Approach Paper towards preparation of an African Green Minerals Strategy

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African Development Bank Group
Abidjan 01, Côte d'Ivoire;
Phone (Standard) : +225 2720263900
Internet: www.afdb.org.

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Abbreviations and Acronyms

4IR	4th industrial revolution
AfCFTA	African Continental Free Trade Area
AfDB	African Development Bank
AGMS	African green minerals strategy
ALBATTS	Alliance for Battery Technology Training and Skills
ALSF	African Legal Support Facility
AMDC	African Minerals Development Centre
AMV	African Mining Vision
ANRC	African Natural Resources Centre
ARIPO	African Regional Intellectual Property Organization
ASSBs	all-solid-state batteries
AU	African Union
AUCS	African Union Commodity Strategy
BADEA	Arab Bank for Economic Development in Africa
BTM	behind the meter
CAEB	African Centre of Excellence for Advanced Battery Research
CEN–SAD	Community of Sahel–Saharan States
CET	common external tariff
COMESA	Common Market for Eastern and Southern Africa
CRMA	Critical Raw Materials Alliance
CRMs	critical raw materials
EAC	East African Community
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
ESG	economic, social and governance
EV	electric vehicle
FTA	free trade area
FTM	front of the meter
GDP	gross domestic product
GHGs	greenhouse gases
HRD	human resources development
ICE	internal combustion engine
ICT	Information and communications technology
IEA	International Energy Association
IGAD	Intergovernmental Authority on Development
IPCC	Intergovernmental Panel on Climate Change

Abbreviations and Acronyms

LPI	Logistics Performance Index
LSF	Liquidity and Sustainability Facility
NDCs	nationally determined contributions
NTBs	non-tariff barriers
OAGS	Organisation of African Geological Surveys
PFS	pre-feasibility study
PV	photovoltaic
RBI	resource-based industrialisation
RDI	research, development and innovation
REC	Regional Economic Community
REEs	rare earth elements
RMCs	regional member countries
RoO	rules of origin
SADC	Southern African Development Community
SDGs	sustainable development goals
SDS	sustainable development scenario
SSA	Sub-Saharan Africa
SNEL	La Société Nationale d'Electricité
STEM	science, technology, engineering and mathematics
STEPS	stated policies scenario
UMA	Arab Maghreb Union
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey
VRE	variable renewable energy

Acknowledgments

Harnessing the opportunities created by the transition to low-carbon economies is at the heart of preparing an African Green Minerals Strategy (AGMS). This strategy is intended to augment the existing body of mineral development policies with a focus on the extraordinary opportunities being created by the green transition and the digital future.

In the transition to a reduced reliance on fossil fuels, the metals and minerals used in electrification, renewable energy generation, electric mobility and new forms of energy storage are required in far larger quantities than has hitherto been the case. Africa's vast mineral resource endowment positions it well to play a central role in this new context. Africa has been targeted as purely a raw material supply source and this narrative must be reversed by the creation of an African strategy to develop the value chain to provide benefits for global decarbonising efforts and industrialising Africa.

To formulate a strategy that is grounded in the prevailing circumstances of African countries and informed by local, regional and global conditions, this Approach Paper has been prepared by the African Development Bank and its partners [the African Minerals Development Centre (AMDC), the African Legal Support Facility (ALSF), the United Nations Economic Commission for Africa (UNECA) and the United Nations Development Programme (UNDP)] as a precursor study for a fully-fledged African Green Mineral Strategy which will follow.

This Approach Paper was produced under the overall guidance of Vanessa Ushie, Acting Director of the African Natural Resources Management and Investment Centre. The study was directly supervised by Fred Kabanda, Manager Extractives. The technical team that worked on this study and on the resulting report was led by Jerry Ahadjie, Chief Minerals Officer of the African Natural Resources Management and Investment Centre. Staff of the following departments of the African Development Bank provided valuable contributions and inputs at various stages of the study: Africa Natural Resources Management and Investment Center (ECNR); Governance and Economic Reforms (ECGF); Country Economics (ECCE); Macroeconomics Policy, Forecasting and Research (ECMR); and the Staff Council (SCO).

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Executive Summary

As the world grapples with the challenges of climate change, the transition away from fossil fuels is having a major impact on the minerals industry. Metals used in electrification, renewable energy generation, electric mobility and new forms of energy storage have become critical to these expanding low and no carbon industries. Africa is endowed with many of the most important minerals, and the increased demand makes it imperative that stewardship of these resources be guided to maximise the benefits of their exploitation to the continent and her people.

The African Natural Resources Management and Investment Centre (ANRC) within the African Development Bank and its partners the African Minerals Development Centre (AMDC), the African Legal Support Facility (ALSF), the United Nations Economic Commission for Africa (UNECA), the United Nations Development Programme (UNDP) have initiated the development of an African Green Minerals Strategy (AGMS) to proactively engage with the new conditions flowing from the energy transition. The strategy is intended to augment the existing body of mineral development policies with a focus on the opportunities created by these new conditions.

To formulate a strategy that is grounded in the prevailing circumstances of African countries and informed by local, regional and global conditions, this Approach Paper has been prepared as the precursor study for a fully-fledged African Green Mineral Strategy (AGMS) which is to follow.

Minerals required for the energy transition and which are produced on the continent define the scope of the AGMS. The vision for the strategy is to guide Africa to strategically exploit the continent's green mineral resources for industrialisation and to assert control over its destiny to create an African presence in emerging green technologies.

Four pillars support the strategy to deliver this vision:

1. Advancing mineral development by increasing geological knowledge, conducting feasibility studies to attract investment, establishing the infrastructure to create an enabling environment and aligning mineral resource management with the African Mining Vision (AMV).
2. Developing people and technology capabilities by identifying the skills needed to capitalise on opportunities and building the institutions ready to generate them.
3. Building key value chains to achieve resource-based industrialisation and access wider regional and continental markets through the African Continental Free Trade Area (AfCFTA). The case is made for establishing battery and electric vehicles value chains as a priority, starting with two- and three-wheeled vehicles and commuter buses.
4. Promoting mineral stewardship to responsibly guide the environmental, social and governance aspects of green minerals, together with increasing material reuse and recycling.

By focusing on creating the conditions to use Africa's green minerals to industrialise and achieve economic diversification, this Approach Paper describes a theory of change to drive the elaboration of the full African green minerals strategy. Indicators that the strategy is working to link green minerals up and downstream would be seen by increased investments in the value chains. Impacts of the strategy would be seen in the products generated by the value chains targeted for batteries, electric vehicles and upweighted participation in global value chains.

CHAPTER 1

Introduction: Challenges for the Governance and Development of Natural Resources in Africa

Modern society was built on minerals and metals. They are so central that, until recently, they were almost taken for granted. The current transition away from fossil fuels towards products and services requiring the metals and minerals used in electrification, renewable energy generation, electric mobility and new forms of energy storage have made their importance increasingly apparent. This change is shining a spotlight on those minerals most critical to the energy transition. Africa has been blessed with most of these minerals and it is increasingly imperative that natural resource stewardship becomes a proactive part of African engagement with these unfolding developments. There is a need to augment the existing body of mineral development policies with a strategy that comprehensively focuses on the value chains of those minerals that are critical to the energy transition. Hence the preparation of an African Green Minerals strategy (AGMS).

The African Development Bank (AfDB) provides finance and thought leadership to support its regional member countries (RMCs) to achieve sustainable national and regional socio-economic development. With regard to renewable and non-renewable natural resources, the Bank's African Natural Resources Management and Investment Centre (ANRC) performs the role of advising RMCs on the stewardship of their natural resources for optimal, environmentally sound and economically integrated development. The ANRC and its partners, the African Minerals Development Centre (AMDC), the African Legal Support Facility (ALSF), the United Nations Economic Commission for Africa (UNECA), and the United Nations Development Programme (UNDP) have initiated the development of an African Green Minerals Strategy, starting with this Approach Paper.

Africa's vast mineral resources positions it well to play a central role in the energy transition and yet there are major threats that may hinder member states' ability to fully reap the benefits. All around the world, other continents and countries are scrambling to create their own critical minerals strategies to secure supplies needed for new economic growth sectors and national defence. Africa has been targeted as a raw material supply source and this narrative must be reversed by Africa developing its own strategy to develop the necessary value chains with win-win outcomes for the economy, people and nature. About 23% of Africa's gross domestic product (GDP) is created in economic sectors that are highly dependent on nature (WEF, 2020) which could be severely compromised by a mishandled minerals rush.

Significant quantities of the minerals needed for the energy transition and green industries are found in Africa. In terms of global reserves, Africa hosts 6 per cent of copper, 53 per cent of cobalt, 25 per cent of bauxite, 21 per cent of graphite, 46 per cent of manganese, 35 per cent of chromite, 79 per cent of phosphate rock, and 91 per cent of platinum group metals (USGS, 2022). Beyond reserves, Africa accounts for an even greater share of the current production of many of these minerals, including a commanding 70 per cent of cobalt. Although not a significant lithium producer yet, this mineral is mined in Zimbabwe and Mali. Namibia, Ghana and the DRC also have resources. While not major producers, rare earth elements (REEs) are mined in Angola and Burundi with further projects in development in Malawi, South Africa, Tanzania, Madagascar, Morocco, and Mozambique.

Africa is part of the global value chains for green and transition minerals, however this role is concentrated at their start through exploration, extraction, and some processing. Limited quantities of battery-grade manganese and nickel are produced, together with vanadium electrolyte for flow batteries. Lithium-ion batteries are assembled into battery packs for management systems, cooling and support electronics using imported battery cells for applications in remote power systems, telecommunications, and security systems. Manufacturing specialised equipment for mining, logistics and food transport using lithium-ion cells is taking place in South Africa, as well as the building of off-grid renewable energy generation projects with battery storage using lithium-ion batteries assembled locally (Montmasson-Clair, Moshikaro, & Monaisa, 2021). Hybrid electric vehicles are being assembled by Toyota in Durban, South Africa, from semi-knocked down vehicle imports. Companies such as Ampersand in Rwanda, MAX in Nigeria, Bodawerk in Uganda, ARC in Kenya, and Agilitee in South Africa are part of a rapidly growing African electric motorcycle industry which is run by mostly young innovative entrepreneurs presenting convincing business cases who are producing new electric motorcycles or retrofitting conventional ones with electric motors. Several companies across the continent, such as Kira Motors in Uganda are converting internal combustion engine (ICE) buses and light trucks into electric vehicles. These activities should be regarded as nascent industrial activities which demonstrate technical and manufacturing capabilities that can be scaled up with supportive policy, skills, infrastructure and investment environments.

Five interconnected factors are unfolding across Africa:

- the growth of a new minerals boom linked to the demand for green minerals;
- Africa's developing strength in the mineral resources required by the energy transition;

- the imperative to reorient economic growth to a low-carbon future to anticipate carbon reduction measures in multilateral and bilateral trade regimes as well as access to finance, and to contribute to mitigating the growing damage from climate change-induced extreme events being experienced by the African countries;
- the need to drive industrialisation and economic diversification that can take advantage of the emergence of new industries, in particular the manufacture of batteries and their application in manufacture of electric mobility products; and
- the creation of the African Continental Free Trade Area (AfCFTA) to deepen market integration and thereby provide scale economies for investment projects all along the green mineral value chains.
- How Africa strategically engages with these interconnected factors will shape mining and upstream and downstream value chain development. At the policy level, the call for the development of an African Green Minerals Strategy arises from the need to formulate one that is grounded in the prevailing circumstances of African countries and informed by local, regional and global conditions to optimise the opportunities that minerals present. This Approach Paper has been prepared as a precursor study for a comprehensive African Green Minerals Strategy (AGMS).

The Approach Paper is structured as follows. Starting with the context of Africa's green mineral resources, minerals critical to the energy transition are assessed and those that are contextually relevant are defined as Africa's 'green' minerals. Their current and potential contribution to the energy transition and mitigation of climate change is outlined. A scan of challenges and emerging issues is conducted to identify risks and opportunities, following which the guiding orientation for the strategy is laid out in four themes:

i. advancing the development of minerals;
ii. developing people and technology capabilities.
iii. building key value chains; and,
iv. mineral stewardship.

To enable the final AGMS to successfully guide actions that will channel investment into the expanded production of products and services, a theory of change is proposed. This sets out the linkages between inputs and outcomes to transform the green minerals sector and proposes how to measure progress towards the vision of Africa maximising her green mineral potential. After a risk analysis and a risk mitigation discussion, the paper ends by outlining an action plan to develop the complete African Green Minerals Strategy, charting a course towards the expected optimisation of the battery and electric vehicle (EV) value chains in Africa.

CHAPTER 2

Context of Africa's Green Mineral Resources

Global energy production makes up 74 per cent of the greenhouse gases (GHGs) which are driving anthropogenic climate change. Fossil fuel use, together with deforestation and other human activities, has raised the atmospheric concentration of CO2 from some 280 parts per million (ppm) at the start of the industrial revolution to 420 ppm in June 2022 (CO2.earth, 2022). As a result, the planet is now around 1.16 °C warmer and this alternation is already damaging lives and livelihoods and posing an existential threat to people and the planet's ecosystems. In response, the international community has acted under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC) to combat climate change and every UN member has adopted the 2015 Paris Agreement, committing to prevent the mean global temperature from rising by more than 2°C above pre-industrial levels and to make a concerted effort to keep it below 1.5°C. At a global level, through the Paris Agreement and subsequent accords as well as at a national level though Nationally Determined Contributions (NDCs), countries are committed to modify their GHG output. In order to improve the probability of achieving climate safety, the Intergovernmental Panel on Climate Change (IPCC) has stressed the importance of striving for the 1.5 °C limit which requires the combined effort of all countries to achieve net zero GHG emissions by 2050.

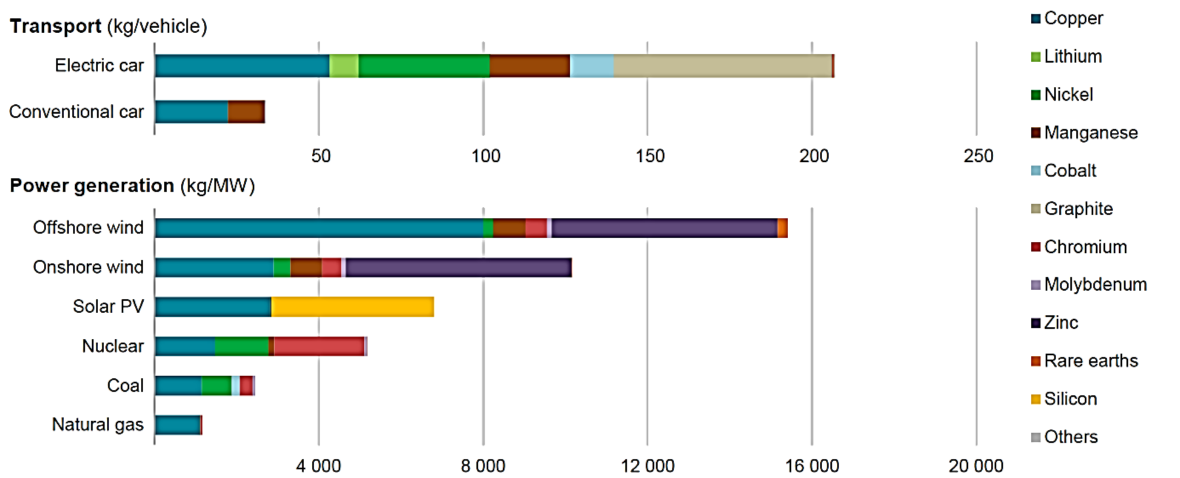
On the current GHG trajectory of NDCs, likely warming will exceed 1.5 °C during the 21st century. Furthermore, policies covering energy, transport and other major sources of GHG emissions are projected to result in higher global emissions than implied by the NDCs (IPCC, 2022, pp. SPM-15) and the war in eastern Europe has resulted in some clean energy transition reversals. All of which indicates that the world is way off target. Without strengthening policies, currently rising GHG emissions, coupled with positive feedback loops that trigger more rapid warming, for example the drying of rainforests which turn them from carbon sinks into carbon sources, projections lead to a median global warming of 3.2°C by 2100 (at medium confidence) (IPCC, 2022, pp. SPM-21). African countries are particularly vulnerable to the effects of climate change due, for example, to sea levels rising 2mm per year faster than the global average for some East African regions (WMO, 2020, p. 12) or deforestation occurring at a greater rate than the global average (ECA, 2018).

Driven by the significant contribution that energy production makes to climate change, a central focus for climate safety is given to the energy sector and the transition from fossil fuels (coal, oil, and gas) to zero-carbon energy sources such as wind, solar, geothermal, hydro, ocean, biomass and nuclear, or fossil fuels accompanied by carbon capture and storage. Downstream energy use for transport and industry needs to be sourced from zero-carbon sources, preferably by directly electrifying them, for example by switching to electric vehicles powered by batteries or by using zero-carbon power to synthesise green fuels in the form of hydrogen or green ammonia which can provide mobile energy without releasing CO2 into the atmosphere.

For the minerals industry, the energy transition is altering how mining is powered, with significant implications for building the African mining supply chains, and affecting which minerals are in greatest demand. An energy system powered by zero-carbon technologies differs profoundly from one fuelled by traditional hydrocarbon resources. Building solar photovoltaic (PV) plants, wind farms and electric vehicles (EVs) generally requires more minerals than their fossil fuel-based counterparts. The minerals critical to the energy transition are copper, lithium, nickel, manganese, cobalt, graphite, chromium, molybdenum, zinc, silicon and rare earth elements. Steel and aluminium are ubiquitous metals used throughout traditional and energy transition industries. A typical electric car requires six times more mineral inputs than a conventional car by weight, and an onshore wind plant requires nine times more of these critical minerals in kg per MW than a gas-fired power plant. Since 2010, the average amount of these minerals that are needed for a new unit of power generation capacity has increased by 50 per cent as the share of renewables has risen according to the International Energy Association (IEA, May 2021, p. 5). Achieving full decarbonisation will take time as clean energy sources are increasingly brought online. During the transition, the most polluting fossil fuels should be retired first and natural gas used as a transition fuel.

FIGURE 1:

Minerals used in selected clean energy technologies compared to fossil fuel equivalents



Source: (IEA, May 2021)

Energy transition minerals are those identified by the International Energy Association (IEA) as rare earth minerals: silicon, manganese, graphite, cobalt, nickel, lithium, and copper.

