodological framework is summarized in Figure 12 below.

[8] For the BESS second-life case, we assume that repurposed EV batteries have a shorter service span and therefore require replacement after four years of stationary use, to reflect their reduced state of health at the time of entry.

FIGURE 12

Methodological flow for estimating BESS mineral demand



Note: 1 PJ = 277.8 GWh

The choice of battery chemistry is a critical factor in designing BESS (even though LFP dominates, other chemistries like NMC, sodium-sulphur, vanadium flow, and zinc-bromine hold a small share) Different technologies offer various trade-offs in terms of cost, energy density, lifespan and efficiency. Among these, LIBs remain the dominant technology for BESS applications today. Within the LIB family, LFP batteries have become the most commonly used chemistry for grid-scale storage due to their safety, stability and cost advantages. For the purpose of this analysis, we assume that LFP accounts for 80 percent and NMC for 20 percent of the BESS market share in 2025. This share transitions over time to 100 percent LFP by 2040, reflecting observed trends in global battery deployment.

To assess the critical mineral requirements for manufacturing batteries, mineral intensity estimates are used, which quantify the amount of material required per unit of installed energy capacity. Table 8 presents the mineral intensities [60]—expressed in tons per gigawatt-hour (t/GWh) of installed capacity—for various battery chemistries, highlighting the differing raw material demands across battery types.

TABLE 8

Material intensities of batteries (t/GWh)

Minerals	Mineral Intensity (t/GWh)		
	LFP	**NMC 622**	**NMC 811**
Li	100	100	83
Ni	-	533	650
Co	-	183	83
Mn	-	167	83
Al	733	550	500
Cu	433	317	333
Gr	1100	833	750

3.2.3 Mineral Requirements for BESS

This section presents the projected annual demand for critical minerals required to support BESS deployment in Nigeria under the BAU and NZE 2060 scenarios. Figure 13 and Figure 14 illustrate the estimated annual mineral requirements, disaggregated by mineral type for the period 2025–2060. While two cases were considered—one relying entirely on new batteries and the other incorporating a share of second-life EV batteries—the resulting mineral demand across both scenarios is not significantly different. This is because only a small volume of retired EV batteries becomes available for reuse within the analysis period, and the short second-life duration necessitates replacement with new batteries thereafter. As a result, the mineral savings from reused batteries are largely offset by the additional demand from replacement units, leading to overall mineral requirements that remain largely similar across both cases.

FIGURE 13

Projected annual mineral demand from BESS (BAU)

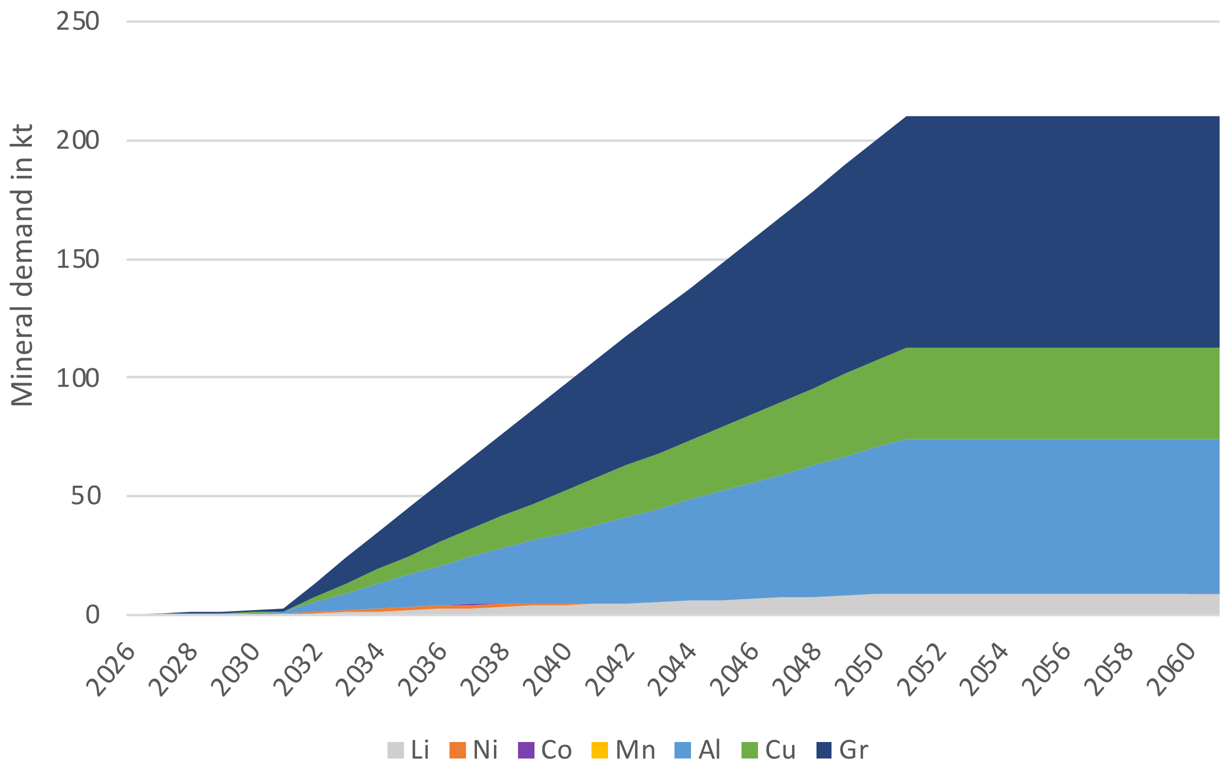
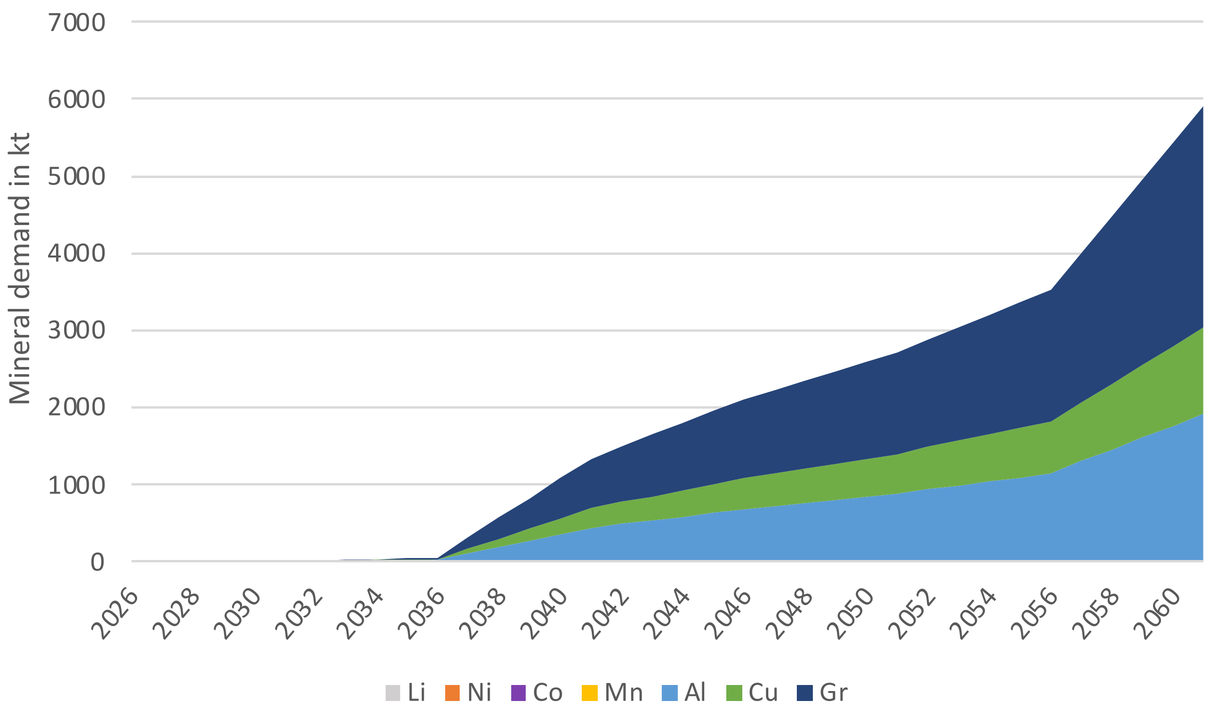


FIGURE 14

Projected annual mineral demand from BESS (NZE 2060)



Source: Author's Analysis

As shown in Figures 13 and 14, copper, aluminum and graphite dominate total material demand due to their substantial usage across both battery chemistries. Other minerals such as lithium, nickel, cobalt and manganese also contribute to the total, but at comparatively lower volumes.

The results indicate the total embedded mineral requirements associated with BESS deployment, encompassing materials that may be either produced domestically, imported for processing or embedded within imported components for domestic assembly. The cumulative demand estimates presented in Table 9 highlight the scale of critical mineral needs over time under both scenarios. However, it is important to note that not all of this demand will be met through primary extraction. A significant share can be offset through the recovery of materials from EoL batteries.

TABLE 9

Cumulative mineral demand from BESS, 2025–2060 (kt)

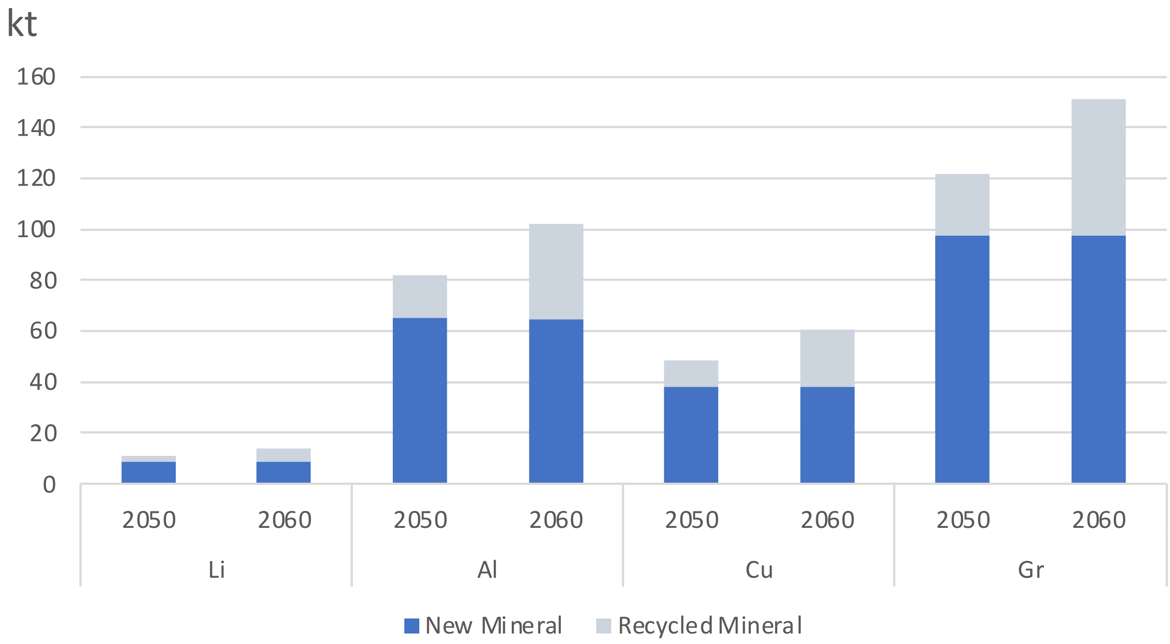
Minerals	Cumulative Demand (kt)	
	BAU	**NZE 2060**
Li	183	2921
Ni	9.7	38
Co	1.4	5
Mn	1.4	5
Al	1343	21409
Cu	794	12649
Gr	2015	32129

In addition to estimating mineral demand from new battery deployments, this analysis also evaluates the potential for mineral recovery through battery recycling, based on the projected volume of batteries reaching EoL. Batteries are assumed to be retired when their capacity falls below 70–80 percent of the original rating. For this analysis, we assume that EoL batteries retain 70 percent of their original capacity, and that 70 percent of these retired batteries will be recycled initially, with the recycling rate increasing progressively to 90 percent by 2060, reflecting a high-recycling scenario.

As previously outlined in the context of EV battery recycling, this analysis considers mineral recovery through hydrometallurgical techniques, given their effectiveness in extracting lithium and other critical minerals from EoL batteries. This analysis applies the same recovery assumptions to EoL BESS units, with initial recycling rates of 70 percent, increasing to 90 percent by 2060 under a high-recycling scenario. Recovery efficiencies are projected to improve gradually, reaching 98–100 percent by 2060, based on expected advancements in recycling technologies. The assumed recovery rates for key minerals by chemistry type are presented in Table 6, consistent with parameters used in the EV battery assessment. Figure 15 presents projected annual demand and the share met through recycling under a high-recycling scenario for the BAU case.

FIGURE 15

Annual demand and recycled minerals from BESS



Source: Author's Analysis

By 2050, recycled minerals are projected to meet a notable share of annual mineral demand. Recycling could meet 26 percent of lithium, aluminum, and copper demand, and 25 percent of graphite demand. By 2060, this contribution increases considerably; recycled minerals are expected to meet over 55 percent of lithium and graphite demand, and nearly 58 percent of aluminum and copper demand. There is no projected demand for nickel, manganese or cobalt in BESS applications, as these systems are predominantly LFP-based. This growing recovery potential reflects the increasing retirement of BESS installations, emphasizing the importance of scaling up recycling infrastructure to support long-term mineral sustainability in the energy transition.

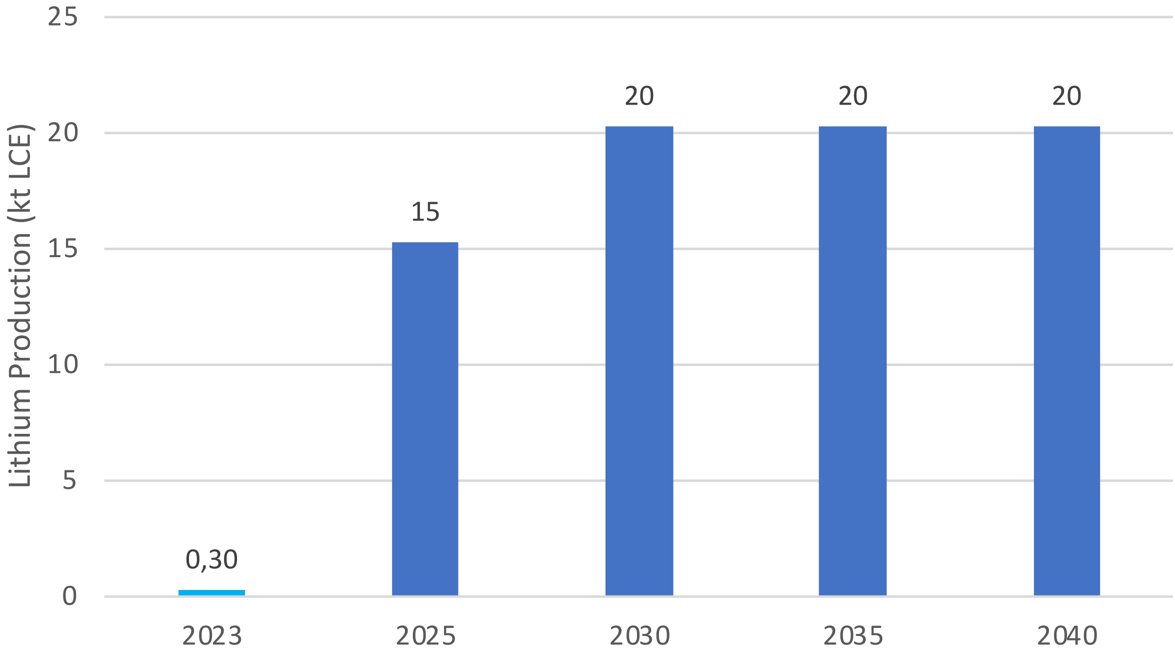
3.2.4 Domestic Production vs Projected Demand (Lithium and Manganese)

Lithium

Nigeria holds substantial lithium reserves, with significant deposits in Cross River, Ekiti, Kaduna, Kwara and Nasarawa states [61]. To capitalize on this resource, the government is advancing domestic value addition by commissioning multiple lithium processing plants—a USD 600 million facility near the Kaduna–Niger border and a USD 200 million refinery near Abuja—with additional plants planned in Nasarawa [62]. Figure 16 presents the estimated domestic lithium production capacity over time.

FIGURE 16

Domestic lithium production (kt LCE)



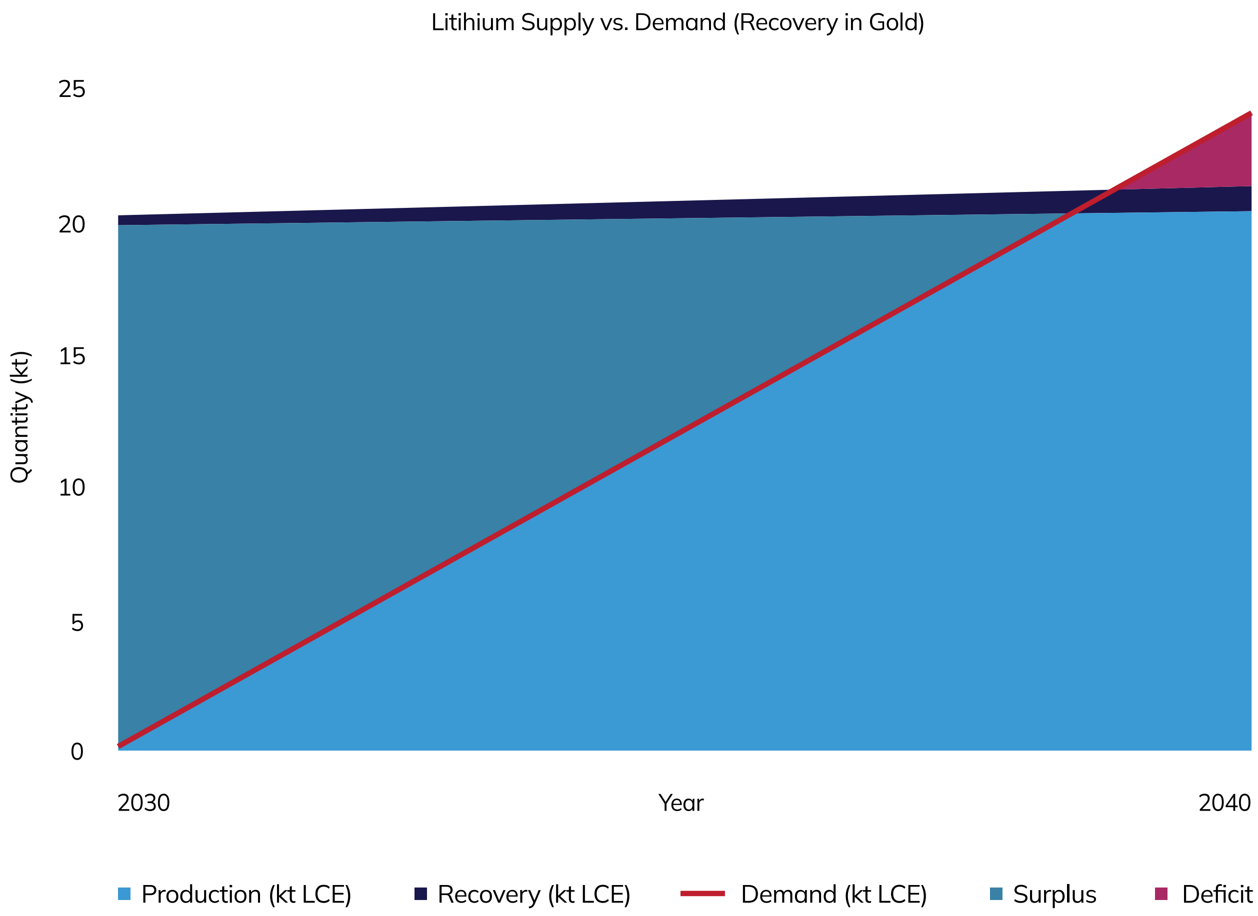
Source: Benchmark Mineral Intelligence. LCE = Lithium Carbonate Equivalent.

Note: According to World Mining Data (WMD), 930 tons of production (Li2O-Content) were reported in 2023, equivalent to 2.3 kt LCE. The figure varies from production of 0.30 LCE reported by Benchmark Mineral Intelligence.

By 2030, domestic lithium production is expected to reach 20.3 kt LCE, which is more than sufficient to meet the projected demand of 0.55 kt LCE. However, this balance begins to shift in the next decade. By 2040, lithium demand rises to 24.2 kt LCE, exceeding the steady domestic production level of 20.3 kt LCE and resulting in a supply gap of around 3.9 kt LCE. Although lithium recovery from EoL batteries begins to contribute by this time, the recovered volume—estimated at 1.8 to 1.9 kt LCE—remains relatively small. Even with this contribution, a net gap of over 2.1 kt LCE persists (Figure 17).