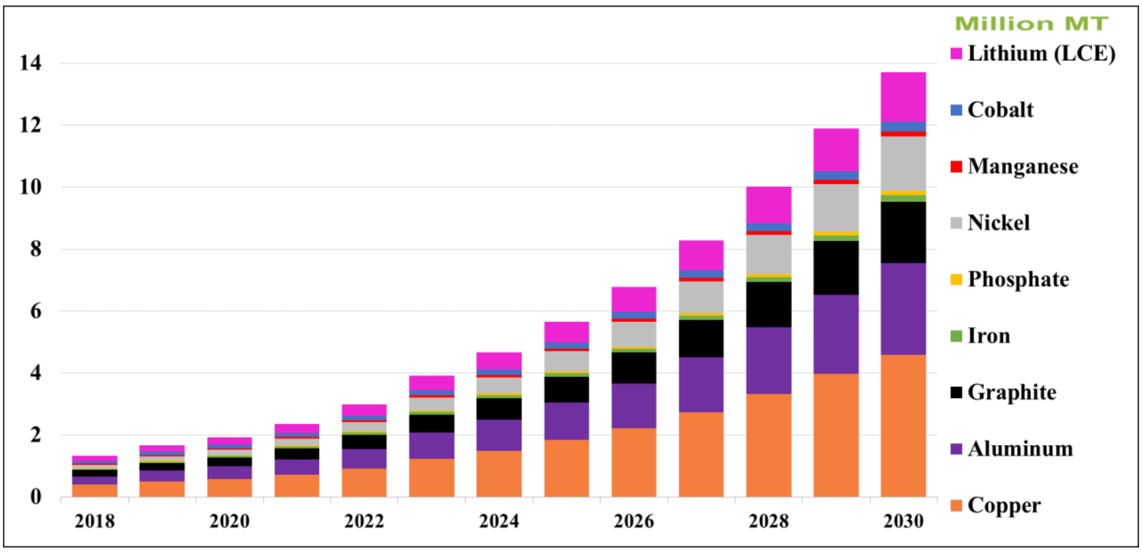
The energy transition and the development of green industries is giving rise to new opportunities, scaling up the demand for these minerals and metals by many multiples. This is epitomised by the wider use of lithium-ion batteries which have migrated from consumer electronics to power electric vehicles which now makes up the largest market by value for such batteries. Owing to the tight coupling of battery manufacturing and electric car assembly these value chains are intimately linked with battery production usually located close to vehicle assembly, even though the battery value chain is global, and the bulk of the intermediate inputs are manufactured in Asia.

Manufacturing lithium-ion batteries will materially increase the demand for metals destined for energy storage. Forecasts for the metals demanded by lithium-ion battery production are given in Figure 2 and comprise copper, aluminium, phosphorus, iron, manganese, graphite, nickel, cobalt, and lithium. By 2030, batteries are forecast to require an average of 5.5 times more of these metals than were consumed in 2021 (BloombergNEF, June 30, 2021).

Utility-scale energy storage is also a growing application for lithium-ion batteries as they are gradually falling in cost to become viable for coupling with variable renewable energy generation to ensure dispatchable electricity supply. Other battery energy storage technologies are in development, such as vanadium redox flow batteries, zinc-air and sodium-ion, and thus it is expected that a range of battery technologies will develop in future to complement other forms of energy storage such as pumped-hydro, compressed air or gravity systems.

FIGURE 2:

Global metals demand and forecast from lithium-ion batteries [Million Metric Tonnes



Note: Metals demand occurs at mine-mouth, one year before battery demand. All metals are expressed in metric tons of contained metal, except lithium, which is in lithium carbonate equivalent or LCE. Source: (Creamer Research Channel, 2021) after BloombergNEF.

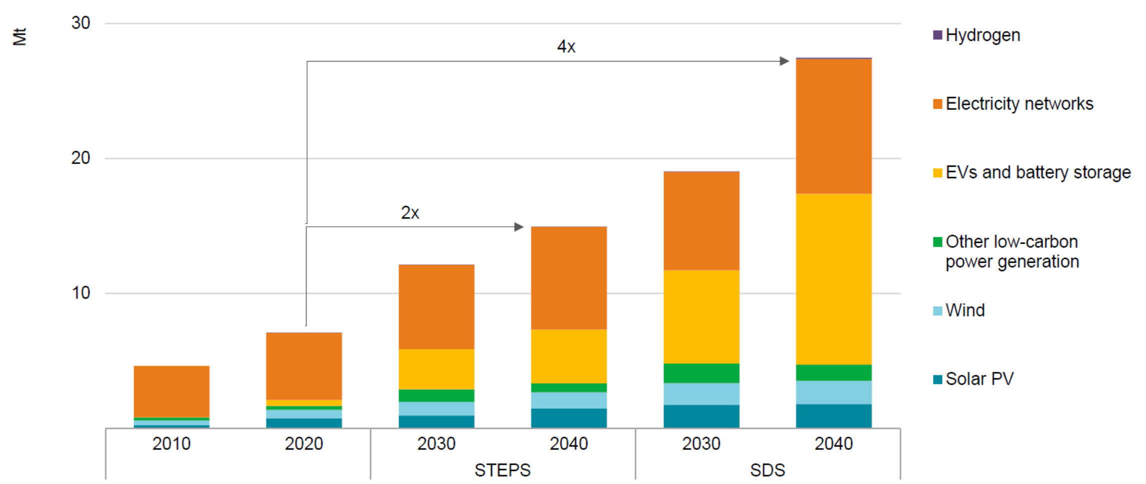
Estimating Africa's demand for minerals used in the energy transition is outside the scope of this paper, therefore references will be made to the most up-to-date global estimates made by the IEA. These estimates aggregate mineral demand from a wide range of clean energy technologies – such as low-carbon power generation (renewables and nuclear), electricity networks, electric vehicles, battery storage and hydrogen (electrolysers and fuel cells). Demand estimates are derived from two main IEA projected scenarios: the 'stated policies scenario' (STEPS) and the 'sustainable development scenario' (SDS). Results have been adjusted to account for mineral intensity improvements. The following minerals are included in these aggregate estimates: chromium, copper, major battery metals (lithium, nickel, cobalt, manganese, and graphite), molybdenum, platinum group metals, zinc, REEs and others. Steel and aluminium, which are necessary inputs for all of the above technologies have been excluded from these forecasts.

In the following figures graphical representation is made of the major uncertainties that developing a strategy for green minerals needs to account for, namely:

- the volume and time frame for demand for different levels of metals to grow;
- the extent to which climate policies, country commitments and actual adjustments take place;
- tipping points when minerals used in energy transition technologies overtake their use in other markets, such as the steel industry for alloys and industrial markets for non-energy related applications; and
- the variation in ratios of metals needed for different technologies competing for leadership.

FIGURE 3:

Total mineral demand for clean energy technologies by scenario

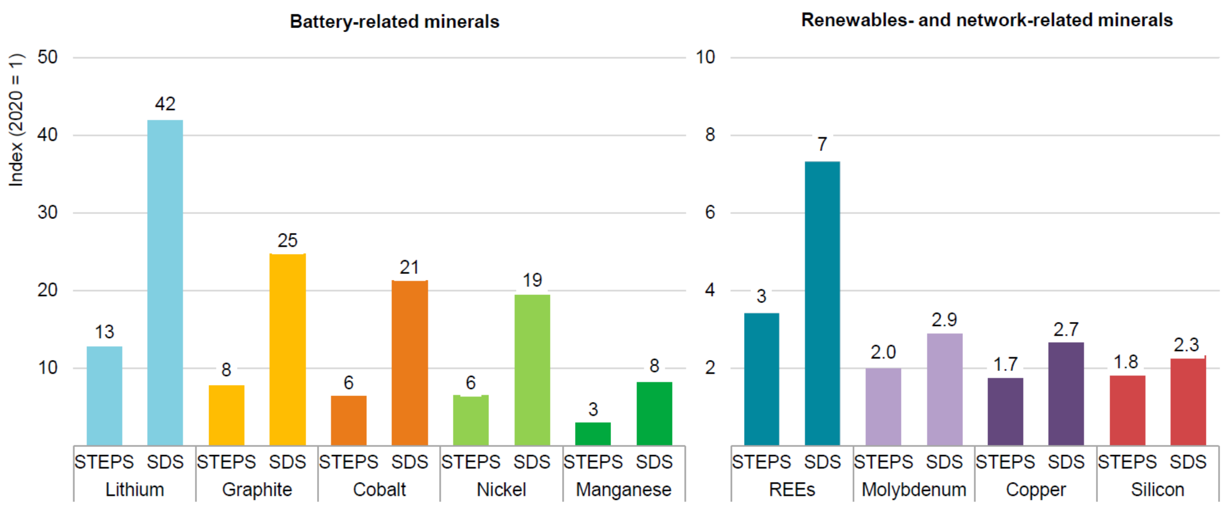


Source: (IEA, May 2021)

The total demand for minerals from clean energy technologies by 2040 is set to double in the more conservative, STEPS scenario and quadruple in the SDS scenario estimates seen in Figure 3. According to the IEA, EVs and battery storage account for about half of the mineral demand growth from clean energy technologies over the next two decades, spurred by the surging demand for battery materials. Mineral demand for use in EVs and battery storage grows nearly tenfold in the STEPS and around 30 times in the SDS projections over the period to 2040. By weight, mineral demand in 2040 is dominated by copper, graphite and nickel. Lithium sees the fastest growth rate, with demand growing by over 40 times in the SDS. The shift towards lower cobalt chemistries for batteries will help to limit growth in cobalt, displaced by growth in nickel.

FIGURE 4:

Growth in demand for selected minerals from clean energy technologies in 2040, relative to 2020 levels



Source: (IEA, May 2021)

The forecast out to 2040 in Figure 4 is much higher than the forecasts out to 2030 shown in Figure 2 (using a different method) but show that metals demand will rise more rapidly over the longer period which takes into account the accelerating pace of decarbonisation globally. For Africa, with particularly acute deficiencies in electricity transmission networks, it is important to note electricity networks are another major driving force globally for copper (plus aluminium and steel). Electricity networks account for 70% of today's mineral demand from the energy technologies but their contribution shrinks as EV and storage markets ramp up.

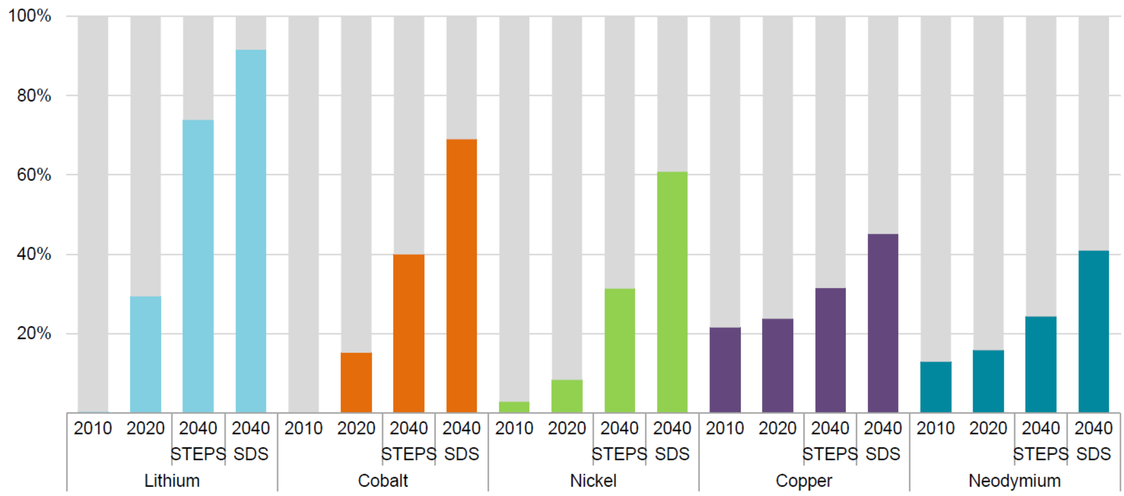
Mineral demand from low-carbon power generation grows rapidly, doubling in the STEPS and nearly tripling in the SDS alternative over the period to 2040. Wind power plays a leading role in driving growth in demand due to a combination of large-scale capacity additions and higher mineral intensity (especially with growing contributions from mineral intensive offshore wind). Solar

PV follows closely, with its unmatched scale of capacity additions among the low-carbon power generation technologies. Growing interest in the hydrogen economy required to meet the SDS scenario underpins major growth in demand for nickel and zirconium for use in electrolysers, and for copper and platinum-group metals for use in fuel cell electric vehicles. Demand for REEs – primarily for EV motors and wind turbines – grows threefold in the STEPS and around sevenfold in the SDS alternative by 2040.

Noting that hydropower, biomass and nuclear (Africa's second nuclear plant is planned in Egypt) make only minor contributions to minerals demand given their comparatively low mineral requirements and modest capacity additions, these clean energy technologies are not given special attention in this paper.

FIGURE 5:

Share of clean energy technologies in total demand for selected minerals

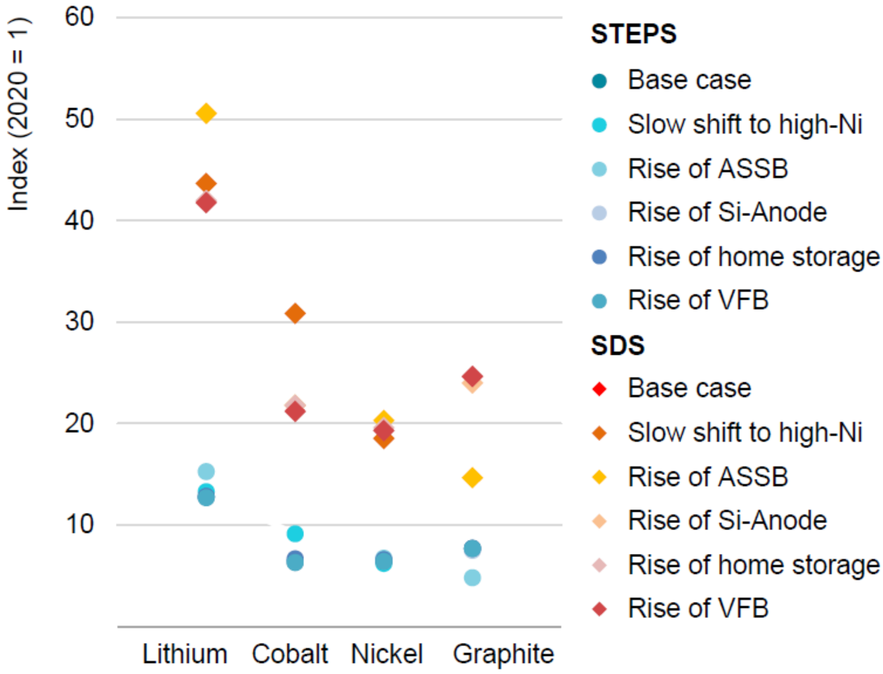


Source: (IEA, May 2021)

Figure 5 provides a useful reminder that the higher attention given to minerals in supporting the energy transition should not obscure their importance in traditional steel alloys, industrial and chemical markets. Furthermore, the contribution African producers make in supplying minerals to world markets remains important for their national economies in delivering foreign exchange earnings. Clean energy technologies become the fastest growing segment of demand for most minerals, and their share of total demand edges up to over 40 per cent for copper and REEs. The tipping point when energy transition is the main demand will be reached in the SDS at 60-70 per cent for nickel and cobalt and almost 90 per cent for lithium by 2040.

FIGURE 6:

Mineral demand from battery technologies in 2040 relative to 2020 under different scenarios and technology evolution trends



Source: (IEA, May 2021)

Figure 6 plots the technical uncertainty for battery chemistries against the two climate scenarios to recognise the possible future impact of technology developments that are currently in early stage or pre-large scale commercial deployment. The technology options include the following: high-nickel batteries have the high energy densities necessary for high performance EVs or commercial vehicles that need long ranges, but nickel is expensive in the required ratio to other battery metals. All-solid-state batteries (ASSBs) replace the flammable liquid lithium electrolyte and polymer separator with a sandwich of lithium metal cathode on a ceramic separator in direct contact with the anode, giving higher energy density, rapid charging, and safety advantages. ASSBs are being trialled by several vehicle manufacturers but are not yet commercially deployed. Silicon anodes used in place of graphite anodes provide higher energy density but will need a solution to the problem that they swell when cycled to be solved before commercial deployment.

Home storage coupled to rooftop solar installations is currently a feasible option, however, the battery is the single most expensive system component, and therefore a material fall in battery costs would drive up demand for more battery storage to make better use of generation and sales by "prosumers" (grid-tied consumers who both purchase and sell power). Vanadium flow batteries are long duration batteries (4 to 12 hours) for use in stationary storage applications for utilities, commercial or industrial users.

In the IEA demand projections, the large variations linked to different technologies lead to a wide range of possible futures. As depicted in Figure 6 above, depending on these scenarios and alternative cases, lithium demand in 2040 may be 13 times higher (if vanadium redox flow batteries rapidly penetrate the market in the STEPS alternative) or 51 times higher (if all-solid-state batteries commercialise faster than expected in the SDS option) than today's levels. Likewise, cobalt and graphite may see 6 to 30 times higher demand than today, depending on the scenario that unfolds. A similar situation applies to REEs (not shown in the figure), where demand may grow by seven times in the SDS, but growth may be as low as three times today's levels should wind companies pivot more towards turbines that do not use permanent magnets for their generators.

2.1. Mineral-based Development

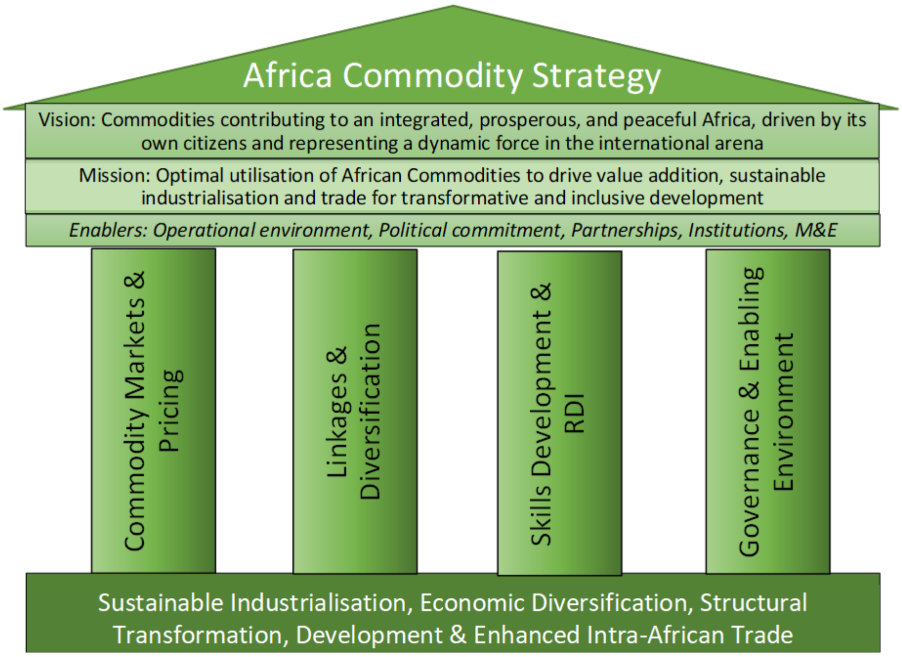
Africa's mineral wealth has historically been viewed as a springboard to modernisation, and often centred on grandiose projects which failed due to a combination of uncompetitive costs, lack of connecting infrastructure or a weak skills base where they were built. Rejecting a historic approach of operating in silos, African Heads of State adopted the African mining vision (AMV) at the 2009 Africa Union Summit and laid the foundation for the way forward.