FIGURE 17

Lithium supply-demand projects to 2040, including recovery



Source: Author's Analysis

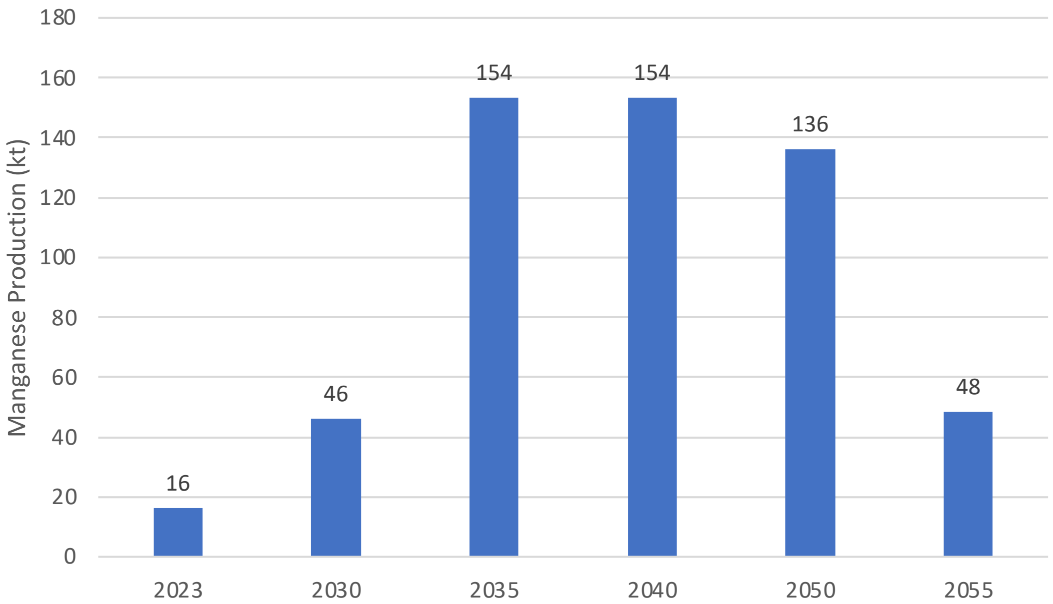
Manganese

Nigeria's manganese endowment is significant, with official surveys estimating approximately 5 million tons of ore reserves [63]. These deposits are primarily located in the northern mineral belts, including Kaduna, Katsina, Kebbi and Zamfara, as well as in scattered schist belt formations across the country. Despite this substantial resource base, formal production remains limited. WMD recorded cumulative manganese production of nearly 67,000 tons between 2019 and 2023 [64] (Table 1), and no large-scale national manganese mines are currently in operation. A few private firms, such as Elipse Internationals and Kelechi Minerals, have initiated small-scale mining at sites including Danko-Wasagu (Kebbi) and Maru-Bukkuyum (Zamfara) [65], although output remains largely artisanal. As part of broader efforts to stimulate the mining sector, the Nigerian government has allocated about USD 630 million for nationwide mineral exploration in 2025 [66]. Taken together, the presence of sizable reserves, recent policy momentum and emerging private-sector engagement suggest strong potential for increased manganese production in Nigeria, provided that infrastructure and investment barriers are effectively addressed.

Based on the estimated 5 million tons of manganese ore reserves in Nigeria, we have developed a production forecast to assess the potential scale and timeline of domestic output. The projections assume a recoverable portion of the deposit and apply a phased mining profile that reflects typical industry practice, including ramp-up, plateau and ramp-down periods. The detailed methodology used to structure this projection is presented in Annexure 4, while the yearly production outlook is illustrated in Figure 18. This forecast provides a baseline for evaluating future supply scenarios under improved investment, infrastructure and regulatory conditions.

FIGURE 18

Domestic manganese production (2023-2055)



Source: Author's Analysis

The projected production of manganese in Nigeria significantly surpasses domestic demand associated with the clean energy transition. For instance, by 2035, output is expected to exceed 154 kt, while demand remains under 0.2 kt. This persistent surplus reflects the limited role of manganese in Nigeria's clean energy demand outlook, where LFP battery chemistries dominate in both EV and BESS applications. The surplus highlights both an opportunity and a policy imperative to position Nigeria as a strategic exporter or building alternate end-use sectors. Similarly, nickel also shows a potential for a strategic exporter with abundant and underexplored deposits in the country. The government's recent announcement of 60,000 tons production capacity plant in Kaduna State for nickel is a step in this direction. Through coordinated investment in extraction, production, processing and transport infrastructure, Nigeria can emerge as a competitive global supplier. The surplus also presents an opportunity for Nigeria to engage in value addition by processing the ore domestically for use in a variety of non-energy transition sectors, including steel through ferroalloys, chemicals and non-ferrous alloys (e.g., aluminum).

3.3. SOLAR PV TECHNOLOGIES

3.3.1. Overview

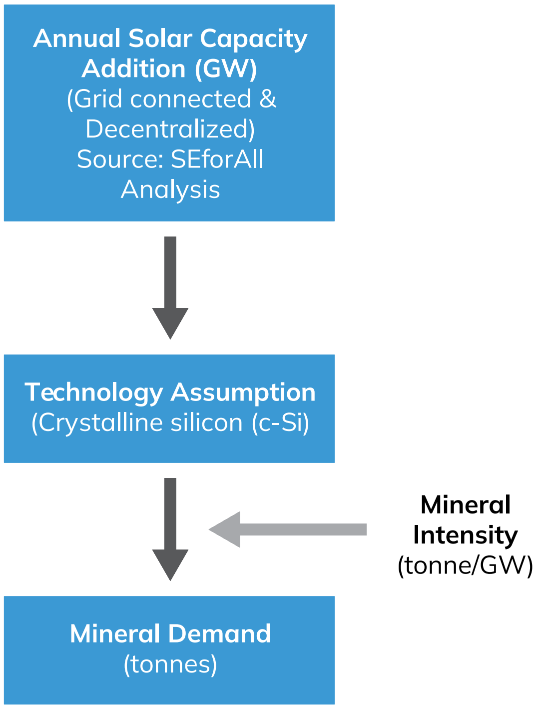
Nigeria has placed solar PV at the centre of its energy transition strategy, with the ETIP projecting up to 197 GW of installed solar PV capacity by 2060 to support net-zero goals [50]. While the total operational grid capacity target for 2030 is 42 GW [50], solar PV is expected to contribute a substantial share through both utility-scale and decentralized systems. This projected scale-up is driven by programmes such as Solar Power Naija, the Nigeria Electrification Project and state-led initiatives, which have expanded off-grid solar adoption and laid the groundwork for larger deployments. Based on these national commitments and deployment trends, our analysis estimates critical mineral demand using annual solar PV capacity additions under both BAU and NZE 2060 scenarios.

3.3.2. Methodology

To estimate the raw material requirements for solar PV deployment, this analysis follows a structured approach that links projected annual capacity additions to mineral demand values. The overall methodology is summarized in the flowchart below (Figure 19).

FIGURE 19

Methodological flow for estimating solar PV mineral demand



The projections for raw material requirements are based on material intensity (Table 10), measured in tons per GW of installed solar PV capacity. This study focuses on the dominant technology—wafer-based crystalline silicon (c-Si)—which currently accounts for approximately 95 percent of global PV production [67].

While structural materials such as glass, steel, concrete and plastic are widely used in solar PV systems, they are not included in this analysis. We focus on four key minerals that are critically important for energy systems and supply chains: aluminum (Al), copper (Cu), silicone (Si) and silver (Ag).

TABLE 10

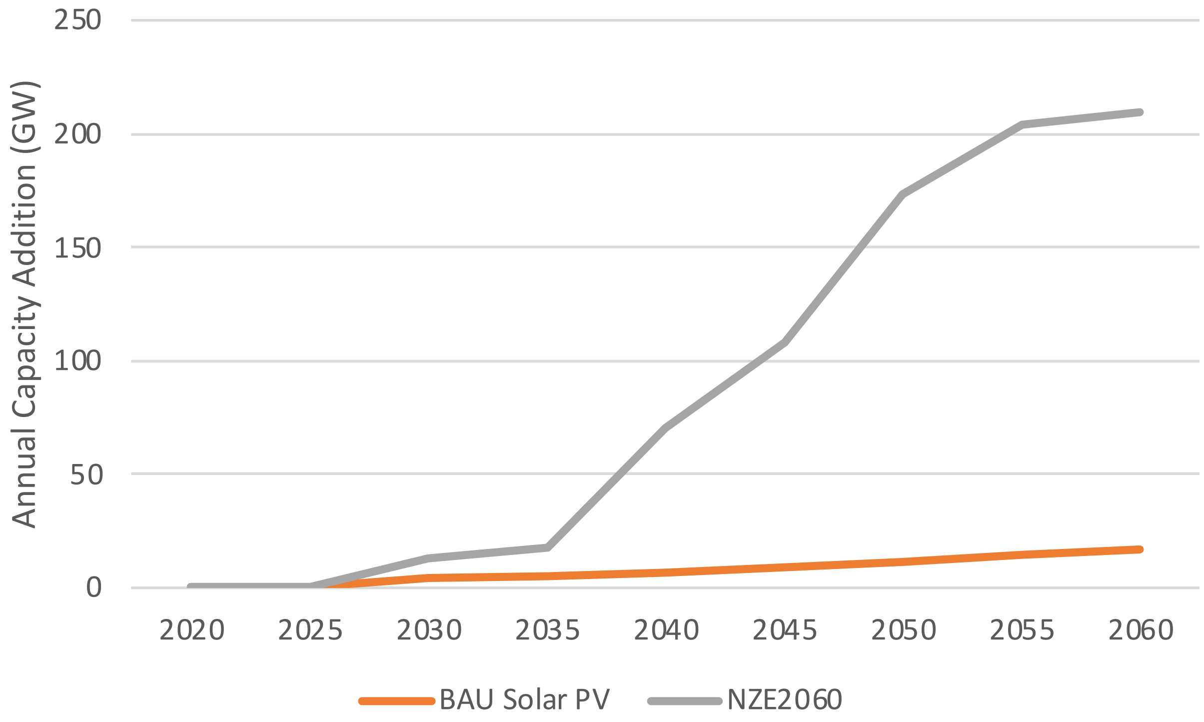
Mineral intensity for C-Si technology (t/GW) [67]

Minerals	Mineral Intensity (t/GW)
Al	7500
Cu	4600
Si	4000
Ag	20

These annual capacity additions reflect Nigeria's evolving solar deployment trajectory, with significantly more aggressive expansion under the NZE 2060 scenario. Figure 20 shows the annual capacity additions that drive the material requirement projections.