The AMV seeks to be holistic by advocating development should extend beyond mining into maximising influential mining sectoral linkages. It seeks to facilitate industrialisation by developing sectors downstream of mining, particularly manufacturing, construction, power and agriculture. Through downstream value addition to produce key feedstocks, the AMV seeks to encourage diversification out of mining. It goes beyond a "mining only" development strategy by proposing ways to develop knowledge linkages (skilling and technology development) for beneficial spill overs into the rest of the economy. It calls for "transparent, equitable and optimal exploitation of mineral resources to underpin broad-based sustainable growth and socio-economic development" (AU, 2009, p. 1).

The recent adoption of the African Union Commodity Strategy (AUCS) by the Ministers of Industry and Trade in September 2021 widens the scope beyond mining. The AUCS is built upon a recognition of the importance of Africa's natural resource endowment and envisages how to harness it for comprehensive development. The AUCS resonates with the AU Agenda 2063 in its own vision of "commodities contributing to an integrated, prosperous, and peaceful Africa, driven by its own citizens and representing a dynamic force in the international arena" (AU, 2021). The AUCS is built on four 'pillars', namely: linkages and diversification; skills development and research, development and innovation (RDI); commodity markets and pricing; and governance and enabling environment.

FIGURE 7:

African Union Commodity Strategy Vision, Mission and supporting framework



Source: (AU, 2021)

Both the AMV and AUCS are relevant in the context of resource-based industrialisation; indeed the AGMS builds on them. As the above discussion about the place of minerals in the energy transition makes clear, roles traditional and new are emerging. It is the task of the AGMS to articulate how Africa plays them to its advantage and provide coordinated guidance to countries wrestling with these unfolding issues.

2.2. Defining Green Minerals in an African Context

Africa's Green Mineral Strategy should be steered by the vision for green growth across the continent: "Green growth is a socially inclusive economic growth and development path that is low-carbon, climate-resilient, resource-efficient, and maintains and enhances biodiversity and ecosystems." (AfDB, 2021).

For low-carbon energy generation, distribution and use in low-carbon mobility, Africa needs to build upon the existing clean energy technologies deployed across the continent and scale them up. These principally involve the following:

- Battery storage (utility-scale and residential);
- Concentrating solar power (CSP: parabolic troughs and central tower);
- Bioenergy for power;

- Electric vehicles (battery electric and plug-in hybrid electric vehicles);
- Electricity networks (transmission, distribution, and transformer);
- Geothermal energy;
- Hydrogen (electrolysers and fuel cells);
- Hydropower;
- Solar PV (utility-scale and distributed);
- Wind (onshore and offshore).

Criteria for defining the scope for minerals to include in the AGMS are proposed as follows:

1. Minerals that are used in clean energy technologies and green industries;
2. Minerals that maximise the benefits of Africa's mineral endowment; and,
3. Minerals that are feedstocks for resource-based industrialisation of clean energy industries.

TABLE 1:

Core Minerals for the African Green Mineral Strategy

Mineral	Mineral	Solar PV	Hydrogen and fuel cells	Energy Storage	Electric Vehicles
Aluminium	✓	✓		✓	
Chromium	✓				✓
Cobalt			✓	✓	
Copper	✓	✓		✓	✓
Graphite				✓	✓
Iron - steel	✓	✓		✓	
Lithium			✓	✓	✓
Manganese	✓			✓	
Nickel	✓	✓		✓	✓
Platinum group metals			✓		✓
Rare earth elements	✓		✓		
Vanadium				✓	✓
Zinc	✓	✓			

Source: Authors

Table 1 lists the minerals proposed for focus which form today's core ingredients of clean energy generation from wind, solar PV and hydrogen electrolysers or fuel cells and the application of minerals into key industries including battery energy storage and electric vehicles. Clean energy use makes up only a small part of the ubiquitous use of aluminium from bauxite and steel from iron. These are included on this list nevertheless because they are core to multiple industrial applications. The minerals listed in Table 1 are frequently required in alloys, including metals with specially-desired properties. Steel itself is a key metal across a range of technologies, indeed it is a fundamental requirement for industrialisation. Steel is critical to building the backward component of the green minerals value chains (the African mining supply chains) which also need to migrate away from fossil fuels, particularly in trackless mining systems.

The minerals proposed are required for wind turbines and towers and generators using permanent magnets that require rare earth elements, particularly neodymium, dysprosium, praseodymium, and terbium that are also used in permanent magnet electric motors for electric vehicles. They are also used for solar PV panels, frames and conducting stringers. Platinum and palladium catalysts for proton exchange electrolysers for hydrogen production as well as hydrogen fuel cells are covered by their inclusion. Lithium-ion batteries manufactured using cobalt, lithium, graphite, copper, aluminium, nickel, and manganese are also covered, as well as their use in electric vehicles.

The AGMS needs to maintain the flexibility to adjust the minerals included in the core list according to future changes in technology, mineral discoveries on the continent or the advent of new industries such as the fabrication of semiconductor material for solar PV panels. Two additional principles should therefore be added to the criteria for defining the scope for minerals to include:

1. monitoring a watchlist of minerals used in local low-carbon energy generation and green energy technologies; and,
2. regular reviews of the core minerals for strategic focus to take into account technology developments that alter the importance of particular minerals for green technologies.

TABLE 2:

Watch List Minerals for the African Green Mineral Strategy

Mineral	Main green technology uses
Arsenic	PV semi-conductor
Boron	EVs
Cadmium	PV semi-conductor
Gallium	PV semi-conductor
Germanium	PV semi-conductor
Indium	PV semi-conductor and coating anodes for electrochemical processes and as a chemical catalyst
Lead	Lead acid batteries and PVs
Magnesium	Steel alloys
Molybdenum	Steel alloys for geothermal plants
Niobium	Steel alloys
Selenium	PV semi-conductor
Silicon	PV semi-conductor
Silver	PV semi-conductor
Tantalum	Steel alloys
Tellurium	PV semi-conductor
Tin	Protective coating
Titanium	Lithium-ion batteries
Tungsten	Wear resistant steel alloys
Zirconium	Hydrogen electrolysers alkali process

Source: Authors

Critical minerals lists have been drawn up by several countries to guide their national policy on the minerals required for low-carbon energy generation and important green industry technologies. While the United States has for many years maintained strategic stockpiles of critical minerals, defined as non-fuel minerals or mineral materials essential to the economic or national security of the US and which has a supply chain vulnerable to disruption, there has been a recent flurry of countries following suit. In February 2022 the United States Geological Survey (USGS) released a new list of 50 critical mineral commodities (USGS, 2022). India recently published a research paper assessing the criticality of 23 select minerals for India's manufacturing sector (Chadha & Sivamani, 2021). In March 2022 the Australian Department of Industry, Science, Energy and Resources published a critical minerals strategy (Commonwealth of Australia, 2022). In July 2022 the United Kingdom published a policy paper entitled "Resilience for the Future: the U.K.'s Critical Minerals Strategy" (GOV.UK, 2022). Where reference is made to these broader lists of crucial minerals defined as nationally strategic, the term "critical minerals" will be used.

There are obvious parallels between the proposed core list of minerals for the AGMS and critical minerals lists, however, the latter are strongly influenced by an industrial-military paradigm which seeks a security of supply by countries that are in some cases not themselves major producers of these minerals. We would argue that such an approach is unsuited to Africa's needs, but nevertheless raises an important issue of the very real competition for resources and opportunities, as well as the risks posed by the rising demand for green minerals.

2.3. The Role of Minerals in Africa's Energy Transition

Mining and mineral processing performs many roles in national and regional economies across the continent, responsible for a significant share of exports and foreign exchange, a large share of revenues, a smaller share of growth and extremely small share of employment, due to the low employment elasticities of the sector. This is a situation that the Africa Mining Vision seeks to change. Where progress has been made to implement the AMV and apply local content programmes to facilitate the development of upstream and downstream linkages, there is clear evidence of the pivotal role it plays in resource-based industrialisation. For Africa's energy transition, there are four specific roles to highlight that, while interconnected, are roughly sequenced from the present to the longer term as follows:

1. The role of minerals in the recovery from the COVID–19 pandemic and its accompanying economic shocks;
2. The role of minerals in the imperative to energise Africa using renewable energy sources;
3. The role of minerals in African industrialisation and to enable the building out of green mineral value chains, including mining supply chains; and
4. The role of minerals in supporting the economic restructuring of economies that are highly dependent on exports of fossil fuels (coal, oil and gas).

The COVID-19 pandemic exacerbated existing vulnerabilities across the continent, just as Africa was starting to recover from the 2008/9 financial crisis (the US toxic debt crisis) and set back progress on achieving both Agenda 2063 and the global sustainable development goals (SDGs). In response, national governments and efforts at the regional and continental level have been directed at developing recovery plans. At the apex level, the African Union developed the Green Recovery Action Plan 2021 – 2027 to steer a recovery that is clean, resilient and inclusive (AU, 2021). Supporting renewable energy, energy efficiency and national just transition programmes is one of the five priority areas in the Plan. Promoting investments in renewable energy, it is argued, is crucial to creating employment in the green energy sector and extending access to affordable electricity to the millions of people currently without access. Scaling up renewable energy requires increased quantities of the minerals identified above for wind, solar PV, concentrated solar power, geothermal, hydroelectric and the new energy industries growing up to produce green hydrogen and green ammonia.

Attention is needed to promote energy efficiency and access, for unless transmission and distribution networks are built, power cannot be evacuated from the most suitable sites for renewable energy generation to reach load centres in cities, industries, or mines. For example, the best solar potential is located in Africa’s driest areas with low population densities, whilst the highest demand is often in areas with low renewable energy potential. Many African countries are faced with major challenges to fund investments in both generation and transmission assets. This is such an important point that the plan argues that “the ‘just transmission’ programme should focus on ensuring that African countries invest in transmission grids” (AU, 2021, p. 14) and facilitate regional energy integration through regional power pools. The minerals needed to build transmission and distribution networks are galvanised steel (zinc-coated), aluminium, copper, and grain-oriented steel (electrical steel) for transformers.

Almost 600 million Africans are currently without access to electricity and clean energy services (AfDB, 2022, pp. 40-41), so the second imperative is to harness minerals to energise Africa. Energy is the main enabler of economic development and an essential component of the SDGs and Agenda 2063. Thus, guaranteeing energy access should be the priority of African countries with the transition from fossil fuels to cleaner forms of energy a complementary priority.

Essentially, the energy transition for Africa is taking a unique form, depending on the energy mix in each country and region, because new low-carbon sources of supply need to be simultaneously matched with evolving centres of demand. In a highly simplified generalisation, new efficient and economically sustainable power systems, together with costly infrastructure investments, are required to support the substantial penetration of variable renewable energy resources in the electricity mix. Without industrial demand to anchor investments, the inadequacy of the transmission and distribution network will prevent the energy supply from reaching users, which is one of the main causes of the low levels of energy access on the continent. To close this gap, the AfDB's New Deal on Energy for Africa supports regional projects and utility companies to extend their national and regional grids (AfDB, 2016).

Off-grid generation assets can provide basic energy services for low-income consumers far from the grid to close the access gap. Declining costs for variable renewable energy generation coupled with battery storage, are shifting off-grid projects from being only suitable for providing basic energy access to communities to being a cost-effective solution for industrial demand and remote mines, which can drive the economic development the region needs. However, all of these options require green minerals for the manufacture of power sources.

Thirdly, the AGMS needs to provide strategic guidance on how to harness the continent's green minerals to fuel resource-based industrialisation. The African Mining Vision provides guidance on how to optimise the extractive sector's contribution to facilitating holistic development by deepening the linkages between mining, manufacturing, services, and the knowledge economy (AU, 2009). It is in its potential to stimulate manufacturing that the transformative role of green minerals comes to the fore. Manufacturing creates large employment multipliers through the economy and fosters diversification, therefore it is essential that a Green Minerals Strategy makes value addition, through building forward and backward linkages into manufacturing, a central objective.

Africa's comparative advantage in the quality of its renewable energy resources (wind, solar, hydro, geothermal and bio energy) needs to drive the industrialisation of renewable energy equipment value chains. This can be achieved by developing explicit policies to acquire technology and successively increase local content requirements for large projects to build the capacity and demand for equipment manufacturing industries. Furthermore, the AGMS needs to set a course for establishing high-technology green industries built around plans to establish battery storage manufacturing and electric vehicle assembly plants (and supply chains) as anchors (AfDB, May 2022).

Finally, there is an important role for minerals in supporting the economic restructuring of economies that are highly dependent on the exports of fossil fuels (coal, oil and gas). Such restructuring will be complex and require many aspects of economic diversification to make the transition from high fossil fuel export dependency. For this transition to be just, significant climate financing will be required by the African countries impacted. Many new instruments have been introduced across Africa, such as green and blue bonds, climate-for-debt swaps, and the Liquidity and Sustainability Facility (LSF) launched by the United Nations Economic Commission for Africa (UNECA). These provide a domestically-owned base to complement funds from development partners, although actual transfers fall far short of pledged commitments.

Having built competencies in fossil fuel energy-based industries it is important that such countries begin to pivot to low-carbon energy based industries and test opportunities emerging from the production of green energy carriers, most notably green hydrogen and green ammonia. Expertise in oil and gas producing countries must not be lost in the transition but transferred into new energy industries. At the continental level, it is important to observe that Africa's resource richness in the new paradigms of green industries should increase its wealth, not reduce it as fossil fuel exports are phased out. Fossil fuels currently comprise over 40 per cent of Africa's exports (AU, 2021) making this a major risk to be managed carefully.

Projections for Africa made by the IEA indicate that revenues from copper and battery metals at the current market share will reach parity with fossil fuel earnings by 2050, or if the continent's market share were raised from the current 13 per cent to 20 per cent of the global market, revenue could more than quadruple by 2050 (IEA, 2022).

Africa's exceptional renewable energy resources lies behind a boom in green hydrogen projects. Work is underway on a USD 40 billion project in Mauritania being developed by CWP Global (Energy Capital & Power, 2022). The Namibian Government has set ambitious targets to become a leading green hydrogen exporter (Energy Monitor, 2022). Many governments are also reviewing their energy plans to assess the role of hydrogen.

Summing up, with the right policies the role of minerals in Africa's energy transition will enable the creation of new green industries manufacturing equipment for renewable energy assets as well as for the green mining and processing of these minerals (building mining supply chains). These will require large amounts of key metals to extend electricity transmission and distribution networks and draw significant amounts of green minerals into the manufacturing of batteries and their application in electric vehicles. Furthermore, the energy transition will create demand for electrical appliances and related manufacturing through the development of downstream linkages from the minerals industry.

2.4. Key Role in Addressing Climate Change and Biodiversity Loss

Africa's historical cumulative net anthropogenic CO2 emissions (1850 to 2019) is only 7 per cent (2 per cent from fossil fuel and industry and 5 per cent from land use and land use change) of the global total (IPPC, 2022, pp. SPM-11). Africa has made among the lowest contribution to GHG emissions, yet its key development sectors have already experienced widespread loss and damage attributable to anthropogenic climate change, including biodiversity loss, water shortages, reduced food production, loss of lives and reduced economic growth, without any compensation from the industrialised nations who have been most responsible for climate change. The severity of current and future risks posed by climate change calls for focused global effort with material technical and financial transfers to developing countries, particularly by the principal industrialised nations who have been most responsible for climate change.

Green minerals have two important roles in addressing climate change. First, it has a role in climate resilient development and second, in addressing the climate impacts of mining itself. In both cases this is a journey that governments, industry, and social sectors have already embarked on, and such actions are not occurring in isolation.

At the apex level the African Union's Climate Change and Resilient Development Strategy and Action Plan (2022–2032) sets out intervention areas and accompanying action plans for harmonised and coordinated measures to respond to the impacts of climate change and develop firm plans for the continent's low-emission future. Logically, these support the existing national climate commitments, efforts, and aspirations of member states in their nationally determined contributions. Attention is given to the key priorities: enhancing climate-resilient and low-emission energy and infrastructural systems; exploiting the continent's renewable energy potential; articulating strategies for inclusive low emission and resource efficient industrialisation tapping its rich natural resources; as well as prospects for developing African value chains and integrating into global value chains (AU, 2022). It is somewhat surprising therefore, that the climate change strategy does not explicitly refer to the role that green minerals can play in resilient development. The AGMS will play an important role in filling this gap and aligning efforts on climate change, nature-positive and resilient development. Climate change's toll on African livelihoods is already high, causing losses of up to 15 per cent of its GDP per capita (AfDB, 2022).

Attention also needs to be given to the issue that supplying clean technologies required for a carbon-constrained future could create a new suite of challenges for the sustainable development of minerals and resources. A green technology future is materially intensive and, if not properly managed, could negate the efforts and policies of mineral-supplying countries to meet their objectives of meeting climate and related SDGs. Mining also carries potentially significant impacts for local ecosystems, water systems, and communities (World Bank, 2017). The global mining industry is estimated to be responsible for 4 to 7 per cent of all GHG emissions[1]. Between 30 to 50 per cent of the production of copper, gold, iron ore, and zinc is concentrated in areas where water stress is already high (Henderson & Maksimainen, 2020). The mining industry is accordingly under pressure from governments, investors, and society to reduce emissions. However, the industries supplying greener mining and processing technologies and systems also need to be located in Africa rather than importing goods manufactured elsewhere. Africa's pivotal role in the global green transition must not increase emissions and environmental degradation on the continent – new energy sources for mining and industry must harness Africa's potential for renewable energy, and investments in the continent by external partners must enable this.

Responding to pressures to reduce the climate impacts of mining and mineral processing, mining companies are actively pursuing decarbonisation strategies. Notable examples are Anglo Platinum in South Africa which is starting to trial its green hydrogen fuel cell and battery-powered heavy haul truck. Anglo American plans to migrate its global fleet of 300 diesel-powered heavy haul trucks to hydrogen power by 2030. Kamoa Copper in the DRC has signed a second memorandum of understanding for a public-private partnership with the DRC's state-owned power company La Société Nationale d'Electricité (SNEL) to expand existing electricity supply from hydropower plants. Once hydropower plants are upgraded, SNEL will supply a combined 240 MW to the Kamoa Copper mining complex and associated planned smelter allowing sustainable electricity for future expansions (Mining Review Africa, 2021). These examples illustrate the steps mines are taking, including locking in renewable power purchase agreements to reduce the Scope 1 and 2 emissions and ensuring that suppliers and inputs purchased have calculated carbon footprints that are both carefully monitored and reduced over time. Similarly, for Scope 3 emissions generated using mineral products, mines are monitoring, reporting and setting reduction targets.

2.5. Challenges, Emerging Issues, Opportunities of the Global Green Minerals Landscape

Among the challenges and emerging issues influencing the global green minerals landscape, important themes that are pertinent to the AGMS concern the following: the concentration of mineral processing into precursors in the end user markets; the backward integration of metals users to secure access to supplies of raw materials; the range in projections for green mineral demand; the uncertainty over the investment pipeline to bring metals to markets; and the price volatility of key minerals, which increases the complexity and risk of project development. Each of these themes will be discussed in turn.

Battery minerals are not refined and fed into battery manufacturing plants in the countries where they are mined, with the notable exception of China. Australia, the world's largest producer of

[1] Scope 1 and Scope 2 CO2 emissions from the sector (those incurred through mining operations and power consumption, respectively) amount to 1 per cent, and fugitive methane emissions from coal mining are estimated at 3 to 6 per cent (depending on the time horizon at which the warming impact of methane is calculated: lower number 100-year time frame, higher number 20-year time frame) based on research by McKinsey's Basic Materials Institute.

lithium carbonate has recently seen the establishment of a lithium refinery, but so far achieved only limited battery manufacturing. China has developed a formidable metals refining capacity in critical minerals. The country refines all of the lithium and cobalt currently going into battery production. The US and Europe are implementing programmes to domesticate battery manufacturing, owing to the dominant position that Asian producers have in these industrial sectors that are now regarded as strategically important. The European Battery Alliance, cofounded by the European Union, has set up a business investment platform to drive investment and analyse the strategic position of national interests across the entire battery value chain (European Battery Alliance, 2022). In June 2021 the US Department of Energy announced new immediate policy actions to scale up a domestic manufacturing supply chain for advanced battery materials and technologies, as well as developing strategies to increase the local mining and processing of key green minerals. The Biden administration released a blueprint for lithium-ion battery production over the period 2020-2030, backed by a USD 9 billion investment (US Department of Energy, 2021).

Cost and technical factors have driven electric vehicle automakers to favour co-locating battery manufacture for EVs close to assembly plants. Vehicle battery packs are heavy and therefore costly to transport. Lithium-ion cells contain a flammable electrolyte and pose safety risks when transported outside battery packs that are fitted with cooling and safety devices. These are among the main reasons why major battery factories currently being constructed in Europe and the US are generally co-located with assembly plants. BMW has stated its intention to co-locate automobile assembly with lithium-ion battery manufacturing where it is feasible, to control logistics costs and gain visibility over battery production. As the EV ecosystem scales up in Europe, the localisation of battery production is also preferred to provide visibility and security of supply (Harrison, 2021). Meanwhile, the development of lithium-ion battery manufacturing in Africa will help to address the concerns of many that dependence on one or two suppliers increases the exposure to geopolitical risk, with the region providing a highly viable alternative.

Access to supplies of green minerals for use in the country in which they are mined is not assured due to commercial relations between producers and their customers. In short, geographical proximity alone is insufficient. Two related issues are existing offtake agreements between producers and processors, for example CMOC in the DRC mining copper and cobalt to supply refineries in China, or offtake agreements with metals traders such Glencore and Trafigura who manage global connectivity between miners, smelters, and refined metal fabricators. Despite more than 70 per cent of cobalt coming from mines in the DRC, most of the metal is refined in China. Second, backward integration between end users and mines which are essential to secure access to critical feedstocks.

Mining is a global industry where companies tend to invest in projects that fit well into their minerals portfolios and expertise. In the lithium and cobalt mining sector there has been considerable activity by mining companies to acquire new projects and therefore more control over output. Ganfeng Lithium Co. of China, one of the world's biggest lithium producers, announced in June 2021 it would pay USD 130 million for a stake in the Goulamina hard-rock mine in Mali and take at least half of its first-phase output of spodumene concentrate (Reuters, 2021).

In addition, battery manufactures, and EV makers have invested in mining projects to secure access to metal supplies. Development of the Kisanfu copper and cobalt deposit close to the Tenke Fungurume mine in the DRC includes investment from a battery manufacturer alongside the mine owner, CMOC. This development is to be funded by a strategic partnership with battery manufacturer Contemporary Amperex Technology Limited. This is an example of battery manufacturers vertically integrating to secure their critical material supplies. Tesla in their periodic 'battery day' briefings has referred to their desire to secure their own supplies of lithium from clay deposits in Nevada or in Mexico. Tesla has signed an offtake agreement for graphite active anode material production refined in the US by Syrah Resources from high grade graphite mined at their Balama graphite mine in Mozambique (Syrah Resources, 2021). Tesla communicated that the motivation for this agreement is to reduce dependence on China for graphite.

Projections for the minerals required to achieve the energy transition and slow global warming have been generated by several institutions, among them the World Bank (World Bank, 2017), (World Bank, 2020) and the European Union, (Huisman, et al., 2020) (IEA, May 2021). The quantities of minerals required to reach climate targets are substantially greater than the current production and consumption by green sectors. Whether these projections will be matched by actual demand, however, is uncertain. This is a very significant issue requiring considerable focus on what needs to be done to manage an effective transition by governments, industry and society, taking into account that the current business trajectories are a modified form of 'business as usual' within which the world will not achieve the Paris Agreement goals. The largest source of demand variability comes from uncertainty around the stringency of climate policies. The problem that mineral suppliers face is whether or not the world is really heading for a scenario consistent with the Paris Agreement with effective incentives and disincentives to ensure compliance. As has been observed (IEA, May 2021), current revenue from coal production is ten times larger than those from energy transition minerals. However, there could be a rapid reversal of fortunes in a climate-driven scenario, as the combined revenues from energy transition minerals overtake those from coal well before 2040, although this timeline could be later because of the war in eastern Europe and the EU's desire to reduce its reliance on gas imports from Russia.

The IEA has argued that current supply and investment plans are geared to a world of more gradual change, with insufficient action on climate change modelled as their more conservative stated policies scenario (STEPS) trajectory. These plans are not ready or inclined to support more accelerated energy transitions. While there are a host of projects at varying stages of development, there are also many vulnerabilities that may increase the possibility of market tightness and greater price volatility (IEA, May 2021).

Major mining companies have estimated that to limit global warming to 2°C will require almost USD 2 trillion in capital investment to be channelled into expanding mining and processing over next 15 years (S&P Global, 2022). However, lengthy permitting and development schedules, as well as delays caused by opposition to mining projects are interrelated factors, posing a challenge to the timely production of the minerals for green technologies. Recently, the head of Anglo American raised doubts about whether the projected demand could be met by supply, owning to the limited pipeline of actual mining projects (Mining News, 2022).

Major mining operations are looking to expand their copper production. However, it is getting increasingly difficult to expand production around the world. On average it takes 16 years from discovery to first production (IEA, May 2021, p. 12) with many projects in jurisdictions which have rights to review projects by affected parties, taking far longer. Opposition to getting new mines built is considered one of the biggest future challenges by mining executives, with major projects stuck in limbo from the US to Peru. In January 2022 the Serbian Government revoked Rio Tinto's licence to develop a lithium mine in which the company was planning to invest USD 2.4 billion.

FIGURE 8:

Prices for Cobalt (LHS) and Lithium Carbonate (RHS) 2018 - August 2022 (USD/t)

Source: (Trading Economics, 2022)

Lithium carbonate prices in China remain near the record high of USD500,000 from March and 430% higher year-on-year amid high demand and restrained supply (see Figure 8). Recent tight supply has been buoyed by cash subsidies from Chinese local governments including Beijing, Shanghai, and Wuhan, for customers replacing petrol cars with new EV purchases to revamp activity in the sector after demand for durable goods plummeted during the strict pandemic lockdowns. Cobalt prices have softened over the second quarter of 2022 but their recovery since mid-2019 (Figure 8) has triggered expansion projects including the Mopani Copper Mine in Zambia which has been shuttered for over a decade.

CHAPTER 3

SWOT Analysis of Africa's Minerals Landscape

An analysis of the strengths, weaknesses, opportunities and threats to minerals development was conducted to inventory the range of issues with which the AGMS should engage. The topics listed are not ranked. Broader issues influencing the operations of the minerals industry that go wider than green minerals alone need to be considered in formulating the AGMS. These are briefly discussed below.

Africa's extensive mineral resource endowment is the natural starting point for a minerals strategy, yet when the policy objectives of the African Mining Vision are compared to the extent of resource-based industrialisation actually achieved, it is clear that the way the AGMS is crafted needs to emphasise the uses to which minerals are put as the key consideration which matters for development. At 5500 exajoules per year, Africa is by far the world's richest region for renewable energy potential, with 44.8 per cent of the total technical potential of renewable energy (AfDB, 2022, p. 80). Tapping that energy for mineral development, green supply chains, powering industrialisation and energy exports are strengths the AGMS needs to capitalise upon.

Africa's mostly lower-middle income and upper-middle-income economies mean that the consumer side of a mineral strategy needs to work with affordability constraints when it comes to e-mobility options. Infrastructure gaps increase the cost of production and hold back trade, amongst other problems. Good stewardship of mineral rents, their contribution to the fiscus and the predictability of stability that mines lay down should be used to fund economic infrastructure to serve both the mine and the adjacent regions wherever possible. Among the weaknesses observed are the few African-based exploration and mining companies and the linked issue of a dependence on imported technology. Overcoming these weaknesses requires upgrading science, technology, engineering and innovation systems among member states. The several schools of mines on the continent should be encouraged to expand teaching and research in earth sciences and engineering. Through a focus on technologies evolving in the clean energy and e-mobility fields, the AGMS can contribute to that goal. Establishing new industries such as lithium-ion battery production or encouraging consumers to switch to electric vehicles in developed country markets has been achieved with various forms of state assistance such as consumer subsidies and industry grants. Africa's Green Minerals Strategy will need to make an impact by stimulating the development of value chains with limited, if any, state funding. For this reason, strategies should be adroit at pooling resources or combining efforts at a regional level for greater impact. Africa justly deserves substantial financial transfers from the developed countries that have generated the bulk of GHG emissions to make its energy transition. Financing investment to fund value chains that deliver GHG emission reduction impacts will need to be raised from domestic sources, the African diaspora and multilateral development finance institutions.

TABLE 3:

SWOT Analysis of Africa's Minerals Landscape

STRENGTHS	WEAKNESSES
• Significant resources of green minerals. • Large continental market. • AMV and regional economic community (REC) policies for integrated development of mineral value chains (mining linkages). • Massive potential renewable resources. • Tertiary institutions teaching mining, metallurgy, and earth sciences	• Low GDP per capita limiting domestic markets. • Few strong national geoscience bodies. • Limited mineral beneficiation. • Infrastructure gaps, especially in transport and power. • Limited industrial demand for green mineral feedstocks. • Limited African-based exploration and mining companies. • Dependent on imported technology due to limited R&D capability. • Fiscal weakness limits public funding of industrial policy instruments, human resources development (HRD) and RDI.
OPPORTUNITIES	**THREATS**
• Framework for resource-based industrialisation adopted by AU (AMV). • REC and continental Free Trade Areas (FTAs) to overcome limited domestic markets. • Continental aspirations for closer economic integration. • Geopolitical advantage for Africa as an alternative source of green mineral supply. • Lack of systematic geological survey (mapping), therefore potential to increase mineral resources. • Science, Technology and Innovation institutions. • Decarbonising mining by tapping renewable resources and producing renewable machinery. • Licence access to minerals conditional on local processing. • DRC-Zambia cooperation agreement on lithium-ion batteries. • Battery and EV production in Morocco. • Green industries building batteries, manufacturing electric two- & three-wheelers, converting ICE to EVs.	• Geopolitical interests of Asian and Western producers to secure unprocessed raw materials. • Substitution of cobalt to weaken producer power and sourcing concerns. • Pervasive imports of used vehicles undermine potential African EV industry. • National ambivalence to substantive economic integration, particularly to Common External Tariffs (CETs) and the elimination of all non-tariff barriers. • Competition from current incumbents targeting African markets. • Delay in finalising rules of origin for motor vehicles.

Source: Authors

The focus on minerals because of the metal requirements of energy transition technologies is an opportunity to reaffirm the principles of mineral stewardship. Within the scope of this AGMS Approach Paper batteries and electric vehicles have received attention as new value chains which are important to develop. Steel is such an essential input into all sectors of the economy that it has been included in the scope of the strategy as a driver of resource-based industrialisation. New factors influencing the competitiveness of mineral supply chains that place a premium on lowering GHG emissions in their production will play to Africa's strengths in renewable energy. Inter-sectoral linkages needed to build value chains will not occur spontaneously, they will need purposeful industrial strategy with incentives and conditions to drive miners to increase the amount of processing at mine source.

Risks accompanying the expanding demand for minerals used in the energy transition could thwart the objectives of the AGMS if they are not effectively mitigated. Supply relationships where minerals are exported as ores or concentrates from Africa have to be redefined to support more mutually beneficial development. Market expansion into regional FTAs and at a continental level through the AfCFTA is essential to overcome the limitations of small domestic markets, however, formal trade openness will have little practical effect without parallel market development measures to protect markets through common external tariffs and to eliminate non-tariff barriers (NTBs).

The erosion of multilateralism in international politics that is undermining collective action by the international community on the existential threats from climate change will make implementing the AGMS more challenging.

CHAPTER 4

SWOT Analysis of Africa's Minerals Landscape

Chapter 4 sets out the proposed skeleton of the AGMS, starting with a vision statement and linked objectives and then unpacking four themes that will provide the body of the strategy: advancing mineral value chain development; developing people and technological capacity; building key renewable energy value chains and mineral stewardship. It is envisaged that the final AGMS will further expand these themes.

4.1. Vision and Objectives

Reemphasising the objective of the AGMS Approach Paper, the vision for the strategy should articulate the following:

- Position Africa well to capture and exploit the opportunities in the emerging new green technology sectors;
- Channel mineral feedstocks for industrial development and strengthen intra-industry linkages;
- Guide the development of investment, expansion, upgrading and value capture along green minerals value chains into final products and supporting knowledge-based services;
- Articulate the role that green minerals can play to advance Africa's industrial, energy, trade, climate and social development goals in fulfilment of Agenda 2063 and strategic plans of regional economic communities.

Vision statement:

An Africa that harnesses green mineral value chains for industrialisation, creating green technologies and sustainable development to enhance the quality of life of its people.

4.2. Thematic Areas

4.2.1. Advancing Mineral Development

Over a decade has passed since the adoption of the African Mining Vision by Heads of State at the February 2009 AU summit. The AMV represents a foundational statement for the optimal exploitation of mineral resources to underpin broad-based sustainable growth and socio-economic development, which is directly relevant to the AGMS. However, it is equally clear that follow-through in applying the strategies it advances has been so far sorely lacking. Two factors stand out: first, limited regional market integration to reach the minimum scale for investment in the manufacture of equipment and consumables. Secondly, disjointed local content and state procurement policies are effectively limiting demand to individual member states rather than the RECs. Both these issues require resolution.

4.2.1.1. Increasing Geological Knowledge About Green Minerals

Public institutions conducting scientific surveys of geological provinces provide valuable public goods for government functions responsible for planning, risk management and the identification of economic minerals resources. National geological surveys in many countries across the continent are poorly resourced and have low capacity, and are therefore often unable to perform these seminal functions.

It is important to make the case for increasing geological knowledge of green minerals to governments, citing the high return on investment that well-functioning geoscience institutions return to their countries over the longer term. Three avenues for advancing geosciences and building geological survey institutional capacity should be pursued in parallel:

1. Budgets should be part-funded from mineral rents (by royalties and taxes);
2. Collaboration between geoscience institutions and joint research should be encouraged and resourced, perhaps coordinated by the REC body. These should include specialist HRD programmes funded from technical development programmes with development partners;
3. More focus should be given to multi-country geological surveys to assess mineral resources under the guidance of the Organisation of African Geological Surveys (OAGS) or REC strategies to create updated mapping using low cost techniques such as the use of satellite imagery and the use of drones for geophysical mapping.

It is essential that member states capitalise on the global focus on critical minerals to resource and upgrade their geoscience survey capabilities. This will underpin targeted minerals exploration and put them in a stronger position to set terms for their exploitation. Ideally, information about the mineral investment targets identified by state geological survey entities should be developed to enable the compilation of a “project prospectus” to facilitate the competitive auction of the mineral property. This could require clarity about important factors including: a) specifying the state’s share of mineral rents; b) making commitments about mineral value chain development (local content and beneficiation; c) requiring an annual spend on science technology engineering and mathematics (STEM) skilling and RDI; and d) the provision of public infrastructure such as logistics, power and water.

Rapidly evolving technologies, collectively referred to as the fourth industrial revolution (4IR), that integrate digital technologies into all aspects of exploration, mining, and processing, alter the interface between humans and machines (Mutanga, et al., 2021). 4IR technologies are improving exploration techniques through, including big data analytics, and machine learning. Importantly for mining efficiency, which allows lower grades to be mined profitably and safely, 4IR seems to offer the greatest benefits in core operations (PWC, 2021).

4.2.1.2. Role for Pre-feasibility Studies to Facilitate Investment

Conducting a pre-feasibility study is a valuable way to facilitate investment and direct development in a purposeful way to implement high level strategies and plans. Pre-feasibility studies have the following advantages:

1. They signal governmental commitment to develop specific sectors and economic activities;
2. They provide baseline information on the viability of investments to support new economic activities and value chains;
3. They provide information to enable the costs and benefits of committing public resources for new economic development to be evaluated if the activity will be undertaken by state-owned enterprises;
4. They identify project dependencies and factors that should be addressed prior to promoting a project, such as in the field of regulation or infrastructure,
5. They increase the government’s understanding of the economics of projects which reduces the information asymmetry which usually favours private sector parties. This enables governments to reach more favourable terms in contracting with the private sector.

The benefits of conducting pre-feasibility studies are so compelling that they should be recommended as a good practice routine prior to committing any investment resources in a project in the AGMS guidelines to develop green minerals.

It is instructive to reflect on the reasons why pre-feasibility studies are not conducted or poorly conducted. Prominent reasons include defining an emerging sector as of such strategic importance that countries fear a delay created by undertaking a PFS will result in a missed opportunity. Reasons for failed or poorly executed pre-feasibility studies include:

1. They are expensive, so the scope may be narrowed to such an extent that results are compromised;
2. The commissioning party may develop a poor specification because they lack the knowledge or expertise to scope the work sufficiently to obtain useful results; and
3. A reluctance to accept negative pre-feasibility results which may require a subsequent redesign of the project.

In the green minerals sphere, overlooking the need for careful planning and preparation is imprudent and must be avoided. The determination to obtain sources of green minerals by importing countries needs to be leveraged to advance geoscientific knowledge and technical assistance with pre-feasibility studies, accompanied by support for institutional capacity-building, and these requirements should be included in multi-lateral development programmes.