FIGURE 20

Annual capacity addition (GW)



Source: SEforALL projections [13]

3.3.3. Mineral Requirements for Solar PV

Based on the projected annual capacity additions under each scenario and the material intensity values previously outlined, we have estimated the total annual demand for aluminum, copper, silicon and silver from solar PV deployment. The overall mineral demand for these four materials is projected to reach 270–3372 kt by 2060, driven primarily by aluminum, copper and silicon (Figure 21 and Figure 22).

FIGURE 21

Projected mineral demand for solar PV - BAU

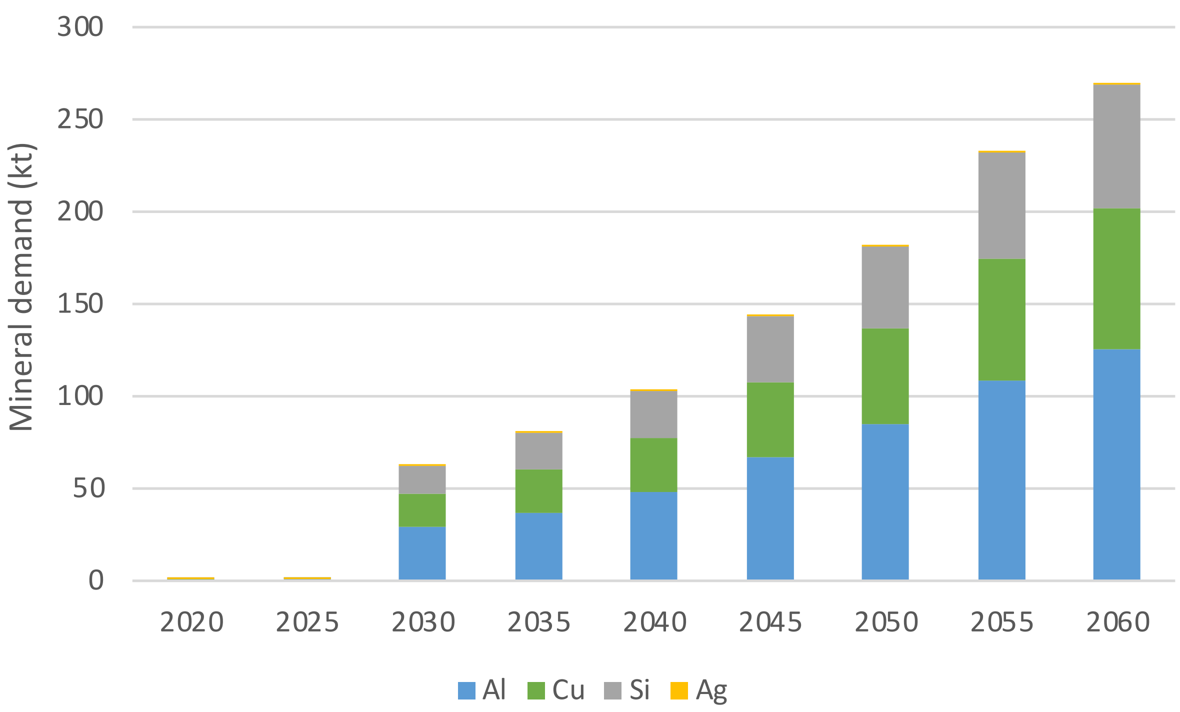
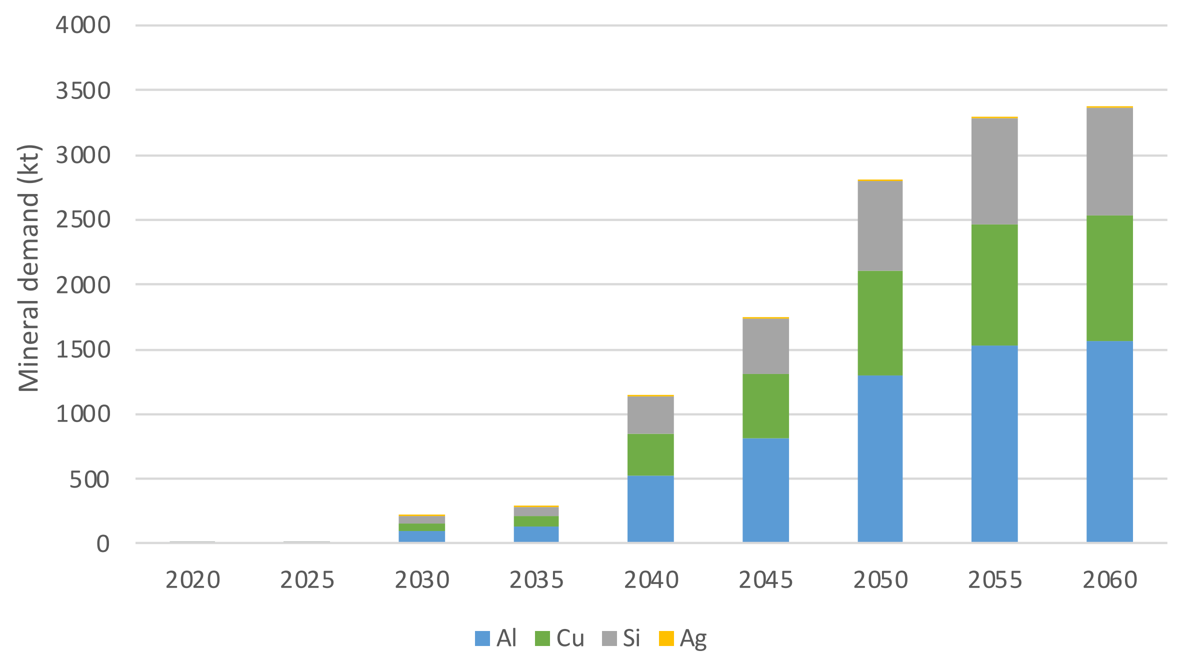


FIGURE 22

Projected mineral demand for solar PV - NZE 2060

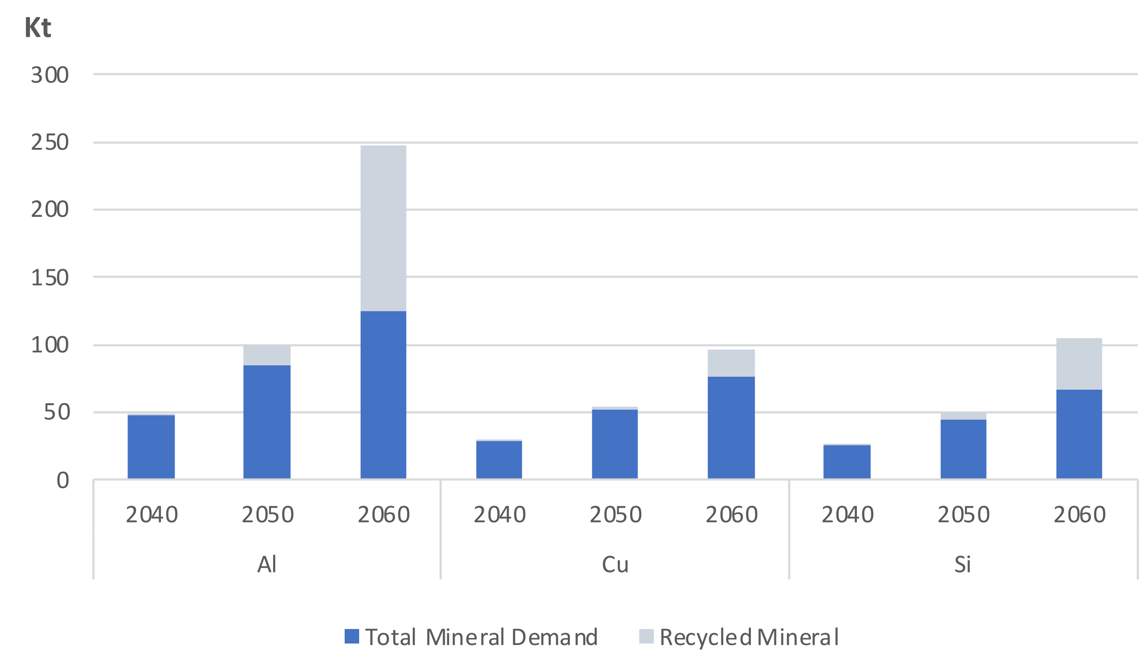


Source: Author's Analysis

Nigeria's solar PV expansion will generate large volumes of EoL modules over the coming decades. To capture this, a Weibull distribution model was applied to estimate cumulative PV waste and recoverable minerals for the period 2025–2060 (methodology provided in the annexure 7). The results show that cumulative waste could reach about 10 million tons in the BAU scenario to 49 million tons in the NZE2060 pathway. With recovery rates increasing from negligible levels today to around 80% by 2060, and recycling efficiencies for aluminum, copper, silicon, and silver ranging between 80–95%, a substantial share of this waste could be recovered. The cumulative demand, recycled minerals, and recovery potential for BAU case is presented in Figure 23.

FIGURE 23

Annual Demand and Recycled Minerals from Solar PV



Source: Author's Analysis

Recycling from EoL PV modules contributes only modestly in the early decades, both because most of the installed capacity is still operating and recovery systems are not yet fully developed. Even as some waste begins to emerge, only a fraction of the material can be captured given the limited infrastructure in place. By 2050, recycled materials are projected to meet about 18% of aluminum, 5% of copper, 10% of silicon and 6% of silver demand, underscoring Nigeria's continued dependence on primary supply in the medium term. After 2050, as the large cohorts of modules reach the end of their lifetimes and dedicated recovery systems are established, secondary supply becomes a central pillar of PV mineral security. By 2060, recycling is expected to supply more than 97% of aluminum demand, 26% of copper, 58% of silicon, and 31% of silver. Aluminum approaches near self-sufficiency because of its dominant share in module frames and relative ease of recovery, while copper, silicon, and silver provide steadily increasing though more moderate contributions.

The broader implication is that PV recycling follows a delayed but transformative trajectory. Its role is marginal in the near term, limited by both small waste flows and constrained material recovery, but it becomes decisive after 2050 once large volumes of modules retire and recovery systems are operating at scale. Timely investment in collection, dismantling, and refining infrastructure is essential to ensure that Nigeria can capture this future potential and embed circularity into its solar sector.

3.3.3 Aggregate Mineral Requirements and Recovery Potential

As Nigeria advances toward large-scale electrification of its transport and energy systems, the cumulative demand for critical minerals used in batteries will increase substantially. This section presents the total mineral requirements associated with battery use across both EVs and BESS under the BAU and NZE 2060 scenarios. While primary mineral extraction will remain essential, EoL battery recycling offers a promising pathway to reduce long-term dependency on virgin materials. By recovering key materials such as lithium, nickel, aluminum, copper and graphite from retired batteries Nigeria can enhance resource security and support the development of a circular battery economy. This section quantifies both the overall material demand and the potential for offsetting it through recycling over the 2025–2060 period (Table 11and Table 12).