4.2.1.3. Infrastructure and Services for an Enabling Environment

Power, transport and water infrastructure is essential for mineral extraction, processing and the movement of intermediate forms of processed minerals (concentrates) to the subsequent production stages. Low levels of infrastructure stock and poor maintenance of infrastructure assets is a serious impediment to the expansion of African firms. As products become more elaborately transformed, non-tariff barriers (NTBs) increase in importance as a trade friction which effectively chokes intra-African trade. High trade costs are due to a mix of poor infrastructure and non-tariff barriers (OECD, 2017), which translate into transport costs that are more expensive by at least USD 13/ton than in economies of comparable incomes (Vilakazi, 2018). NTBs are discussed further in section 4.2.3.2.

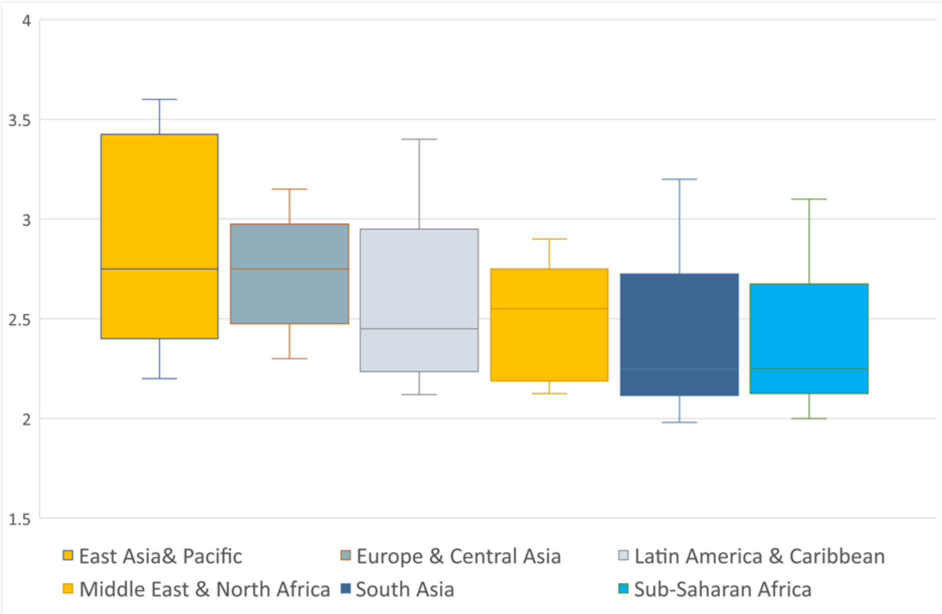
Inter- and intra-regional freight movement is captured in the Logistics Performance Index (LPI) which is a comprehensive measure of the efficiency of international supply chains. Figure 9 shows the Logistics Performance Index for world regions and illustrates that sub-Saharan Africa has the lowest median LPI and the Middle East and North Africa the third lowest score.

Improving transport and communication connections across the continent is understood to be an imperative to secure the potential benefits of increased African trade. Upgrading communications and logistics links lies on the critical path of all regional development strategies and the AGMS should add its voice to stress the importance of implementing these plans for the mineral strategy to succeed.

The wide disparity in electricity access for African households which have a mean coverage rate of 58 per cent tends to overshadow the impact of poor power quality on the productive sector. Unreliable electricity is a major cause of the low productivity of African firms and a binding constraint on their expansion with negative spill overs in reducing capital accumulation and employment. Some 80 per cent of businesses in Africa (except in North Africa) experience outages, compared with 66 per cent in South Asia and 38 per cent in Europe. Power outage durations tend to be far longer in Africa than in Asia and Europe, with large variations between countries (AfDB, 2022).

FIGURE 9:

Logistics Performance Index for World Regions



Source: Data from Sustainable Mobility for All. 2019, based on (World Bank LPI, 2018)

2019 estimates by the African Development Bank suggest that the continent's infrastructure needs amount to USD 130–170 billion a year, with a financing gap in the range of USD 68–$108 billion (AfDB, 2019). These figures are dwarfed by the financing requirements for Africa to implement its climate action commitments and NDCs which are estimated between USD1.3 trillion and USD 1.6 trillion, averaging USD 1.4 trillion (AfDB, 2022).

The green minerals sector requires reliable and affordable infrastructure services and predicable, consistent fiscal and regulatory environments, supported by governments that impartially and efficiently promote business while protecting public interests. These are desirable traits which business in general seeks to attain, however, where the mining industry is distinct is where mines in remote locations are compelled to provide their own utility services and frequently other functions that also have a positive impact on affected communities. Current thinking on mining governance frameworks refers to this objective as a 'sustainable development licence to operate' (Pedro, et al., 2017).

As minerals undergo further downstream processing, and if the ambitions to build full value chains for green minerals in Africa are to materialise, the range of intermediate inputs and services required becomes increasingly diverse. Firms may be able to meet some of their power needs through installing renewable energy plants, however, as these plants will require automated production equipment, they will need to be assured of reliable utility supplies. Locations that cannot provide such assurances will be too risky as sites for investment. A Green Minerals Development Strategy to foster development along entire value chains is dependent on an operating environment that matches the needs of highly technical production processes. By extension it will need to encourage reforms to the electricity supply industry to sustainably energise the manufacturing sector and help the development of the digital economy.

Infrastructure and services which are directly relevant to an enabling environment for green minerals also conform with carbon disclosure and monitoring measures. This is especially the case for internationally-traded minerals and products which require access to clean energy supplies as well as carbon tracking and auditing services to be able to certify supply chains and products.

For African firms engaged in international trade, the medium- and long-term carbon monitoring of supply chains is becoming increasingly important. As international companies are committing to Scope 3 net zero targets, African firms need to ensure low-carbon emissions along their value chains. This implies that trading with African businesses in a country with high fossil fuel shares in their energy mix becomes more expensive and less attractive. Several regions and countries, including the European Union, Japan, and Canada, are planning carbon border adjustment mechanisms intended to prevent carbon leakage and support their increased ambitions on climate mitigation (AfDB, 2022, p. 85).

4.2.1.4. Improving Mineral Resource Management in Line with the African Mining Vision

By focusing on the opportunities and risks facing the minerals industry as it adjusts to conditions for the energy transition and production in a carbon-constrained context, the AGMS will play an important role in bringing existing mineral resource management frameworks in line with these new realities. This contribution should complement and augment existing frameworks and highlight the opportunities for building value chains in Africa that respond proactively to climate change and take advantage of the continent’s non-renewable and renewable energy resource endowments.

Foundational policy for mineral development is set out in the African Mining Vision. The AMV seeks to be holistic by advocating development beyond mining into maximising all of the seminal mining linkages to facilitate industrialisation and the development of other sectors particularly manufacturing, construction, power, agriculture. This will be not only through downstream value addition to produce key feedstocks, but also through developing the upstream mining supply chains and knowledge linkages (skilling and technology development). The AMV calls for “transparent, equitable and optimal exploitation of mineral resources to underpin broad-based sustainable growth and socio-economic development” (AU, 2009, p. 1) through the realisation of mineral linkages (down-, up- and side-stream).

A consistent theme in the suite of policy documents that link Africa's commodity dependency with attempts to foster diversification is the focus on building backward and forward linkages found in the 2013 UNECA Economic Report on Africa titled "Making the most of Africa's commodities: industrialising for growth, jobs and economic transformation", which emphasises developing mineral linkages for resource-based industrialisation (RBI) or commodity-based industrialisation (CBI). "On top of offering short- to medium-term comparative advantages, commodity-based industrialisation can, with the right industrial policies, serve as a launching pad for long-term diversification and competitiveness in new and non-commodity sectors" (UNECA, 2013, p. 9). These themes are reiterated in the African Union Commodity Strategy adopted in 2021 with a mission to support "optimal utilisation of African Commodities to drive value addition, sustainable industrialisation and trade for transformative and inclusive development" (AU, 2021).

Finally, state-owned mining companies are a means for directly structuring investment, allowing exploitation of particular minerals, increasing sales of minerals and procurement of inputs. Lessons from the history of state mining companies provide guidance on managing the political - administrative interface for commercial sustainability.

The AGMS stresses building value chains which better reflect the global nature of manufacturing in which a far higher proportion of trade is in intermediate inputs than in final goods. Moreover, a focus on value chains has the advantage of guiding firms to find entry points where they can insert themselves competitively.

4.2.2. Developing People and Technology Capabilities

4.2.2.1. Skills Required for Mining, Processing and Manufacturing

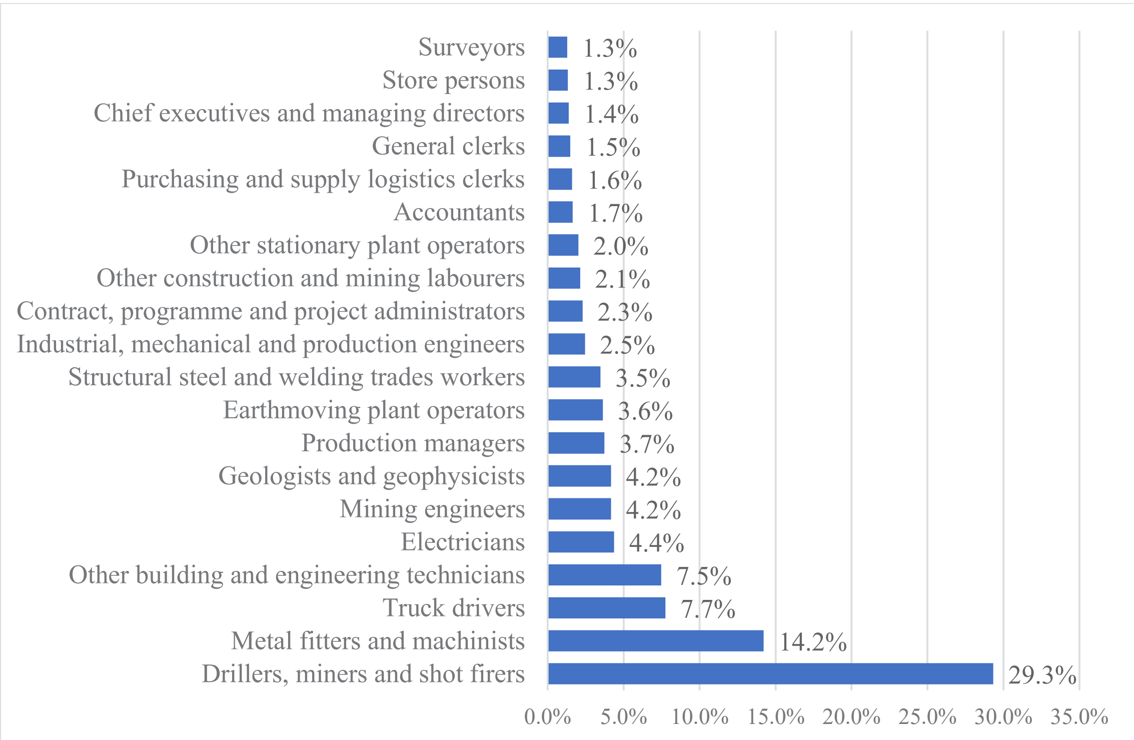
Strategies for developing skills for mining, processing and manufacturing need to work with number of moving parts. There are differences in needs between opencast and underground mining operations as well as hard or soft rock mining; the fit between training and education performed by education authorities and institutions of higher learning and occupational requirements is important; the role played by in-service training; how shortages of skills are handled, including recruitment into employment and exit on retirement; developing policies requiring employment opportunities for local communities; the list goes on. For the purpose of the AGMS, the focus should be on a minimum mining annual spend on STEM skilling (proposed as about 5 per cent of payroll) and on government policymakers to articulate their key requirements on skills relevant to establishing new value chains.

For the main occupations in the mining sector today, shown in Figure 10, there is a broad consensus that technological advances will increase automation and reduce mining employment for physical jobs in highly structured and predictable roles, reducing overall mining employment and increasing the ratio of employees required with mechatronic skill sets. Employment of truck drivers, drillers, miners and shot firers will see the most reduction. Less certain is how automation trends will apply in developing countries where science, technology, engineering and mathematics skills are already in short supply. Policymakers and training institutions should work closely with the mining industry to stay up-to-date with changes. They will need to align training provision with industry needs at the same time as anticipating the need for more STEM skills and providing more resources for their creation.

However, studies in South Africa and elsewhere have indicated that the mechanisation of mining could approach job neutrality (Ashworth, MacNulty, & Adelzadeh, 2002) only if the machinery, equipment, systems and services are locally manufactured and not imported. This would be difficult to achieve in any single African state due to limited demand, but could be attainable at a regional (REC) level, or better still, at a continental level (AfCFTA with a common external tarrif on mining inputs). Put simply, the idea is not to replace machines with people, but to gradually replace imported machinery with locally-produced machinery through knowledge transfer (as against knowledge imports), technology transfer (as against technology imports) and innovations. The localisation in Africa of green minerals mining and processing needs to go hand-in-hand with STEM skilling and should comprise a key element of an AGMS.

FIGURE 10:

Main employing occupations in the mining sector

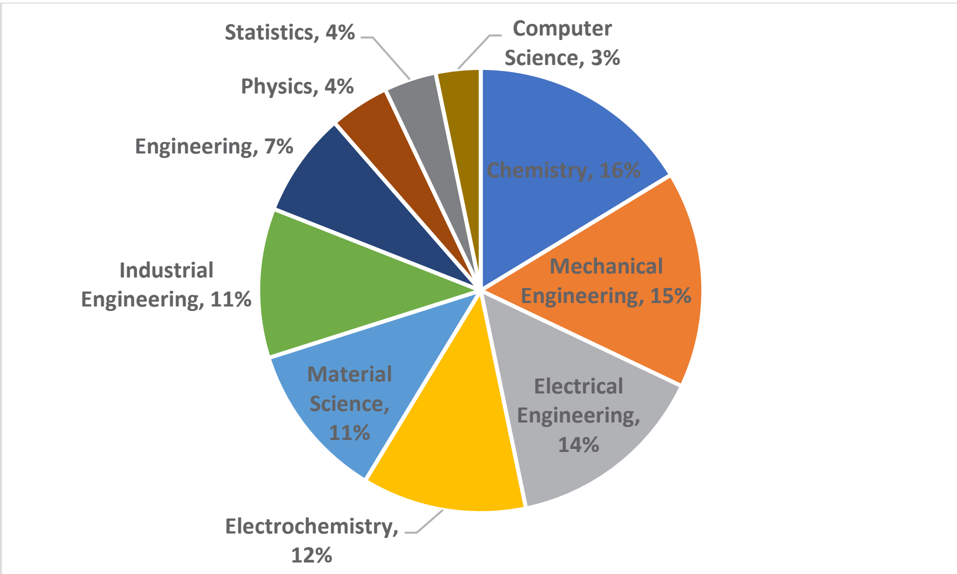


Source: (Ramdoo, 2018)

As Europe has geared up to create a battery manufacturing and electric vehicle sector, the Alliance for Battery Technology Training and Skills (ALBATTS) funded by the EU has analysed what a large-scale battery manufacturing plant consists of in terms of departments and teams to determine who works there, and what kind of skills, competencies, and education are required. This is relevant as the research was undertaken precisely because a pool of battery/EV skills did not exist and therefore had to be created (Albatts, 2021). The most desired academic competencies for battery production and maintenance are chemistry, mechanical engineering, and electrical engineering ranked according to need, as seen in Figure 11.

FIGURE 11:

Battery Production and Maintenance – Academic Competences



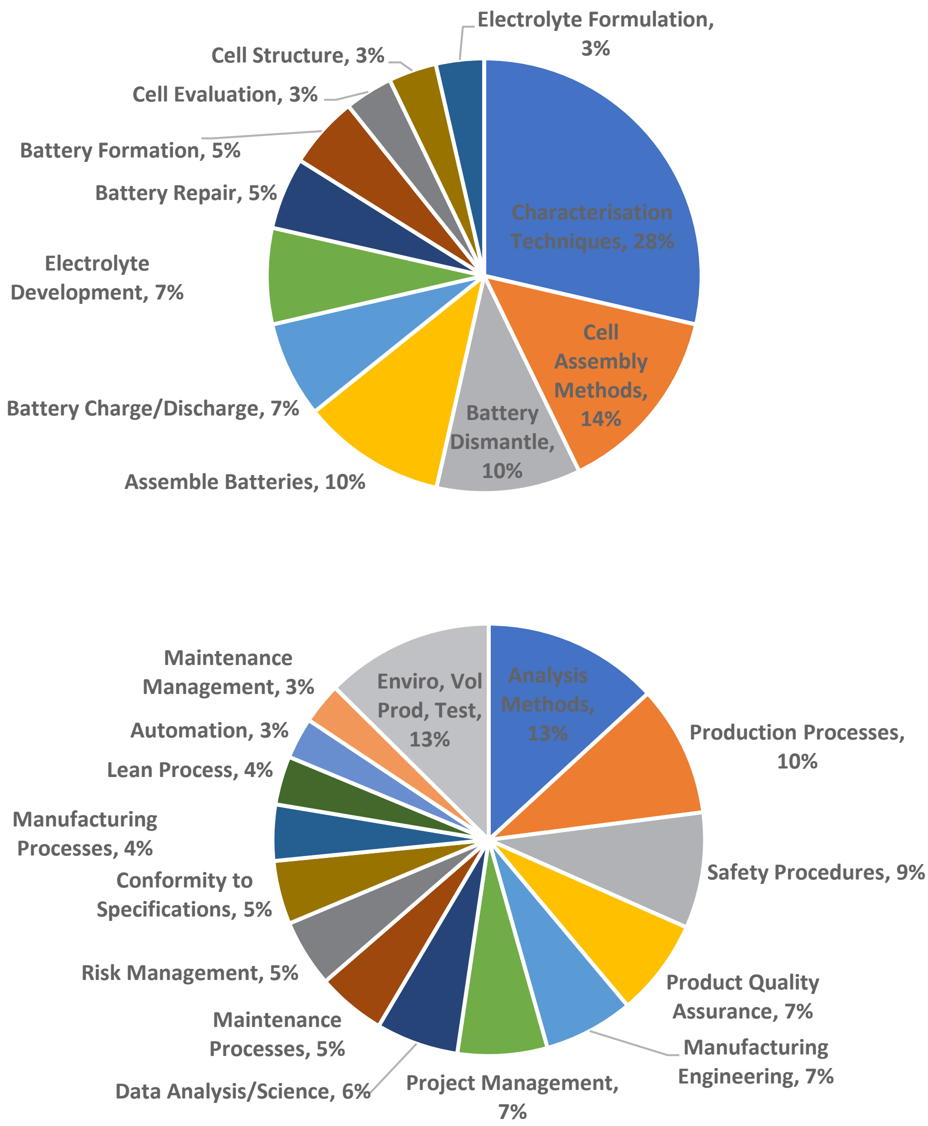
Source: data from (Albatts, 2021)

The ALBATTS research shows that a wide range of categories including soft, academic, general transversal, cross-sectoral specific and sector-specific competencies are required. In some instances, these do not exist in the labour force where a battery industry has not yet been set up and would need to be created by the investors, a relevant point for the AGMS to consider.