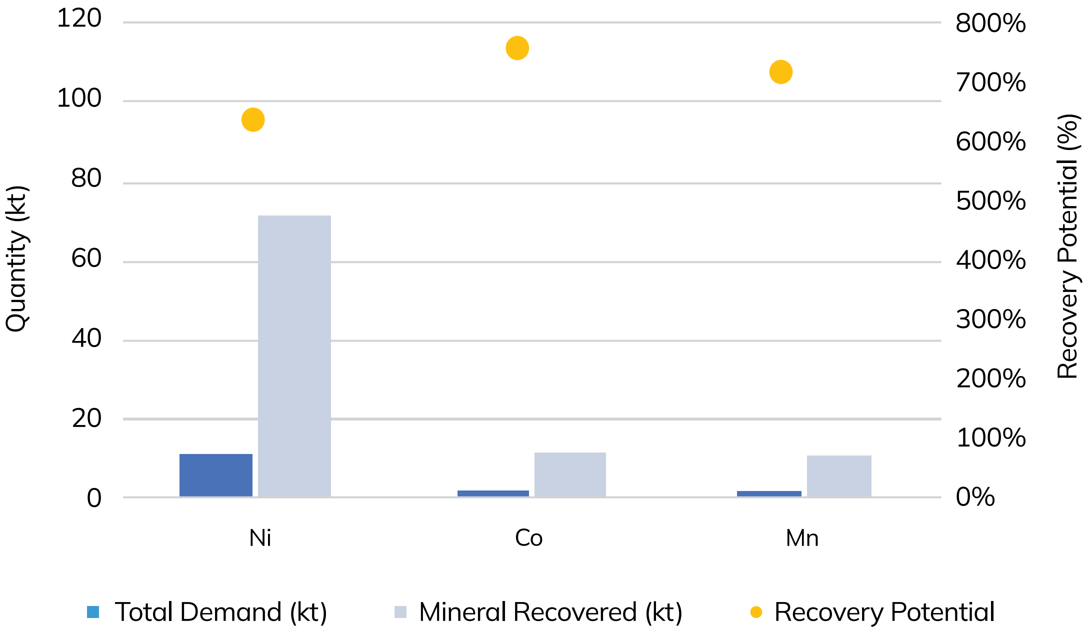
TABLE 11

Cumulative mineral demand and recovery potential (2025–2060) – BAU (kt)

Mineral	EV	BESS	Solar PV	Total Demand	Mineral Recovered	Recovery Potential
Li	1.82	183.46	-	185.28	66.98	36%
Ni	1.53	9.68	-	11.22	71.15	634%
Co	0.19	1.37	-	1.57	11.80	753%
Mn	0.18	1.35	-	1.53	11.00	717%
Al	13.96	1343.03	2241.32	3598.31	1170.78	33%
Cu	10.49	793.87	1374.68	2179.04	856.21	39%
Gr	19.36	2015.46	-	2034.82	708.38	35%
Si	-	-	1195.37	1195.37	209.33	18%
Ag	-	-	5.98	5.98	0.57	9%

FIGURE 24

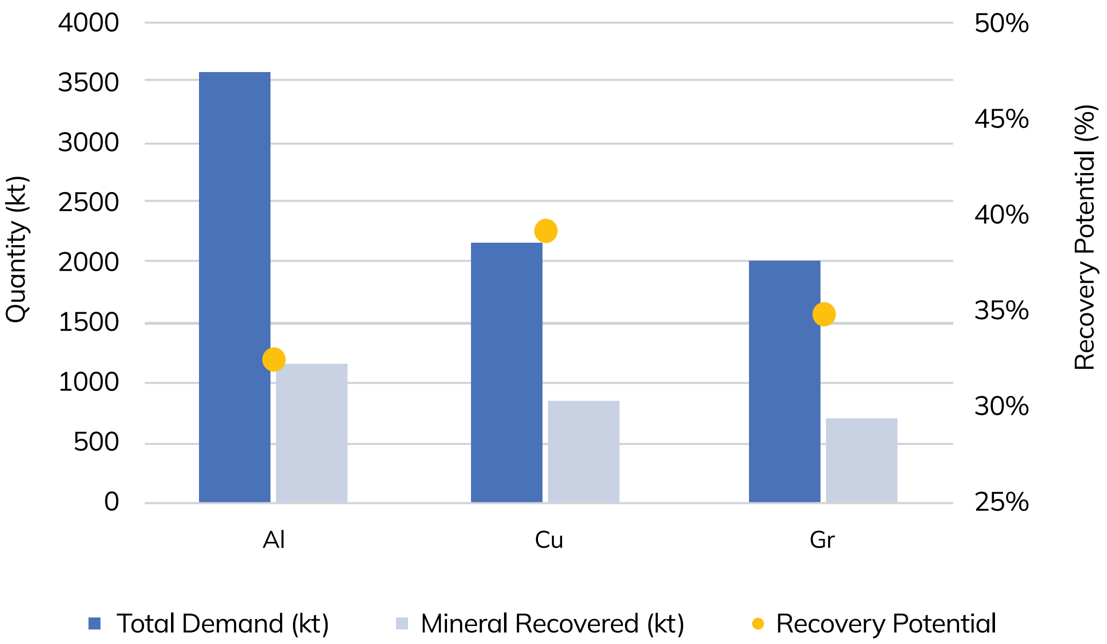
Mineral demand and recovery potential – nickel, cobalt and manganese (2025-2060)



Source: Author's Analysis

FIGURE 25

Mineral demand and recovery potential – aluminum, copper and graphite (2025-2060)



Source: Author's Analysis

In the BAU scenario (Figure 24 and Figure 25), cumulative demand between 2025 and 2060 is dominated by aluminum and copper, which are critical to both batteries and PV systems. Their recovery potential remains modest at around 33% for aluminum and 39% for copper, leaving a continued reliance on primary supply. Among the other battery-grade minerals, graphite and lithium are the most significant contributors to cumulative demand. Recycling offsets roughly 35-36% of the demand, helping to supplement supply but still leaving substantial demand for virgin material. Nickel, cobalt, and manganese remain relatively minor in terms of demand due to the assumed dominance of LFP chemistry. However, unlike bulk minerals, their recovery potential is exceptionally high, reaching around 634% for nickel, 753% for cobalt and 717% for manganese. This is primarily because the recycling stream includes EoL batteries from second-hand electric cars, which introduce additional recoverable minerals into the system beyond domestic demand. As a result, recycling could generate recoverable volumes of these minerals far above cumulative domestic requirement. For other PV-specific minerals, silicon and silver add a distinct layer of demand linked to module manufacturing. Recycling covers only about 18% of silicon and 9% of silver demand, underscoring the limited role of secondary supply in these cases.

This highlights that while recycling will strengthen Nigeria's long-term mineral security, its contribution differs significantly across minerals. For high-volume minerals such as aluminum, copper and graphite, secondary supply can only partially offset future demand growth, meaning dependence on virgin extraction and processing will remain substantial. In contrast, recycling could become a major secondary source for lower-demand battery minerals such as nickel, cobalt and manganese due to the future availability of end-of-life batteries from imported second-hand EVs. Therefore, the strategic task is to align mineral exploitation with domestic processing and manufacturing, while at the same time building recycling systems. Early investment is essential so that recycling technologies, regulatory frameworks, and markets can mature in step with the growth of EoL flows. By preparing in advance, Nigeria can ensure that when large volumes of retired material enter the system, the infrastructure is ready to capture them, transforming a future waste challenge into a strategic supply opportunity.

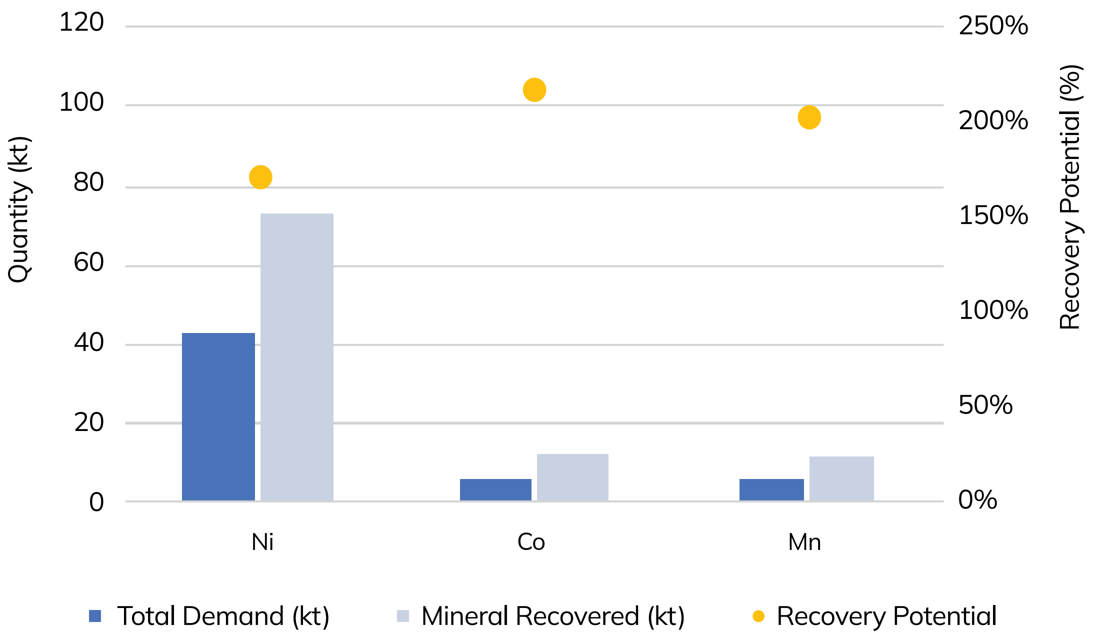
TABLE 12

Cumulative mineral demand and recovery potential (2025–2060) - NZE 2060

Mineral	EV	BESS	Solar PV	Total Demand	Mineral Recovered	Recovery Potential
Li	5.04	2921.66	-	2926.69	543.20	19%
Ni	4.64	37.97	-	42.61	73.19	172%
Co	0.59	4.99	-	5.57	12.06	216%
Mn	0.55	4.97	-	5.51	11.25	204%
Al	38.40	21409.29	48150.86	69598.55	7455.80	11%
Cu	28.84	12649.11	29055.89	41733.84	3005.80	7%
Gr	63.27	32128.52	-	32191.79	5938.11	18%
Si	-	-	14241.69	14241.69	1029.16	7%
Ag	-	-	71.21	71.21	2.79	4%