Battery production and maintenance departments make up the largest number of employees in a battery factory. Figure 12 compares the sector-specific skills with the cross-sector specific knowledge required by workers in that department.

FIGURE 12:

Battery Production and Maintenance: Sector-Specific skills (upper) versus Cross-Sector Specific Knowledge (lower)



Source: data from (Albatts, 2021)

Other important job functions include material handlers or planners and various purchasing roles and technicians for managing inventory, logistics, product testing/quality sampling and process improvement.

Turning briefly to the skills required for electric vehicle assembly, these fall into three main occupational groups, namely:

1. engineering professionals, in various fields: electrical, mechanical, sensor, mechatronics, optoelectronic, industrial, automation;

2. information and communications technology (ICT) professionals: such as user interface developers, industrial mobile devices software developers and various types of ICT-related profiles which include application developer, system developer and network engineer;
3. technicians and associate professionals such as robotics engineering technicians, industrial robot controllers and motor vehicle engine testers.

An analysis of skills for the Turkish automotive industry, anticipating the shift towards electric vehicles, finds that the introduction of new technologies will not diminish the need for those professions on which the sector has been historically dependent, such as electric and mechanical engineers. New skills requirements driven by the introduction of new technologies, include user interface developers, sensor engineers, and industrial mobile devices software developers. The latter profile is related to the growing importance of connected cars on the product side, and the internet of things on the process side (European Training Foundation, 2021).

4.2.2.2. Institutions for Technology Acquisition, Development and Applications

The AGMS also needs to foster the spread of research and development efforts at universities to expand the production of intellectual property rights over innovations in producing Africa's green minerals. Efforts in this regard could work towards a vision for a pan-African green mineral innovation ecosystem involving industry, academia and government collaboration.

In the meantime, the Centre Africain d'Exellence pour les Betteries en R.D. Congo (CAEB) at the University of Lubumbashi provides a template to guide such important work.

In November 2021, the DRC Government in collaboration with its partners (AfDB, ALSF, UNECA, AFC, AFREXIMBANK, BADEA and UN COMPACT) organized the DRC Africa Business Forum on fostering the development of a battery, electric vehicle, and renewable energy industry value chain and market in Africa. Among the discussions, developing skills for battery development in DRC was identified for action.

Launched on 22 April 2022 CAEB includes cooperation with the University of Zambia and the Copper Belt University. The mandate of the centre is to create the skills and competencies needed by the battery industry as well as to support the emergence of a competitive battery, electric car and renewable energy value chain in Africa. CAEB is working with industry to identify skills and research needs and designing Masters and PhD programmes to both research and generate advanced human capital in these fields.

4.2.3. Building Key Value Chains

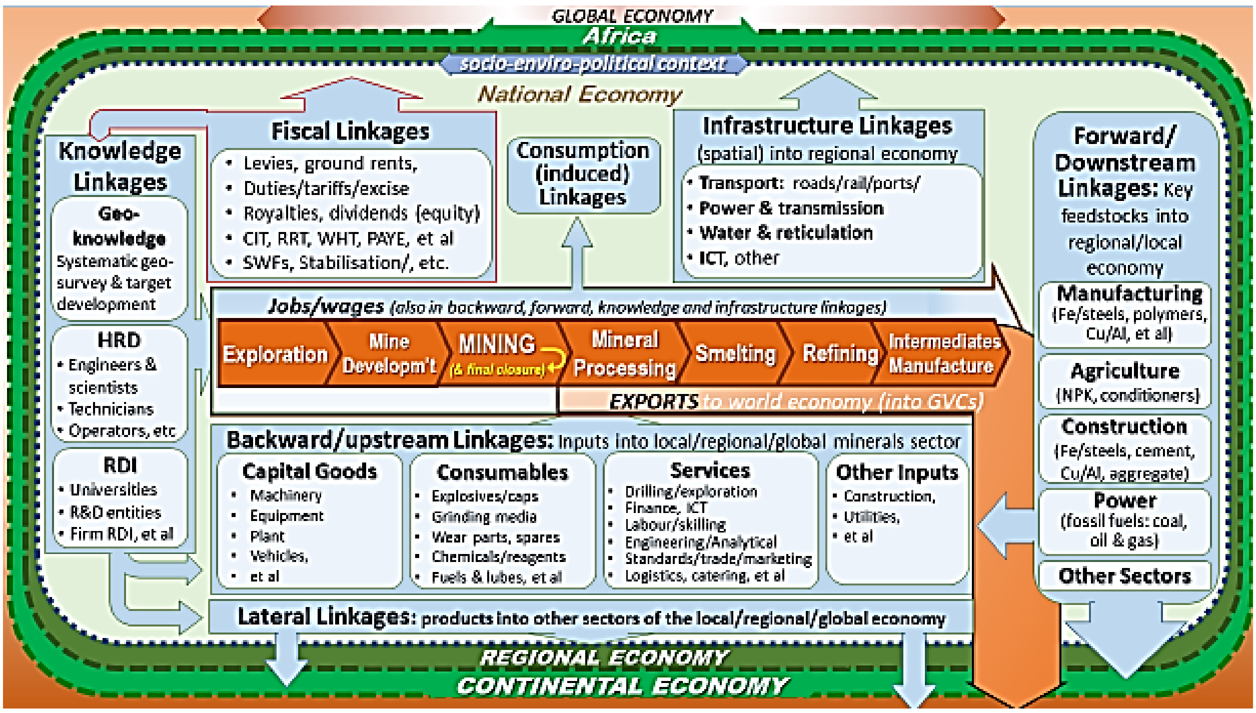
4.2.3.1. Resource-based Industrialisation Through Creating Linkages

Using intersectoral linkages to achieve economic diversification downstream of the primary resources sector has been a central part of development theory underpinning commodity-based industrialisation and resource-based industrialisation strategies set out in the AMV and AU Commodity Strategy. The role of the AMGS regarding resource-based industrialisation (RBI) is to extend this argument and to highlight factors with particular applicability to developing green mineral value chains.

First, a brief recapitulation. There are four main classes of linkages. Backward/upstream linkages identify the inputs required, such as capital equipment, services, utilities, and consumables for each distinct mineral extraction stage starting with exploration through mining and processing to a saleable product (Figure 13, below). Forward/downstream linkages refer to the inputs required to transform minerals into end products including feedstocks and other intermediate products, together with capital equipment and services. Side-stream or knowledge linkages refer to the skills and technical know-how required by each class of linkage, which is frequently referred to as human capital development owing to the dynamic relationship that technical know-how necessarily has with each production stage and making improvements to that stage possible (Figure 13).

FIGURE 13:

Schematic Mineral Linkages for Resource Based Industrialisation



Source: Authors. Note: GVC: Global Value Chains

Finally, lateral linkages refer to the application of technology, human capital and entrepreneurship that originated with resource-based activity into the production of non-resource-based goods and services (Figure 13). All of the interactions take place within a national economy with its discrete socio-political and environmental context, the regional (REC) economy, the continental economy and the global economy. Most of Africa's minerals are integrated into global value chains as lower value crude ores, concentrates or untransformed metals, for value-addition and job creation abroad (Figure 13).

Resource-based industrialisation is a strategy that seeks to use resource rents from fixed factor endowments that provide comparative advantages to national economies by converting non-renewable natural resources into physical, financial, and human capital.

This paper is not the place to conduct a review of actual experiences of RBI across the continent, but it is nevertheless important for the AGMS to recognise the gap between the stated ambitions of the strategy and the actual extent of linkage development in place. Given the ambition to materially advance undeniably technically complex development plans that call for a large range of factors of production to be available, the following points should be considered to craft RBI strategies that can best succeed in different contexts. It is proposed that fruitful approaches should shift from 'best practice' formulae that overemphasise a single dimension, for example good governance, towards finding and sustaining forward development momentum. Strategies need to be adapted to suit local and regional conditions and operate a range of scales where, as has been argued (Levy, 2014), some narrowly focused initiatives can achieve results even against a backdrop of broader institutional dysfunction. Value chains are not static and need to be animated by constant learning and improvement.

4.2.3.2. Accessing Wider Regional and Continental Markets through RECs and the AfCFTA

Eight regional economic communities are recognised by the Africa Union: the Arab Maghreb Union (UMA), the Common Market for Eastern and Southern Africa (COMESA), the Community of Sahel–Saharan States, the East African Community (EAC), Economic Community of Central African States, the Economic Community of West African States, the Intergovernmental Authority on Development, and the Southern African Development Community (SADC).

Regional economic communities that have formed FTAs are the most effective legal instrument through which regional integration is implemented. The critical role played by RECs to reach the goals of the AfCFTA is explicit in Article 5 of the AfCFTA founding agreement that states that the AfCFTA is governed by specific principles such as "driven by Member States of the African Union; RECs' Free Trade Areas (FTAs) as building blocks for the AfCFTA."

The high number of small national economy countries in Africa prevent firms being able to reach economies of scale and make regional markets essential. Regional economic integration is equally essential to increase that demand to viable scales and for competition to discipline market participants. While RECs are formally committed to regional economic integration, in practice more than 60 per cent of all intra-African trade in goods takes place among the member states of one REC – the SADC. Greater trade facilitation and political backing of cross-border trade is necessary for the AfCFTA to take off. Inadequate transit, road, rail and maritime infrastructure are important impediments to trade but so too are non-tariff barriers which hike the cost of Africa's trade by an estimated 283 per cent (UNECA, 2017, p. 87). Empirical evidence suggests that NTBs in some instances can add as much as 15 per cent to the price of goods, effectively reducing their consumption (UNCTAD, 2016). Fortunately, progress is being made to clear such obstacles. Trade dispute resolution mechanisms developed by the Tripartite Free Trade Area made up of EAC, COMESA and SADC have proved effective and are being used as the model for the AfCFTA Non-Tariff Barriers Annex (TRALAC, 2018).

More complex products involve greater cross-border flows of raw materials and intermediate inputs going into their manufacture. Trade facilitation measures are thus crucial for firms to become integrated into production networks and markets at a regional and global level (OECD, 2013).

Regional approaches to trade facilitation make the greatest impact on reducing of the cost of doing business, facilitating intra-regional investment and building of regional value chains (ITC, 2017). Supporting development finance institutions such as the AfDB, the Arab Bank for Economic Development in Africa (BADEA) and Afreximbank are expanding their financing activities to enable private and state-owned enterprises to take advantage of the AfCFTA.

A critical requirement of the AGMS to meaningfully engage in regional and continental trade are simplified rules of origin (RoO) so firms can participate in regional value chains at scale. Well-designed RoO would widen the range of intermediate goods sourced from within Africa and pave the way for more firms in Africa to participate as suppliers in regional and global value chains and for countries to engage in manufacturing, technological upgrading, and economic and export diversification (UNCTAD, 2019).

In January 2022 AfCFTA State Parties adopted rules that could cover 87.7 per cent of goods on the tariff lines of member states. This paves the way for member states to gazette these legal instruments at the national level so that countries can apply these rules of origin for continental trade. Further negotiations on sensitive goods, including products in the automotive sector, have yet to be finalised.

The AGMS should include in its scope of activities advocacy for trading rules that advantage the development of regional and continental value chains.

Increased trade will drive up demand for transport equipment. Full implementation of the AfCFTA with associated investments into transport infrastructure will create a boom for rail, shipping, air and road freight transport infrastructure and services. Projections for the stock of transport equipment required by 2030 is material. For road freight, which carries the 70 per cent of goods cargo on the continent, the size of the truck fleet should increase by 179 per cent for bulk cargo and 180 per cent for container units compared with the fleet in 2019 (ECA, 2022, p. 113). 1.42 million new heavy vehicles would need to be added to the existing stock of 794 000.

An opportunity of this size should be pursued to anchor strategies for decarbonising heavy vehicles, starting with routes where it is viable to build charging infrastructure for electric trucks or hydrogen supplies for fuel cell vehicles.

4.2.3.3. The Case for a Battery Value Chain

Foundations for building a full battery value chain have already been laid in existing work supported by the AfDB.

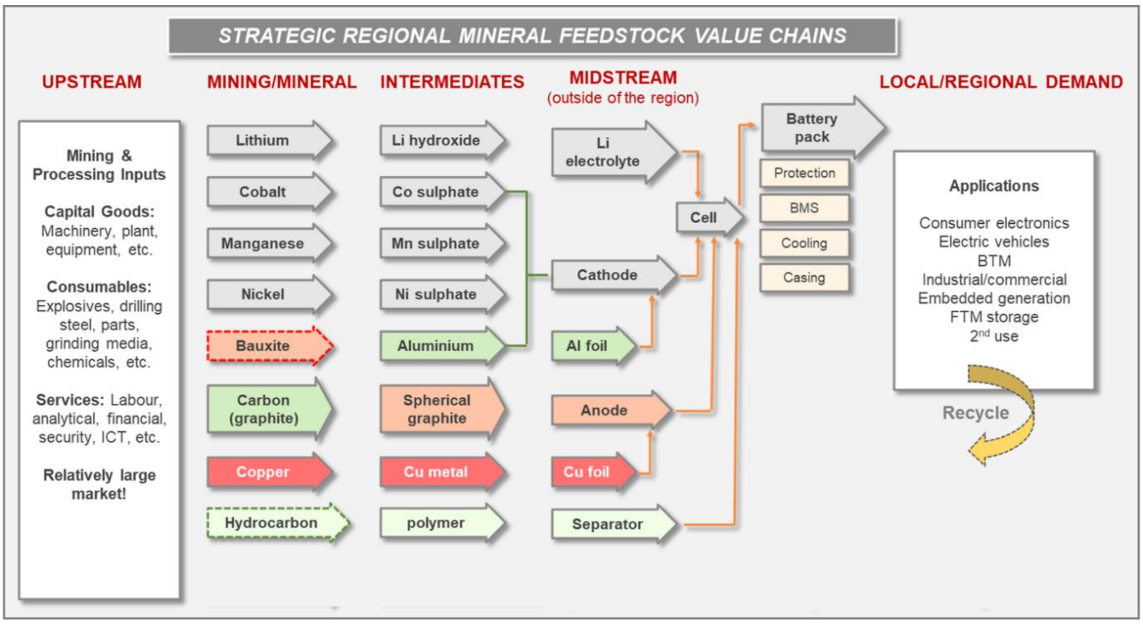
In 2021 the African Natural Resources Management and Investment Centre of the AfDB published the results of their investigation on harnessing the Lithium - Cobalt Value-chain for Mineral Based Industrialisation in Africa (ANRC, 2021). The authors observed that all the lithium-ion battery materials are mined in Africa, which placed the continent on the first rung of the value chain. The low level of beneficiation applied to battery materials, however, realises only 10 per cent of the total end-to-end value of the supply chain, resulting in Africa losing out on opportunities to fully benefit from its mineral resources. The report recommended steps to turn this around through investment in lithium and cobalt processing, strengthening inter sectoral linkages and raising the profile of Africa's resource advantages in these minerals.

In November 2021, the results of a study to determine the cost of producing lithium-ion battery precursors in the Democratic Republic of Congo including benchmarks against the US, China and Poland were published (BloombergNEF, 2021). The report concluded that building a 10,000 metric-ton precursor facility in the DRC for Lithium-Nickel-Manganese-Cobalt-Oxcide (NMC) cathodes could cost USD 39 million. This is three times less than what it would cost for a similar plant in the US. A similar project in China and Poland would cost USD 112 million and USD 65 million, respectively. Two critical caveats to this competitiveness finding must be noted. The capital cost in the DRC was cheaper than all three countries mainly due to the lower cost of land and construction, compared to China and Poland. Second, the report concluded competitiveness is dependent on the secure supply of cobalt on a long-term contract, because acquiring cobalt on a spot price basis would make the plant uncompetitive. DRC's hydropower-based electricity provides additional advantages of lower energy costs and reducing the carbon footprint of the precursor material. Macroeconomic projections made by the DRC Ministry of Finance of a larger scale plant with an annual production of 100 000 tons of NMC622 anode active material, estimated to cost USD 301 million to build at full production would gross USD 3.2 billion – a major step to towards transforming the DRC economy and improving its fiscal stability (Min Finance, 2021).

The current state of the battery value chain more broadly is depicted in Figure 14, which highlights that battery minerals are distributed amongst several member states, and consequently only a regional strategy to aggregate feedstocks would be viable. The midstream stages that involve cell production, mainly in Asia, is the missing part that needs to be filled. This remains the most challenging part of the value chain to complete, due to the massive gigawatt scale at which battery factories on the cutting-edge of technology are being constructed in North America, Europe and Asia. Existing markets for applications in Africa include: electric vehicles (mainly two and three wheelers and vehicle conversions currently); batteries for electricity storage at sites behind the meter that still draw power from the grid; industrial and commercial applications particularly for telecommunications equipment; batteries attached to embedded generation typically off-grid solar installations; and battery storage forming part of generation assets at utility scale, referred to as front of meter storage and second usage batteries, when electric vehicle batteries reach the stage when they can only hold 80 per cent of their rated capacity and are redeployed to stationary storage applications that are less demanding. Some examples of companies active in these markets are referred to in section 1.

FIGURE 14:

Minerals feedstocks into the batteries value chain



Source: data from (Albatts, 2021)

In this battery material precursor study, the DRC demonstrates the potential to close the missing midstream stages. In May 2022 DRC and Zambia signed a bilateral agreement establishing the Republic of Zambia and DRC Battery Council for the purposes of establishing electric vehicle battery manufacturing. The project will be implemented in two special economic zone sites which is a unique cross border configuration. The DRC Government has identified a 200 ha site in Katanga province 2.5 km from the Zambian border with a second site close by in Zambia's Copperbelt Province.

4.2.3.3.1. Potential Partnerships

In view of the EU's stance on minimising and monitoring the carbon footprint and environmental, social and governance (ESG) aspects of batteries brought into Europe (see section ↱ 4.2.4.1), in principle battery manufactures in Europe could be potential partners for African producers able to take advantage of abundant renewable energy resources. In this respect potential partners may be found among the following: Britishvolt, AMTE Power, Northvolt, VARTA, Leclanché, Verkor, ACC, Freyr, Morrow, InoBat, Italvolt and FAAM.

Assistance from the African Legal Support Facility (ALSF) should be obtained to ensure technology transfer and other contracts are beneficial to African countries. Where intellectual property is involved the African Regional Intellectual Property Organization could assist.