FIGURE 26

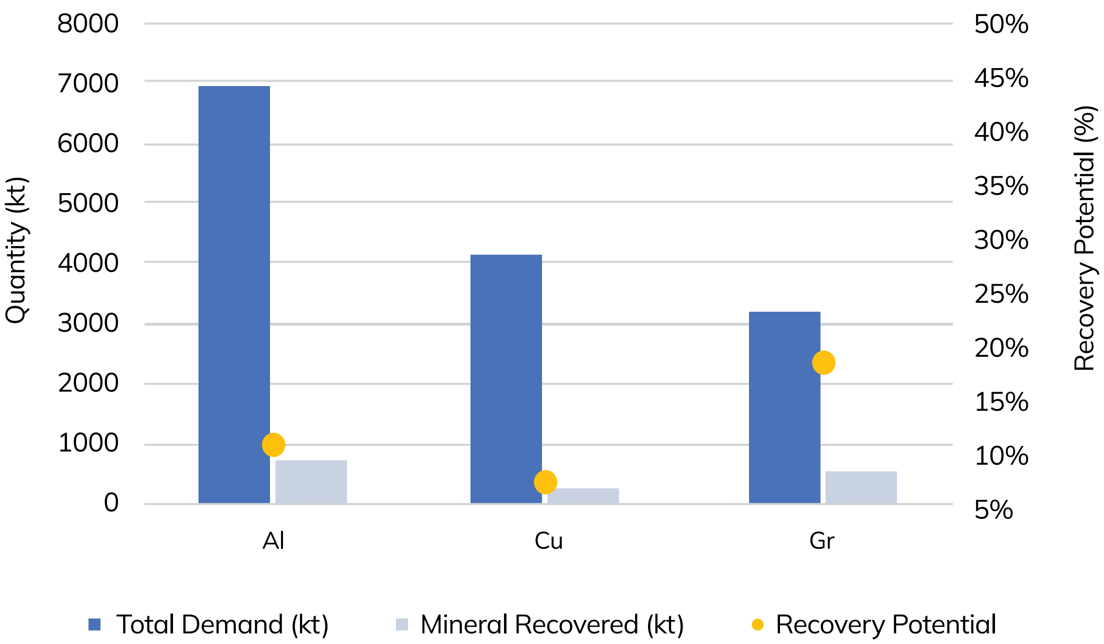
Mineral demand and recovery potential – nickel, cobalt and manganese (2025-2060)



Source: Author's Analysis

FIGURE 27

Mineral demand and recovery potential – aluminum, copper and graphite (2025-2060)



Source: Author's Analysis

In the NZE 2060 scenario (Figure 26 and Figure 27), cumulative mineral recovery volumes are substantial, with over 7 mt of aluminum, 5.9 mt of graphite and 3 mt of copper projected to be recovered by 2060. However, the percentage recovery potential remains relatively low, ranging from 7 percent to 18 percent across key minerals. This is because the overall mineral demand is extremely high, driven by large-scale battery deployment, especially in the BESS sector alongside massive expansion of PV capacity. A significant share of this deployment occurs in the later years of the period (post 2040), meaning that many of these remain in service within the 2040–2060 window, and therefore do not contribute to recovered volumes. As a result, even though recycling volumes are large in absolute terms, they represent a small share of the total cumulative demand.

It is important to note that the recovery potential discussed here reflects the share of total cumulative mineral demand regardless of whether the primary demand is met through embedded mineral content in imported battery packs and PV modules or through direct sourcing of raw materials. While recycling EoL batteries from both EV and BESS applications and modules from PV deployment can contribute meaningfully to future supply, its role varies significantly across minerals, especially in the context of a rapid energy transition. This creates a differentiated policy narrative: Nigeria should secure primary supply for high-demand minerals through long-term contracts, diversified supply chains, and domestic or regional partnerships, while also preparing recycling systems to manage and capture value from EoL batteries and PV modules.

4

STRATEGIC IMPLICATIONS FOR NIGERIA'S CLEAN ENERGY TRANSITION

STRATEGIC IMPLICATIONS FOR NIGERIA'S CLEAN ENERGY TRANSITION

Nigeria holds significant reserves of energy transition minerals including lithium, manganese, tantalum, and niobium. In addition, there are reports of early-stage exploration for graphite and copper. As the government emphasizes local beneficiation and value chain development, several pathways emerge influenced by the size of the domestic market, existing trade and strategic investment relationships, and broader industrial development strategy.

Based on the analysis presented in this report, battery mineral demand for electric vehicles (EVs) and battery energy storage systems (BESS), including copper, aluminum and graphite, account for the largest share of total material requirements, followed by lithium. Minerals such as nickel, cobalt and manganese are required only in smaller quantities, particularly under a lithium-iron-phosphate (LFP) based scenario. Solar PV deployment adds to the minerals needs, especially aluminum and copper, which are required in larger volumes. Despite its geological resources, Nigeria remains primarily a raw material exporter, with limited processing capacity and minimal integration into higher-value segments of global clean energy value chains. This undercuts the potential for domestic value addition and reduces Nigeria's influence in shaping global supply dynamics.

At this juncture, Nigeria's strategic role must go beyond being a raw material supplier reinforced by government's announced priorities. The country will need to actively secure its supply chains by pursuing long-term offtake agreements, diversifying partners, and aligning its exports with ESG and traceability standards that are increasingly required in global markets. Positioning itself within Africa's emerging clean energy ecosystem and building midstream processing capacity will be critical if Nigeria is to convert geological advantage into real leverage in global value chains.

As Nigeria prepares to scale EVs, BESS and solar PVs, the demand for key minerals, particularly copper, aluminum, graphite and lithium, is expected to grow sharply. While battery recycling and circular economy measures will help ease long-term pressures, they require targeted measures to mature. In the meantime, Nigeria must craft strategies tailored to each mineral's demand trajectory, domestic availability and trade potential. It is crucially important to note that energy transition technologies represent one end-use sector case for several minerals analyzed in this report. While lithium has a narrow end-use case in the battery sector, other minerals, such as copper, graphite and manganese, find a larger set of applications across industries prioritized by the government for development.

The following points outline the strategic pathways for selected key minerals, based on current demand forecasts and Nigeria's geological position.

LITHIUM: A STRATEGIC DOMESTIC PRIORITY

Given current trends, lithium stands out as Nigeria's most investment-ready critical mineral, with active production in Nasarawa and additional facilities planned in Abuja and Kaduna. Lithium has a narrow end-use case with high dependence on demand from battery value chain for electric mobility and stationary applications. Long-term demand for lithium remains robust as the global energy transition picks up pace even as new battery chemistries emerge and begin to be deployed at scale. However, Nigeria's domestic demand for battery technologies, although growing rapidly, is not large enough to support a local integrated value chain. As the analysis presented in this report finds, even under a scenario of a fully localized supply chain, a shortfall in lithium resources is only anticipated beyond 2040. Furthermore, lithium prices have experienced significant volatility in recent years, with a dramatic surge from late 2021 into 2022 reaching USD 80,000 per metric ton, followed by a steep decline through 2023 and into 2025 with prices dropping by approximately 80-90 percent. Nigeria will need to prioritize short- to medium-term opportunities to ensure it maximizes the socio-economic benefits from its lithium resources, including building domestic stockpiles, continuing to invest in processing and refining, developing local battery assembly ecosystems, and advancing recycling.

Value added between lithium ore and processed oxides and hydroxides can be up to four times, making it clear that Nigeria must continue to pursue its efforts in attracting investments in local processing and refining of lithium to meet battery-grade requirements. Forward linkages for intermediate materials and underlying agreements must ensure that Nigeria is benefitting fully from the domestic value added economically, as well as through skills building, capability development and job creation. Leveraging trade agreements with off-takers for preferential access to assembled battery cells, including from China, its major lithium trade and investment partner, could enable the development of a local battery assembly ecosystem with forward linkages to end uses in automobile and stationary energy storage sectors. In addition, Nigeria could strengthen its regional role by linking its lithium resources and market demand with emerging African battery initiatives. For example, if a battery plant is established in Kenya, Rwanda, or South Africa, Nigeria could guarantee demand for its output or supply intermediate materials in exchange for competitively priced cells. Such arrangements would create a win–win:

Nigeria would access cost-effective batteries for its transition, while supporting Africa's broader industrialisation efforts. Nigeria could leverage the African Continental Free Trade Area (AfCFTA) and bilateral trade agreements to position itself as West Africa's hub for EV and storage technologies, exporting downstream products to regional markets.

Strategically, starting with assembly opens the door to developing higher-value segments—such as cell manufacturing and potentially full-scale battery production—anchoring Nigeria's ambitions in EVs, renewable energy (RE) and regional exports. However, it will be important for Nigeria to ensure it continues moving up the value chain as other complementary minerals sectors expand, including graphite, aluminum and copper. At the same time, it is essential that Nigeria diversifies its partnerships and develops sustainable industry practices.

MANGANESE AND NICKEL: AN EXPORT-ORIENTED OPPORTUNITY WITH LINKAGES TO LOCAL INDUSTRIALIZATION

Nigeria holds large reserves of manganese ores and nickel. The outlook reveals a persistent and significant production surplus along with high recovery potential, with projected output far exceeding domestic demand from clean energy sector throughout the forecast period. This positions manganese as a high-potential candidate for an export-oriented development strategy. Nigeria could channel part of its manganese and nickel surplus into regional battery supply chains by linking with the DRC–Zambia precursor hub. Exchanging ore for access to cathode materials would give Nigeria a foothold in the African NMC ecosystem, ensuring that its exports translate into reciprocal industrial benefits. At the same time, by investing in extraction, midstream processing, certification and transport infrastructure, Nigeria can position itself as a reliable supplier for global battery and steel industries. More importantly, leveraging consistent exports of these two minerals can serve as a gateway for deeper trade integration—potentially facilitating two-way value chain partnerships that help Nigeria secure access to other critical battery-grade materials, such as copper, aluminum and graphite, which are not yet produced at scale domestically. These materials can be sourced through targeted international collaborations with suppliers in countries such as Chile, China, India, Indonesia and South Korea.

Aligned with the Renewed Hope Agenda, the policy framework designed to achieve national transformation and sustainable growth through sector-wide reforms, Nigeria is laying a strong emphasis on reducing steel imports and revitalizing domestic production. Manganese acts as a deoxidizer, desulfurizer and alloying element in steel production, improving the strength, toughness and other properties of steel. Some manganese ore mined in Nigeria is already used locally in steel production, although the country still faces challenges in fully exploiting its manganese resources to meet industrial demand. There is potential for Nigeria to increase its manganese utilization and develop its steel industry more sustainably with proper beneficiation of its manganese ore to metallurgical grades suitable for steel companies. The country can follow similar pathways for nickel.

COPPER: A MEDIUM-TERM STRATEGIC RESOURCE

Copper also holds strategic potential, with an estimated 10 million tons of ore identified across Nasarawa, Plateau and Zamfara, though commercial-scale mining and processing are yet to begin. It's essential role in EVs and grid infrastructure makes copper a key target for future upstream development, even as investment today remains limited to the exploration stage. Unlocking copper's potential will require targeted geological surveys, feasibility studies and investment incentives for private sector participation. Infrastructure development and adherence to traceability and environmental, social and governance (ESG) standards from the outset will be critical to positioning copper as a strategic growth driver in the medium term. The value of Nigeria's exports of copper ore has steadily grown, with China being the largest trade partner.

ADVANCING CIRCULARITY IN TECHNOLOGY VALUE CHAINS

Circularity will play a vital role in shaping the long-term sustainability of Nigeria's energy transition technology supply chain. The analysis shows that the contribution of recycling will vary significantly across minerals and is strongly influenced by assumptions around second-hand EV imports, which increase the future pool of EoL batteries available for recycling. High-demand minerals will continue to require substantial primary supply through virgin extraction and imports over the coming decades. However, as larger volumes of batteries and solar modules begin reaching end of life after 2040, recycling will become an important secondary source of supply. For nickel, cobalt and manganese, where recovery potential exceeds domestic demand, recycling could also create future export opportunities. This means circular economy measures can strengthen Nigeria's long-term resilience and support new value-creation opportunities, but only if infrastructure, regulatory systems and markets are prepared in advance. Without early investment, Nigeria risks missing the window to transform future waste into a strategic domestic resource.

Government policy will be decisive in shaping this balance. Establishing clear guidelines for EoL battery collection, transport and repurposing—backed by producer responsibility schemes—can create an enabling environment for safe and scalable recycling. Developing partnerships with private recyclers and investing in basic dismantling and sorting infrastructure would also help avoid the leakage of hazardous waste into the informal sector.

Lessons can also be drawn from other maturing technology streams. For instance, solar PV deployment in Nigeria will soon generate some volume of decommissioned modules, and projections suggest a steep rise in PV waste over the next decade. Early government action—such as adopting standards for PV module recycling, supporting research and development (R&D) in low-cost recovery technologies, and fostering local pilot facilities—can help build domestic know-how and create synergies with battery recycling. By designing frameworks that cut across technologies, Nigeria can pool resources, harmonize recycling standards and accelerate the emergence of a robust circular economy for clean energy equipment.

Ultimately, advancing circularity in Nigeria's technology value chains will require not only technical readiness but also policy foresight. Integrating recycling into national energy and industrial strategies, incentivizing formal sector participation, and fostering regional collaboration within the Economic Community of West African States (ECOWAS) could enable Nigeria to transform an impending waste challenge into a platform for innovation, jobs and resource security.

STRENGTHENING FOUNDATIONAL ENABLERS: POLICY, INFRASTRUCTURE AND ESG BENCHMARKS

Advancing Nigeria's mineral sector requires close coordination between key institutions related to minerals, including the Ministry of Solid Minerals Development (MSMD), the Nigerian Geological Survey Agency (NGSA), and other sectors, including energy, finance, trade, and education and training. A unified critical minerals development strategy, aligned with a broader industrialization roadmap, is needed to guide overall value chain development, including infrastructure. Midstream and downstream processes are infrastructure dependent and persistent infrastructure bottlenecks further constrain competitiveness. Poor road connectivity, limited rail access and overreliance on diesel generators increase costs and reduce environmental sustainability.

Nigeria's legal, policy, and fiscal framework is undergoing meaningful reform, but strategic implementation requires closing the gap between policy intent and statutory and fiscal design. Equally pressing is the importance for Nigeria to improve and leverage its existing governance systems to further strengthen traceability and ESG benchmarks. Without credible mine-to-market traceability systems, Nigeria risks exclusion from global clean energy supply chains. Artisanal and small-scale mining (ASM) accounts for the bulk of lithium output and plays a crucial role in local economies. However, ASM typically operates outside formal frameworks and risks being associated with environmental degradation, safety concerns and informality in trade. Rather than displacing ASM, Nigeria must focus on formalizing it by supporting cooperatives, improving access to finance and integrating production into traceable export channels. Any scalable mineral development strategy must address ASM as a foundational element, not a peripheral one.

5

CONCLUSION AND WAY FORWARD

CONCLUSION AND WAY FORWARD

Nigeria's pathway to net zero by 2060 rests on whether it can convert its mineral resource wealth into a foundation for clean energy security and industrial growth. The country's deposits of lithium, manganese, copper, and REE, combined with its growing energy needs, position it as both a prospective hub for Africa's clean energy supply chain and showcase its leadership in mineral-led development.

The analysis shows that Nigeria has a strong resource base, its mineral economy remains constrained by informality, low processing capacity, and governance gaps. Recycling and secondary supply will ease the burdens in the long run but cannot replace the urgent need to scale domestic production, build midstream industries, and align mineral policy with broader industrialization goals.

Among its domestic endowment, lithium, manganese, copper, and nickel, and rare earths stand out as minerals that Nigeria can supply both to meet its own ETIP requirements and to support diversification of global supply chains. Ensuring these resources are developed responsibly and linked to industrial strategies will determine whether they remain raw exports or become building blocks of regional competitiveness. Another potential for Nigeria lies in REEs, widely used in permanent magnets for batteries, EV motors, wind turbines, and advanced technologies in defence, telecommunications, and medical imaging applications. Nigeria accounts for less than 5 percent of global REE output, the country holds promising reserves that are currently underexplored. Although not examined in detail in this study, the REE pathway represents another strategic avenue Nigeria could develop given the rising global demand for magnets and components in EV and renewable energy systems.

Looking ahead, Nigeria's supply chain strategy must be phased. In the near term, the focus will be on securing imports, regional partnerships, and preferential offtake agreements to guarantee battery supply for EVs, BESS, and solar PV modules. In the medium term, Nigeria must expand mining and build midstream industries in lithium, copper, manganese, and graphite to capture value and strengthen domestic resilience. In the long term, as large volumes of EV batteries and PV modules retire post-2040, Nigeria should transform recycling into a "second mine," reducing its dependence on virgin imports and even supplying secondary materials into global markets. This phased approach balances immediate needs with future opportunities, positioning Nigeria as a credible player in Africa's clean energy industrialisation.

The opportunity lies both in supplying the minerals that power global electrification and creating domestic value through refining, manufacturing, and recycling. This requires targeted reforms such as systematic geological surveys, infrastructure upgrades, certification systems, ASM formalization, and investment incentives to bridge the gap between potential and realized outcomes.

If pursued decisively, Nigeria can shift from a resource-dependent economy to the one where minerals underpin clean energy, new industries, and climate resilience – embracing the opportunities of the global energy transition and the long-term benefits of sustainable development.

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ANNEXURES

ANNEXURE 1

Mineral Reserve and Resource Estimation

Mineral	Data Source	Locations	Reserve/Resource estimation
Lithium	WMD (2025), Benchmark Minerals Interlligence (n.d.)	Deposits have been found in Nasarawa, Kogi, Ondo, Osun, Zamfara, Kaduna, Oyo, and Cross River States	Two operating plants Nasarawa (Primary Owner - Avatar Energy Materials Company Limited, China) Artisanal (Nigeria Artisanal Miners, Nigeria) / Inauguration of 50 million Naira lithium plant in Nasarawa State, 2023 (4,000 metric ton per day capacity) & commissioned in May 2024 Abuja Refinery ($200 million, outskirts of Abuja, nearing completion mid-2025) Kaduna Plant ($600 million, near Kaduna–Niger border, commissioning Q2 2025)
Nickel	KPMG (2024), Skyline University Nigeria (2023)	5 million metric tons / northern states of Kaduna, Kebbi, Nasarawa, and Taraba	Exploration Stage / Nigeria currently imports nickel Average concentration of 1-3% deposit For value addition: government announced nickel processing factory in Kaduna State (60,000-ton production capacity) As of now, this remains a proposed project and has not yet reached construction or operational stages.
Cobalt [68]	KPMG (2024), Aliu et al. (2022), Stets & Simwa (2023)	Adamawa, Cross River, Kaduna, Kano, Kogi, Kwara, Nasarawa, Ogun, Osun, Oyo, Taraba	Cobalt is licensed for exploration in Adamawa and Kaduna; Primary cobalt mineral mined is cobaltite (a sulfide ore), other as a byproduct of nickel and copper
Graphite [69]	Ministry of Mines and Steel Development (n.d.)	Bauchi, Kaduna, Adamawa, Taraba	Relatively little or no information about exploration on graphite deposits
Copper	Nigerian Geological Survey Agency (n.d.)	Notable deposits are found in Nasarawa, Plateau and Zamfara	Est. to have 10,000,000 tons of copper ore deposit. Strategic mineral: its occurrence, mineralization and exploration help in understanding geological structures
Manganese [70]	KPMG (2024), MSMD (n.d.)	Niger, Edo, Adamawa, Kebbi, Cross River, Kaduna, Zamfara, Katsina	5,000,000 metric ton deposit
Bauxite (Aluminum) [71] [72]	Biswas (2020), Daya et al. (2021)	Plateau, Taraba, Delta, Ekiti, and Benue	Mambilla Plateau is noted for its low-silica bauxite deposits. Zainudeen et al. (2023) noted the Mambila Plateau has an estimated total reserve of 1,000,000 tons (~1,000 kt)
REE	Veriv Africa (2025)	Adamawa, Gombe, Taraba, Borno, Katsina	135 metric tons of REEs processed weekly (as of 2025) REE: neodymium, cerium, lanthanum, praseodymium, and yttrium may be found in mineral deposits like monazite, xenotime, and bastnasite The United States Geological Survey estimates Nigeria has about six million tons of monazite ore reserves

Note: Resources are deposits that are potentially extractable, and reserves are resources that are economically viable to extract.

ANNEXURE 2

Mineral Commodities included for Import and Export Trade

Data were filtered for Nigeria's trade flows at six-digit Harmonized System (HS) Codes to assess annual import and export records. While this binary method does not quantify trade volumes or values, it offers a clear view of trade consistency, gaps and commodity presence in Nigeria's cross-border mineral flows.