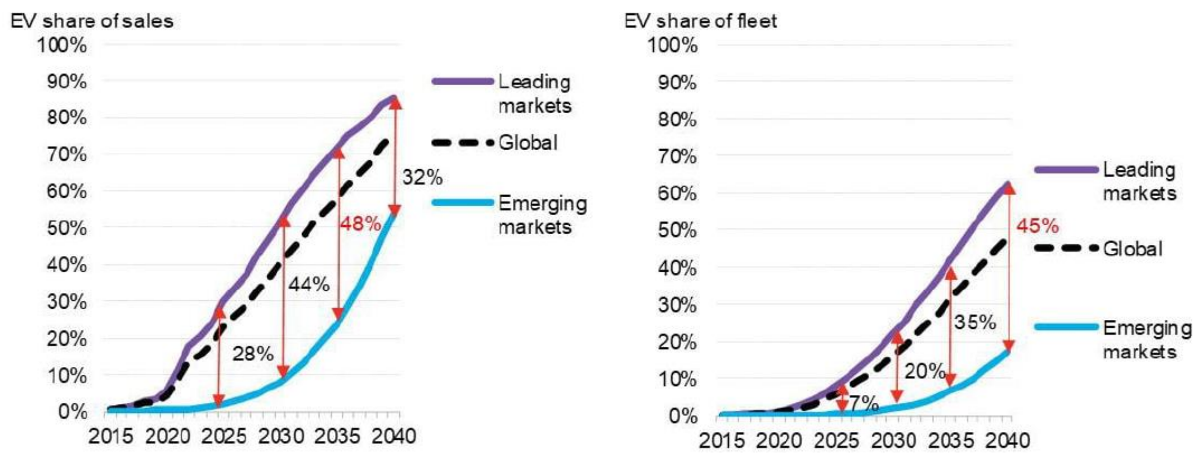
4.2.3.4. The Case for an Electric Vehicle Assembly Industry

Research work on rare earth elements by the AfDB has set out their role in mineral-based industrialisation in Africa. The current state of REE mineral beneficiation is limited to the production of concentrates that are currently exported to be refined. To turn this around several recommendations are made to upgrade REE processing and, with the help of the state, to incentivise large-scale companies to develop the full value chain of REE to produce final products (ANRC, 2021).

The 2022 global outlook for electric vehicles reports that "there are now almost 20 million passenger EVs on the road, 1.3 million commercial EVs, including buses, delivery vans and trucks, and over 280 million electric mopeds, scooters, motorcycles and three-wheelers" (BloombergNEF, 2022, p. 3). Pertinent data from this global outlook with implications for Africa follows. China and Europe account for almost 80 per cent and the US 15 per cent of EV sales in 2025 which will reach total of 77 million passenger vehicles representing 6 per cent of the global fleet. Internal combustion engine (ICE) sales peaked in 2017 and are now in permanent decline. Over half of ICE sales will be in emerging economies by 2035, increasing to 60 per cent by 2040, despite these countries representing a much smaller share of total vehicle sales, meaning means half of ICE cars on the road in 2040 will be located in these countries. EVs take longer to spread in India, Southeast Asia and the rest of the world, including markets like Mexico, Brazil and Russia where policy support is limited or non-existent. These trends suggest a two-tiered global auto market is emerging and that the benefits of electrification are set to accrue very unevenly. Air quality in urban areas is already markedly different between wealthy and emerging economies and this gap will widen further if the EV adoption gap is not addressed. Grid reliability will be a challenge in some countries. Electric bus sales continue to rise steadily, with 44 per cent of new sales and 18 per cent of the global fleet already electric. 98 per cent of the global e-bus fleet is still in China, but activity is picking up in other countries. Buses and two- and three-wheeled vehicles will achieve the highest EV adoption rates by 2040, followed by passenger cars, then light commercial vehicles. By 2040, there are over 700 million passenger EVs on the road and over 750 million electric two- and three-wheelers. The gap between leading and emerging markets is significant. By 2040 EVs are forecast to reach 55 per cent of new vehicle sales but will only represent 20 per cent of the fleet in emerging markets, see Figure 15.

FIGURE 15:

Passenger EV share of sales Left Hand Side (LHS) and share of fleet Right Hand Side (RHS)



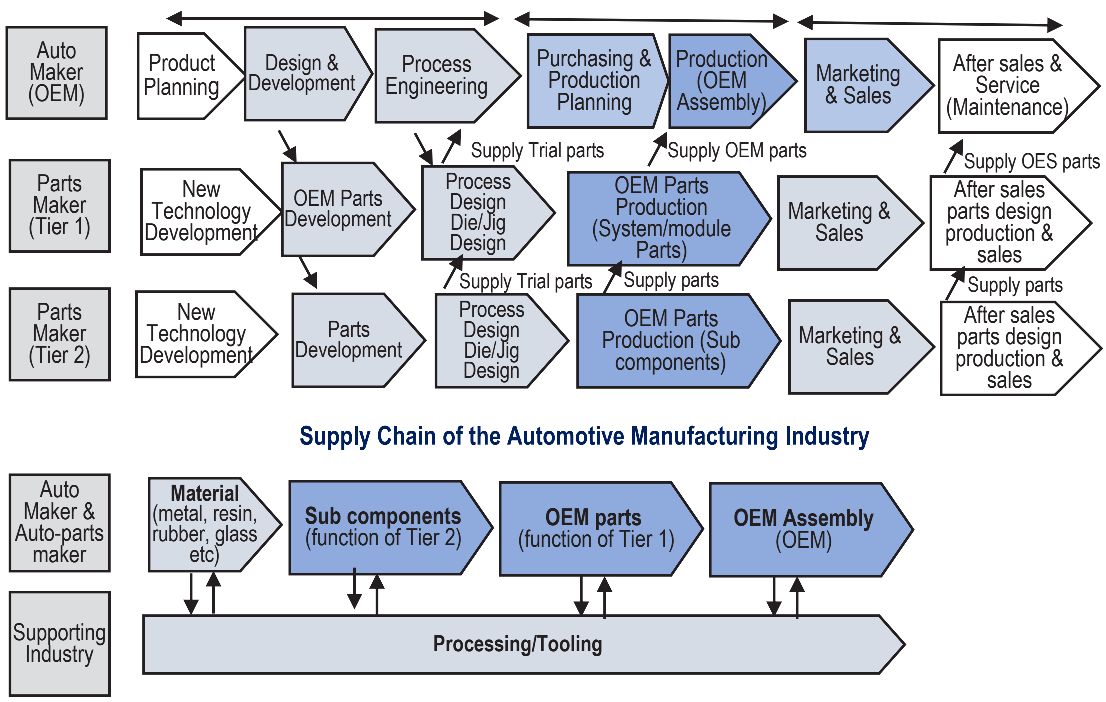
Source: data from (Albatts, 2021)

EV market development in Africa faces several challenges. On the positive side, the market for vehicles in sub-Saharan Africa (SSA), although small, is growing very rapidly. It is currently met by imports, especially of used vehicles. SSA is expected to become a significant global market over the next decade (Black & Makundi, 2017). Yet the key growth constraints to be overcome are weak manufacturing capabilities and the costs of trade diversion, which are particularly high given the large presence of low-priced, imported second-hand cars in most markets (Markowitz, 2019). Used vehicle imports are prohibited in Egypt, Morocco and South Africa, while Côte d'Ivoire, Kenya and Ghana ban imports older than 5, 8 and 10 years respectively. Even in those markets, the current lack of scale prevents many first-tier component suppliers from establishing themselves, however South Africa has some domestically owned first-tier suppliers. With the exception of these three countries, most member states remain extremely reliant on second-hand imports and export very little. Most operations for new vehicles are small-scale and involve minor semi-knocked down assembly, with minimal to no local content (Barnes, Black, Markowitz, & Monaco, 2021).

State-supported industrial policy has historically played a major role in the development of automobile assembly industries owing to the significant effects that the multiple linkages involved have on the manufacturing sector of a national economy, see Figure 16. Considerable work will be needed on market development, especially the importation of used vehicles, before the existing auto assembly hubs centred in North Africa, West Africa and Southern Africa can grow through intra-African trade. Noting that the transition to EVs takes place more rapidly in wealthier countries, as discussed above, automakers in such countries will be incentivised to exit the legacy ICE capacity and are likely to push sales of such vehicles into developing markets, which presents an additional risk to the African auto industry.

FIGURE 16:

Passenger EV share of sales Left Hand Side (LHS) and share of fleet Right Hand Side (RHS)



Source: (JICA; Nomura Research Institute; IMG Inc., 2019)

The high purchase price of electric vehicles and need for simultaneous investments in their charging infrastructure are significant barriers to EV growth in developing country markets (Mali, et al., 2022). Multi-country studies report electric two- and three-wheelers are acceptable to consumers as they are more affordable. In highly congested cities their low speed (less than 45 km per hour) and short range are not limiting factors. Recharging two- and three-wheelers uses domestic electrical supplies and requires no special fittings (Rajper & Albrecht, 2020). These finding suggest that in markets where policy support for EVs via consumer subsidies is both unaffordable and would worsen inequality, support should focus on public transport fleets for commuter services where the high utilisation rate of vehicles improves their financial viability and charging infrastructure is required only at bus depots.

These findings support the AfDB policy brief which identified two- and three-wheelers and e-buses as the segments most suitable for starting e-mobility adoption in Africa (AfDB, May 2022) and also have the greatest impact in terms of affordability and market penetration for Africans.

Finally, trends for heavy haul mining trucks (mentioned in section -2.4) suggest a switch to new energy vehicles (electric or fuel cell) is likely to start with fleets where operators can control charging or hydrogen refuelling. This implies that for commercial and heavy trucks, pockets of new energy vehicles will be confined to special markets. However, this could change rapidly if projections for additional trucks needed to handle AfCFTA trade volumes materialise.

4.2.3.4.1. Potential Partnerships

Companies in China dominate world production of electric two- and three-wheelers. Groups that may be potential partners for manufacturing in member states include Jiangsu Jinpeng Group, Niu Technologies, Yadea Technology Group, Evoke Electric Motorcycles, and Zhejjiang Luyuan Electric Vehicle Co.

4.2.4. Mineral Stewardship

4.2.4.1. New Approaches for the Economic and Social Contributions of Minerals to Sustainable Development

African Green Mineral producers face tight markets for the foreseeable future; indeed, they may struggle to keep up with demand. Past mistakes during mineral booms characterised by governmental overreliance on mineral receipts for revenue and export earnings should be avoided. There are several reasons for optimism: better policy tools for maintaining macroeconomic balances, experience with stabilisation or sovereign wealth funds and, most important of all, more favourable conditions for economic diversification.

More focus is on resources in a world adjusting to the twin disruptions of climate change and the energy transition. The AGMS is an opportunity to also raise the profile of mineral stewardship to perform a developmental role in the allocation of mineral rents between mineral producers, affected communities and the state. Using mineral rents sustainably involves converting natural capital from non-renewable resources into physical and human capital for sustainable development.

New approaches to secure mineral resources for future generations in ways that are economically, environmentally, and socially responsible share a number of common features. Some commentators observe these policies are global in scope, they track minerals through the entire value chain and lifecycle including after use into recycling, they rely on collaboration with society-wide stakeholders, often involve technology improvements, and recognise social norms and practices (Nickless & Yakovleva, 2022). A range of quantitative tools underpin these new approaches and use resource accounting for determining stocks, costs and budgeting for mineral depletion (Nickless & Yakovleva, 2022, pp. 11-12).

Solving complex and interrelated issues while moving towards sustainability requires expertise from the disciplines of economics, behavioural sciences, and design alongside geoscientists and engineers. It has been argued that a reimagined mineral stewardship is key to a transition to a sustainable, responsible and circular future (Nickless & Yakovleva, 2022). A related approach makes the case for a normative agreement between affected stakeholders and mines held to account by a 'sustainable development licence to operate'((Pedro, et al., 2017).

4.2.4.2. Environmental, Social and Governance of Green Minerals

Environmental, social and governance standards are a core component of the AGMS to protect Africa's environment and people and to set exemplary standards for good governance and the management of environmental and social impacts of mining, mineral processing, manufacturing and recyling or safe disposal at end of life.

A risk-based framework for identifying and managing the impacts of projects is documented in the AfDB Integrated Safeguards System (AfDB, 2013) as well as updated climate safeguards decision- making tools for screening and modifying projects to reduce vulnerability to the impacts of climate change (AfDB, n.d.). These provide rigorous ready-made tools for green mineral project evaluation and guidance for enhancing their robustness. Given that the AGMS aims to contribute to industrialisation on the continent which will inevitably have major environmental implications, integrated safeguards should be applied from the outset of project development.

Scrutiny over battery supply chains as well as their assembly into products is a huge opportunity which should be turned to the advantage of African producers by upholding high ESG standards together with developing the verification systems required. This should be led by the private sector and is a issue where non-government organisations can play a crucial role to reinforce transparency and assist affected communities to have a voice in decisions that affect them. Where feasible, mineral producers should become involved in formulating guidelines on the supply chains referred to below, to prevent ESG standards becoming a form of non-tariff barrier for African exports.

High ESG standards are a core part of the EU's strategy to set terms under which both products within Europe and imported into the EU can be controlled, at the same time as it works to build up its own battery and EV value chains. "Sustainable mining is a prerequisite for clean battery value chains" states the European Commission report on implementing the strategic action plan on batteries (European Comission, 2019, p. 12). The relevant aspects for the AGMS refer to sourcing practices for imported raw materials and products. EU strategy envisages a sustainability code of governance for European battery manufacturers that will commit them to comply with internationally-recognised responsible business conduct and sustainability standards such as the Organisation for Economic Co-operation and Development's Guidelines for Multinational Enterprises and Due Diligence Guidance for Responsible Mineral Supply Chains. Also included in these documents are sustainable sourcing elements with regard to battery minerals in the Non-Financial Reporting Directive and reporting on Conflict Minerals Due Diligence.

4.2.4.3. Aiming for a Circular Economy

The AGMS should contribute to the responsible use of mineral resources by advocating circularity for green minerals and materials more broadly. It could do this by setting circularity as an explicit strategy objective (UNIDO, n.d.). As a starting point, recycling should be a clear implementation action. In time, as the stock of lithium-ion batteries that have reached the end of their life grows, recovering valuable metals will become an additional source of feedstocks for battery manufacturing. A recent techno-economic analysis suggested that recycling becomes economical at a feed rate of around 500 tons annually for lithium-ion batteries with high metal values (Gericke, Nyanjowa, & Robertson, 2021).

CHAPTER 5

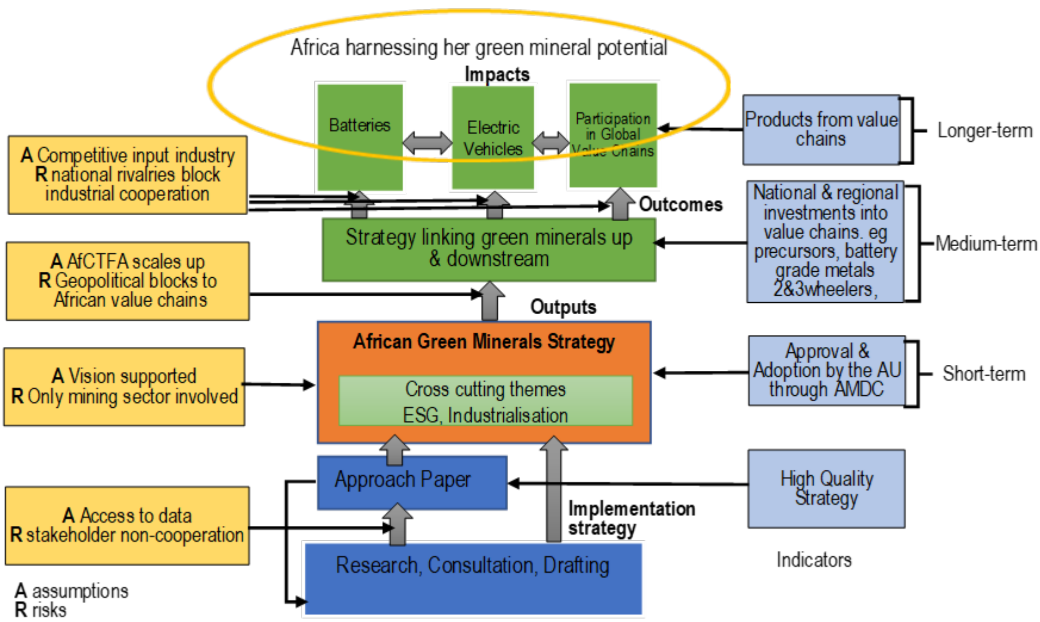
Theory of Change: How Transformation of the Green Minerals Sector will be Achieved Through the Strategy

This Approach Paper is a link in the chain towards the vision of Africa successfully harnessing her green mineral potential to play a significant role in emerging green technologies and value chains for the benefit of both its citizens and the planet.

The next step is the preparation of the fully-fledged African Green Minerals Strategy through iteration of this paper by critique and consultation. What matters for the strategy to be impactful is for it to be translated into manufacturing activity to transform mineral feedstocks into final products. The theory of change depicted in Figure 17 shows the preconditions and requirements for this to happen that have already been discussed in the preceding sections of this paper.

FIGURE 17:

Passenger EV share of sales Left Hand Side (LHS) and share of fleet Right Hand Side (RHS)



Source: Authors

Industrialising Africa, in which the AGMS must play its part alongside other instruments such as the AfCFTA, will involve massive expansion of heavy industry. The needed steel, cement, aluminium, chemicals, fertiliser, polymers, machinery and transport equipment are both energy and emissions intensive. Currently available technology cannot provide the building blocks for industrialisation through carbon neutral processes without substantially higher costs, although there are promising signs that the cost premiums are shrinking (Blank, 2019), (Altebburg & Rodrik, 2017).

A new path to industrialisation that minimises the environmental impacts of heavy industry calls for a paradigm that integrates ESG, industry, innovation and infrastructure (SDG 9) together with the circular economy. This paradigm rejects the notion that there is a binary choice between avoiding GHG emissions by doing nothing or industrialising and polluting. It is also misguided to believe that the use of green technology can side-step the impacts of heavy industry entirely. Economic transformation of the green minerals sector and its downstream linkages requires a pragmatic concurrent application of ESG safeguards and investment project implementation. It will require transfers of cleaner production technology and financial resources from those nations who were able to power their industrialisation with cheap fossil fuels (Triki & Said, 2021), which should including China and India. With little legacy heavy industry, Africa can take advantage of practices such as eco industrial parks and of new production technology, illustrated by the switch to hydrogen for steel-making being implemented by Swedish producer SSAB, which plans complete mine-to-market fossil fuel-free steel for all output by 2026 (SSAB, 2022).

In the short term the strategy, which has its genesis in the Bank's ANRC, needs to find support among policymakers responsible for manufacturing and services, that is both downstream and upstream (mining supply chain) of the mining sector because that is where industrialisation takes place and needs to be driven from.

In the medium-term strategic objectives have to be translated into investment projects, pre-feasibility studies and cost-benefit analyses to screen the most viable projects for investment, raising capital and investment from among development finance institutions, the private sector and state-owned enterprises. The nature of these projects will typically have GHG emission reduction impacts and therefore funding from climate change finance instruments should be tapped wherever possible.
Prerequisites for developing full green value chains in Africa include effective regional industrial cooperation to achieve scale and resources. Over the longer term as value chains are built out, the strategy's effectiveness must be measured by the products flowing from manufacturing on the continent as well as through African participation in global value chains.

CHAPTER 6

Theory of Change: How Transformation of the Green Minerals Sector will be Achieved Through the Strategy

Africa's Green Minerals Sector: Defining Success Factors in the Short-, Medium- to Long-term

High-level indicators of success were depicted in Figure 17 African Green Minerals Development Strategy Theory of Change. Reiterating the importance of securing backing for the strategy upstream and downstream of the mining sector and ensuring its incorporation into the core industrial policy of member states where projects will be based, the following targets and steps could also be set to measure the success of the AGMS in the short-term to medium-term.

1. Effective mobilisation of funding for the AGMS needs to draw on established sources (climate finance, green and blue bonds, climate-for-debt swaps) and search for new approaches. The European Union recently launched a Hydrogen Bank to build the future market for hydrogen. Africa requires similar initiatives, along the lines of a "Green Bank" to raise capital for foundational and core strategic industries like batteries, EVs and green hydrogen, as well as emerging green businesses. A precedent has been set in the agreement between the African Export-Import Bank (Afreximbank) and the African Petroleum Producers' Organization to form the African Energy Transition Bank in support of an Africa-led energy transition strategy (Afreximbank, 2022).
2. Encouraging wider collaboration among universities, training institutes and research organisations is critical to form relevant high-level human capital and launch investigations to solve problems confronting green minerals mining, processing and manufacturing. The University of Lubumbashi, Copperbelt University and University of Zambia collaboration on Centre of Excellence for Battery Research could be used as a template for such initiatives.
3. Mainstreaming the commissioning of pre-feasibility studies for potential investment projects to be screened for opportunities along the mining, battery, electric vehicle, renewable energy or other green technology value chains. These could be undertaken by the private sector, by DFIs, by public-private partnerships with state support or via joint ventures between firms.
4. Developing value chain development strategies to maximise the use of green mineral resource endowments within RECs. The SADC region is the furthest along on the development of battery value chains as it produces all of the required feedstocks (but not yet all to battery grade) and

has strong government backing in the DRC and Zambia to launch battery production. Morocco in the UMA produces cobalt and phosphates and could leverage its participation in the EU automobile industry to invest further in high purity refining of those minerals.

5. Collaborating with the African automobile industry to ensure alignment of planning and timing of initiatives that they are undertaking in each of the production hubs on the continent to introduce electric vehicles into their product mix (especially those 2 and 3 wheelers and buses), in parallel with curtailing the import of used vehicles.

CHAPTER 7

Risk Analysis and Risk Mitigation

This AGMS Approach Paper has attempted to highlight the opportunities presented by the energy transition for Africa's mineral resources and assess their potential to give a significant boost to resource-based industrialisation. At the same time there are risks associated with a surge in demand for green minerals. These opportunities are unfolding against a backdrop of intense competition from developed countries to rapidly build their own battery, EV and renewable energy industries at scale. These developments are spawning a new form of geopolitics over access to critical minerals in spheres of political influence, potentially creating cleavages between supply chains that are oriented to the People's Republic of China on the one hand and supply chains to North America and Europe on the other that are seeking to lessen dependency on Asian suppliers. Potential risks and some mitigations for the strategy to address include the following issues.

1. The potential of getting locked in long-term offtake agreements may present a risk. In the struggle for firms to create strategic advantage, backed by their governments, by securing access to critical minerals African mineral producers may get locked into long-term offtake agreements. This paper has documented cases of vertical integration by battery makers to secure access to such mineral supplies. Such contracts can benefit miners by giving them access to low-cost capital for expansion, but the consequences of such lock-in could also reduce the availability of feedstocks for processing and downstream manufacturing or worse still, perpetuate the position of Africa as a producer of raw materials and not of value-added products.
2. China's control in metals refining could be a risk for African producers. China has built up a large refining capacity which relies on imported minerals, therefore its interests are served by continuing to import mineral concentrates rather than seeing them processed where they are mined. Following this reasoning, Chinese-owned mining operations on the continent may be disinclined to support initiatives to increase processing and downstream value addition.
3. Foreign constrained supply chains present a competitive risk. China and the OECD countries are developing green mining machinery and equipment (such as trackless mining EVs) which they want to export to Africa rather than help develop a green African mining supply chain.
4. The possibility new battery technologies could be developed avoiding the use of cobalt. Cobalt use in lithium-ion batteries and the producer power this confers on the DRC is at risk if there is a major switch to low or cobalt-free battery chemistries, partly due to a perception about "blood

cobalt" from some operations in the DRC, particularly from artisanal and small-scale mining producers.

5. The lack of exploration capital in Africa is a major risk. Lithium and class I nickel are the two battery materials that currently face the greatest supply constraints. This could shift attention in the main battery and EV markets towards Latin America, Australia and Indonesia with the result that Africa receives less mineral exploration and green minerals interest.
6. Rapid technology advancement in battery production could present a risk. Rapid technological advances in battery production create risks of technological obsolescence, particularly for firms entering the battery manufacturing industry that rely on licencing technology.

Strategies to mitigate these possible risks include the following steps.

1. Include provisions in mining licences to ensure that mineral feedstocks are available to regional consumers at export parity prices to improve their competitiveness and to ensure the development of the local/regional supply chain and the development of local-regional content.
2. Promote the work of the Fair Cobalt Alliance and the Cobalt Action Partnership to document responsible cobalt sourcing, to reduce the prevalence of "blood cobalt" perceptions and uphold accountability instruments to combat any use of minerals to fund conflicts and drive state fragility.
3. Develop competitive strategies as nimble technological followers rather than competing head-on at the technological frontier (aim for leading-edge rather than bleeding-edge). Such strategies are better suited to the smaller African markets and where resources for innovation could be directed to product development for local conditions.
4. Ensure the pragmatic and resolute pursuit of the regional economic integration necessary for economically viable feedstock supplies and markets for resource-based industrialisation.
5. Use the African Union's diplomatic clout to shape the relations with major powers to advance the AGMS, particularly as the strategy is relevant to these countries' interests in improving supply chains for critical commodities.

CHAPTER 8

Risk Analysis and Risk Mitigation

Upon completion of the AGMS Approach Paper, the Bank and its partners will have a core document which has been already critiqued by staff and external experts which it can use to build the final AGMS. Considering the broad scope of the information that has been documented in this Approach Paper, it is recommended that the final AGMS should lay out more prescriptive strategy proposals for specific intervention areas and accompanying implementation actions. The motivation for this approach is to provide the target audience for the strategy with objectives that provide more guidance than high-level normative development goals alone can do.

A time horizon for the strategy runs to the achievement of longer-term goals measured by the manufactured outputs from battery and electric vehicle (two and three wheelers initially) value chains. To keep the strategy technologically relevant while green technologies are evolving will require effort from all involved with its implementation who should be encouraged to work transversally across government departments. It is therefore recommended that the strategy should target policymakers responsible for the following functions in member states to raise their awareness of the issues, direction and opportunities it outlines: mineral resources management, industrial development, investment promotion and science and technology.

Data on markets in member states and RECs which have the highest potential for developing effective inter-sectoral linkages should be obtained to channel the strategy to implement value chain building interventions. It is a challenge for a strategy document to connect the vision for the AGMS with the detail necessary for a credible investment proposal for, say, battery manufacturing. To help bridge this gap it is recommended that the Bank, ANRC and its partners include investment officers responsible for industrial financing in a project steering committee to oversee the final preparation of the AGMS. An objective of the AGMS should also be to engage with the private sector to accurately reflect the factors which need to be satisfied for successful investments in new industrial undertakings.

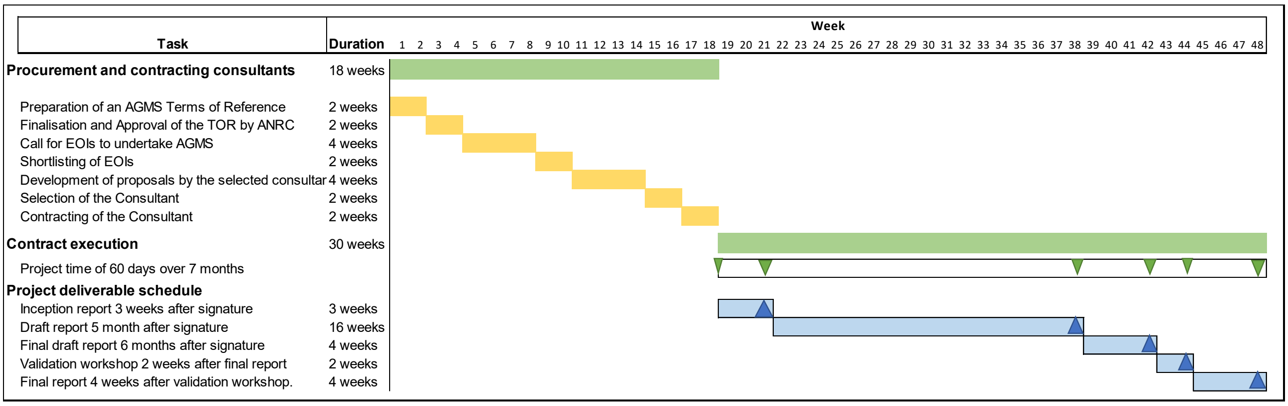
Consultant qualifications and knowledge base required to prepare the full strategy must include depth in earth sciences/mineral economics and investment project scoping as well as transversal knowledge of mineral value chain development issues in Africa. In addition, the selection criteria should be weighted in favour of advanced degrees in engineering, earth sciences or mineral economics, publications record and relevant experience of resource-based industrialisation strategy development.

It is estimated that the strategy development could be completed in 60 person days over a seven-month period to manage the data gathering process from regional economies.

A GANTT chart schedule to complete the AGMS is shown in Figure 18.

FIGURE 18:

African Green Minerals Strategy Action Plan GANTT



Note: Terms of reference (TOR); expressions of interest (EOI)

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Appendix

A definition for critical raw materials by the European industry association, the Critical Raw Materials Alliance (CRMA, n.d.).

Critical raw materials (CRMs) are those raw materials which are economically and strategically important for the European economy but have a high risk associated with their supply. Used in environmental technologies, consumer electronics, health, steel making, defence, space exploration, and aviation, these materials are not only ‘critical’ for key industry sectors and future applications, but also for the sustainable functioning of the European economy.

It is important to note that these materials are not classified as ‘critical’ because they are considered scarce, rather they are classified as ‘critical’ because:

1. They have a significant economic importance for key sectors in the European economy, such as consumer electronics, environmental technologies, automotive, aerospace, defence, health and steel;
2. They have a high supply risk due to the very-high import dependence and high level of concentration of set critical raw materials in particular countries;
3. There is a lack of (viable) substitutes, due to the unique and reliable properties of these materials for existing, as well as future, applications.

United States critical minerals

In the USA, a “critical mineral” is defined as a non-fuel mineral or mineral material essential to economic or national security and which has a supply chain vulnerable to disruption. The list is prepared by the USGS and reviewed periodically to assess supply chain conditions.

TABLE 4:

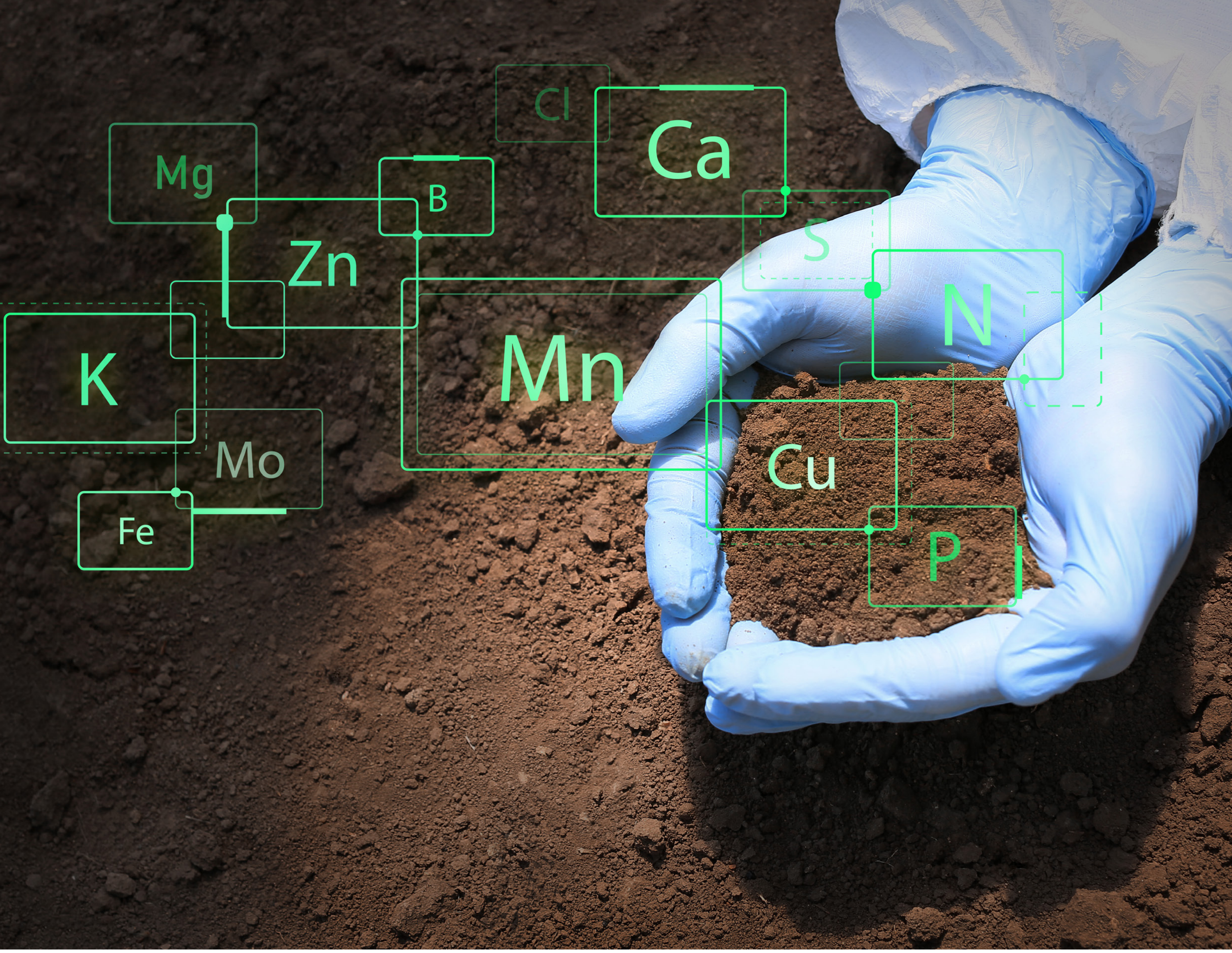
United States’ Critical Minerals List for 2022

Mineral Strategic applications
Aluminium, used in almost all sectors of the economy.
Antimony, used in lead-acid batteries and flame retardants.
Arsenic, used in semi-conductors.
Barite, used in hydrocarbon production.
Beryllium, used as an alloying agent in aerospace and defence industries.
Bismuth, used in medical and atomic research.
Cerium, used in catalytic converters, ceramics, glass, metallurgy, and polishing compounds.
Caesium, used in research and development.
Chromium, used primarily in stainless steel and other alloys.
Cobalt, used in rechargeable batteries and superalloys.
Dysprosium, used in permanent magnets, data storage devices, and lasers.
Erbium, used in fibre optics, optical amplifiers, lasers, and glass colorants.
Europium, used in phosphors and nuclear control rods.
Fluorspar, used in the manufacture of aluminium, cement, steel, gasoline, and fluorine chemicals.
Gadolinium, used in medical imaging, permanent magnets, and steelmaking.
Gallium, used for integrated circuits and optical devices like LEDs.
Germanium, used for fibre optics and night vision applications.
Graphite, used for lubricants, batteries, and fuel cells.
Hafnium, used for nuclear control rods, alloys, and high-temperature ceramics.
Holmium, used in permanent magnets, nuclear control rods, and lasers.
Indium, used in liquid crystal display screens.
Iridium, used as coating of anodes for electrochemical processes and as a chemical catalyst.
Lanthanum, used to produce catalysts, ceramics, glass, polishing compounds, metallurgy, and batteries.
Lithium, used for rechargeable batteries.
Lutetium, used in scintillators for medical imaging, electronics, and some cancer therapies.
Magnesium, used as an alloy and for reducing metals.
Manganese, used in steelmaking and batteries.
Neodymium, used in permanent magnets, rubber catalysts, and in medical and industrial lasers.
Nickel, used to make stainless steel, superalloys, and rechargeable batteries.
Niobium, used mostly in steel and superalloys.
Palladium, used in catalytic converters and as a catalyst agent.

Source: Authors

Mineral	Strategic applications
Platinum, used in catalytic converters.	
Praseodymium, used in permanent magnets, batteries, aerospace alloys, ceramics, and colorants.	
Rhodium, used in catalytic converters, electrical components, and as a catalyst.	
Rubidium, used for research and development in electronics.	
Ruthenium, used as catalysts, as well as electrical contacts and chip resistors in computers.	
Samarium, used in permanent magnets, as an absorber in nuclear reactors, and in cancer treatments.	
Scandium, used for alloys, ceramics, and fuel cells.	
Tantalum, used in electronic components, mostly capacitors and in superalloys.	
Tellurium, used in solar cells, thermoelectric devices, and as alloying additive.	
Terbium, used in permanent magnets, fibre optics, lasers, and solid-state devices.	
Thulium, used in various metal alloys and in lasers.	
Tin, used as protective coatings and alloys for steel.	
Titanium, used as a white pigment or metal alloys.	
Tungsten, primarily used to make wear-resistant metals.	
Vanadium, primarily used as alloying agent for iron and steel.	
Ytterbium, used for catalysts, scintillometers, lasers, and metallurgy.	
Yttrium, used for ceramic, catalysts, lasers, metallurgy, and phosphors.	
Zinc, primarily used in metallurgy to produce galvanized steel.	
Zirconium, used in the high-temperature ceramics and corrosion-resistant alloys.	

Source: (USGS, 2022)



AFRICAN DEVELOPMENT BANK GROUP

African Natural Resources Management & Investment Centre

Avenue Jean-Paul II -01BP 1387,
Abidjan - Côte d'Ivoire

ecnr_info@afdb.org
www.afdb.org