		Import						Export					
HS Codes	**Description**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
282520	Lithium oxide and hydroxide	●	✖	●	●	●	●	●	✖	✖	●	●	●
283691	Carbonates; lithium carbonate	●	●	✖	✖	✖	✖	✖	✖	●	●	✖	✖
260400	Nickel ores and concentrates	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖	✖
283324	Sulphates; of nickel	●	●	✖	●	●	●	✖	✖	✖	✖	✖	✖
260200	Manganese ores and concentrates	✖	✖	✖	✖	✖	✖	✖	●	●	●	●	●
282010	Manganese dioxide	●	●	●	●	●	●	✖	✖	●	✖	✖	✖
282090	Manganese oxide, other than manganese dioxide	●	●	●	●	●	●	✖	✖	✖	✖	✖	✖
260500	Cobalt ores and concentrates	✖	●	✖	✖	●	✖	✖	✖	●	✖	✖	✖
282200	Cobalt oxides and hydroxides; commercial cobalt oxides	●	●	●	●	●	●	✖	✖	✖	✖	✖	✖
250410	Graphite; natural, in powder or in flakes	●	●	●	●	●	●	✖	✖	✖	✖	✖	✖
253090	Mineral substances (unprocessed minerals) – considered for lithium ores and concentrates	●	●	●	●	●	●	●	●	●	●	●	●
260300	Copper ores & concentrates	✖	✖	●	✖	✖	●	●	●	●	●	●	●
260600	Aluminum ores and concentrates	●	●	●	●	●	●	✖	●	✖	✖	✖	✖
281810	Aluminum oxide; artificial corundum	●	●	✖	✖	●	✖	✖	✖	✖	✖	✖	✖
281820	Aluminum oxide; other than artificial corundum	●	●	●	●	●	●	●	✖	✖	✖	✖	✖
281830	Aluminum hydroxide	●	●	●	●	●	●	✖	✖	✖	✖	✖	✖

Source: UN Comtrade (n.d.)

Note: O (data available), X (data not found/not available)

ANNEXURE 3

Applications and potential user industries/companies in Nigeria that might be using imported critical minerals

Nigeria imports a diverse range of minerals, from battery-grade lithium and cobalt to industrial copper and manganese oxides, primarily to support growing sectors like solar energy, electrical infrastructure and chemicals/steel manufacturing. Leading solar companies like Arnergy, GSL and WiSolar are integrating lithium batteries into hybrid and off-grid systems. The cable industry relies heavily on imported copper via firms such as MTN and Nigerchin. However, nickel and cobalt are only present in trace amounts, suggesting nascent involvement in value-added battery research and development (R&D). The broader use of minerals like manganese and aluminum in local refineries, water treatment and cement production underscores Nigeria's reliance on critical imports to sustain industrial growth, though domestic value addition remains limited.

Mineral Description	Main Application/ Sectors	Potential Nigerian Companies / Users	Major Import Source Country – UN Comtrade
Battery-related Materials (Lithium, Cobalt, Graphite)			
Lithium oxide & carbonate	Lithium-ion batteries (LIBs), ceramics, glass	Arnergy, Naseni projects Lumos, Rubitec Solar, GSL Energy	China
Cobalt ores & oxides	Cathode material for LIBs, high-strength alloys	Likely imported for test-scale or industrial battery pilots, possibly under Nigerian Energy Transition Plan (NETP) initiatives	China, India
Natural graphite	Anode material in LIBs, refractories, lubricants	May be used in industrial lubricants, battery pilot R&D, or sold to Nigerian Chemical industries	China, India
LIBs	Solar home systems, EV, UPS	Lumos, Arnergy, Rubitec Solar, Aellopower, and other solar home system companies	China, South Africa, Vietnam
Steel, Alloys & Metallurgy (Nickel, Manganese, Copper)			
Nickel ores & nickel sulphate	Stainless steel, alloy production, battery cathodes	Dana Steel, African Foundries (potential use) Pilot battery assemblers, R&D labs	Germany, USA
Manganese ores, dioxide, oxide	Steel hardening, dry cell batteries, water treatment	Premium Steel, African Foundries Local dry battery makers, chem suppliers, steel rolling mills, glass/ ceramics SMEs	China, India
Copper ores & oxides	Electrical wiring, alloys, piping, electronics	Used by local cable manufacturers (e.g., Nigerchin, Coleman Wires and Cables) and possibly in industrial recycling	India, Italy, United Kingdom (based on OEC Refined Copper in Nigeria [68])
Industrial Chemicals & Others			
Aluminum oxides and hydroxides	Aluminum refining, water treatment, ceramics, abrasives, etc.	Aluminum Smelter Company of Nigeria (ALSCON), First Aluminum Nigeria; also, ceramics, glass and chemical producers	Canada, China, India
Unprocessed minerals (n.e.c.)	Cement, ceramics, chemicals	Dangote Cement, BUA Group	China, Spain

Note: Import source countries are inferred from global trade flows and Nigerian import profile on UN Comtrade.

Company names are based on sector presence and public product/service profile.

Several imports (e.g., lithium and cobalt) are likely low volume and support pilot-scale activities rather than full-scale domestic manufacturing.

ANNEXURE 4

Methodology for Secondhand Imports (Cars)

In addition to new electric vehicle (EV) sales projections, this study includes an estimation of secondhand EV imports, which play a significant role in shaping Nigeria's vehicle market, particularly in the passenger car segment.

To establish a historical baseline, we compiled data on new vehicle sales in Nigeria from 2015 to 2020 [69], alongside used vehicle export data from the US for the same period [70]. Given that the US accounts for approximately 52 percent of Nigeria's secondhand vehicle imports [52], we estimated total used vehicle imports by scaling US export volumes accordingly.

To estimate the EV share within secondhand imports, we utilized EV stock and retirement projections from US vehicle stock modelling. We calculated the proportion of retired EV stock within the overall US vehicle stock and applied this share to the total projected imports entering Nigeria. This provided the estimated number of EVs likely to be imported as secondhand vehicles. For forward-looking projections (2025–2060), we assumed that secondhand vehicle imports will continue to represent a substantial share of Nigeria's total vehicle additions. Initially, imported used vehicles account for 80 percent of total annual vehicle sales, gradually declining to 70 percent by 2032, and reaching 54 percent by 2060 as domestic vehicle assembly and new EV adoption increase. Applying this trajectory to total projected sales and factoring in the estimated share of retired EVs in exporting countries, we developed a secondhand EV import projection that complemented the new EV sales forecast.

ANNEXURE 5

EV Stock Estimation (New + Secondhand Imports)

The age-wise survival function is used to estimate the surviving stock of vehicles in each segment. The following equation, applicable to conventional vehicles, has been applied to EVs with modifications.

$$SF_v = e^{-\left(\frac{g+\alpha_v}{T_v}\right)^{\beta}} \qquad \text{Eq 1}$$

SF = survival function by vehicle (v)
g = age of the vehicle
T = characteristic service life of the vehicle (v)
α, β = shape and scale functions of the SF by vehicle (v)

This equation utilizes a probabilistic Weibull distribution to estimate the likelihood of a vehicle remaining functional over time. The corresponding shape & scale parameters and characteristic service life segment-wise is provided in Table 13.

TABLE 13

Survival Function Parameter

Vehicle Segment	Shape function ( )	Scale function ( )	Characteristic service life
2W /3W	0.1	3.1	8
Cars	-0.5	2.83	10
Buses	-1	3	8
Light-duty trucks	0	3	7
Heavy-duty trucks	0	3.8	8

ANNEXURE 6

Methodology for Manganese Production Estimations

To estimate the production trajectory of manganese in Nigeria, we adopt a bell-shaped mine lifecycle approach commonly used in large-scale mineral resource planning. This model divides mine operations into three sequential phases: ramp-up, plateau and ramp-down, each with distinct production characteristics. It reflects real-world operational patterns observed in global base metal mining, where output gradually increases, stabilizes at peak levels and then declines as ore quality diminishes or reserves are exhausted.

For this analysis, we assume total manganese ore deposits of 5 million tons, with a 70 percent recovery factor, yielding 3.5 million tons of recoverable ore over the mine's life. The mine life is projected to span 27 years, divided as follows:

> **Ramp-up phase (five years):** Production increases progressively from 30 percent to 90 percent of peak capacity, representing the initial commissioning, equipment optimization and workforce training period.

> **Plateau phase (15 years):** Output stabilizes at 90–100 percent of peak capacity, representing the most productive and cost-efficient phase.

> **Ramp-down phase (seven years):** Output declines gradually from 100 percent to 20 percent as reserves are depleted and operational efficiency decreases.

The annual production is distributed across these 27 years using a normalized shape factor for each year (denoted as Si). These shape factors follow a smoothed bell curve profile and are calibrated to ensure that cumulative production equals total recoverable reserves. The estimated annual output for each year is computed using the following formula:

$$Annual\ Output_i = \frac{S_i}{\sum S_i} \times Total\ Recoverable\ Ore \qquad \text{Eq 2}$$

Where,
Si is the shape factor for year i

$\sum S_i$ = sum of all annual shape factors over the 27-year period

This methodology provides a flexible framework for forecasting manganese production, which can be refined further using updated geological surveys and infrastructure development data.

ANNEXURE 7

Methodology for estimating PV module waste and recycling potential

STEP 1

PV Install Capacity and Mass Conversion

Annual installed PV capacity (GW) for the period 2020–2060 was used as the base input. This was converted into physical mass (tons) using a fixed module mass intensity factor of 65,000 tons per GW.

STEP 2

Estimation of Waste Using Weibull Distribution

The Weibull cumulative distribution function was applied to model the probability of EoL failure of PV modules:

$$F\,(t)=1\text{-}e_{(tT)\alpha}\; F\,t=1\text{-}\,e(tT)\alpha \qquad \text{Eq 3}$$

F(t) = cumulative density function; t is time in years; T is scale factor (here, the average useful lifetime of the module taken as 25 years); [9] is the shape factor (5.37 for regular loss). [10] Waste generated (W) from the capacity installed in a particular year (with mass M) using this methodology during the analysis period (2025 to 2060) is given by:

$$W=Mx\sum\nolimits_{t=035}F(t)\;W=Mx\sum t=035(t) \qquad \text{Eq 4}$$

STEP 3

Scenario Assumptions for Recycling Rate

A gradual recycling pathway was assumed, with recovery rates increasing from 1% in 2025 to 80% by 2060.

STEP 4

Recycling Pathway, Material Composition, and Recovery Efficiencies

A gradual recycling pathway was assumed, with recovery rates increasing from 1% in 2025 to 80% in 2060. The total PV waste mass was decomposed into constituent materials using the literature values reported for C-Si modules: aluminum accounts for 10.3% of module mass, silicon 3.48%, copper 1.77%, and silver 0.01%, with the remainder made up of glass, plastics, encapsulant, and backsheet materials.[9] To estimate the effective recovery potential, mineral-specific recovery efficiencies were applied, namely 94% for aluminum, 86% for silicon, 90% for copper, and 81% for silver.

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