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Critical Minerals and Routes to Diversification in Africa: Opportunities for Diversification into Batteries and Fuel Cells and Mining Equipment Technologies - The Case of South Africa

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Abstract

This paper develops a framework that maps the global battery and fuel cells value chain and analyses how South Africa can potentially leverage its mineral resources to localise and capture value within mining equipment technologies, including leading the building and development of battery and fuel cells regional value chains in Africa. In doing this, we develop an in-depth country case study and highlights South Africa's specific routes to diversification, including opportunities for regional coordination and industrial development. The industrial policy lessons for productive transformation across Africa are discussed based on the empirical and sectoral-specific case studies.

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1. Introduction

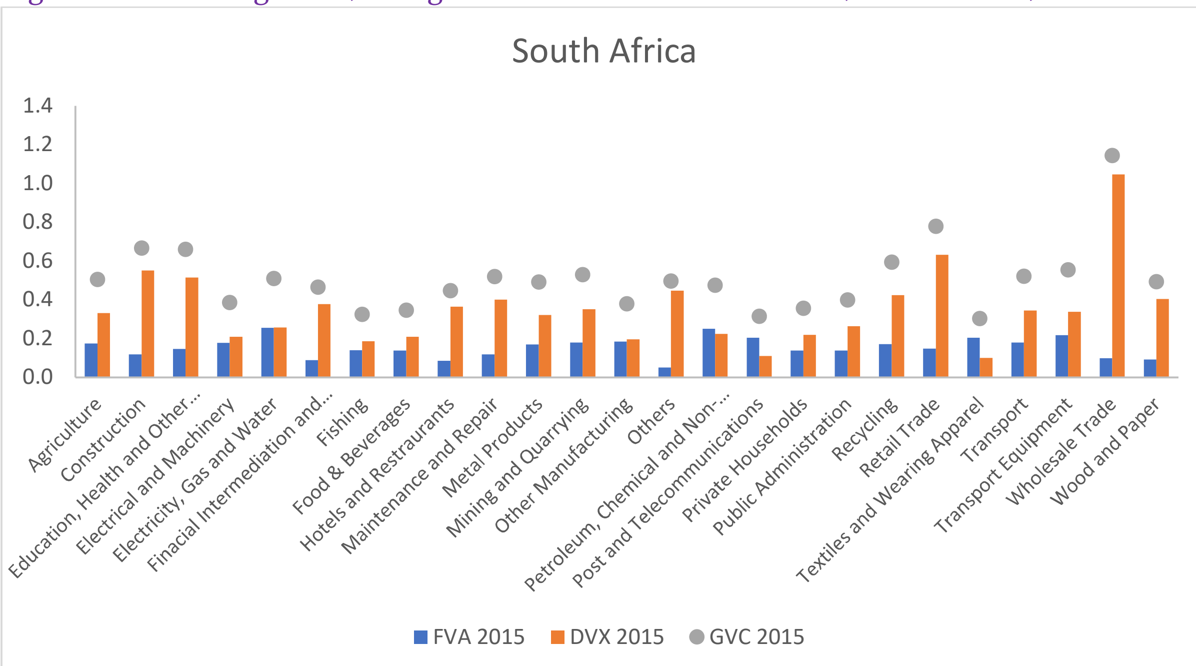
South Africa is an upper-middle country and the most industrialised economy on the African continent. Despite its leading position on the continent, the country has struggled to diversify its industrial base; in fact, over the last three decades since the end of apartheid in 1994, despite increasing openness and internationalisation, the country has shown signs of premature de-industrialisation. South Africa's poor performance overall is evident when compared to its peer group of upper-middle income countries across Latin America and South-East Asia (excluding China). On average, the backward participation of middle-income Latin American countries across medium- and high-tech sectors does not go above 40%.

In two sectors, at least, South Africa is consistently more integrated than Latin American countries – i.e., chemical products, and machinery and equipment. However, if South Africa is compared with Southeast Asian (SEA) countries, the picture changes dramatically. It is clear that South Africa is less integrated than Southeast Asian countries across all sectors, and that the levels of FVA are significantly lower. Overall backward integration in manufacturing is above 40% for all Southeast Asian countries, with country peaks in the chemicals, machinery and motor vehicle sectors above 60% of FVA (Andreoni, et al., 2021a).

Contrary to other middle-income countries, which find it particularly difficult to move from an 'in' to an 'out' phase, South Africa has even struggled with engaging in the 'in' phase of increasing backward integration into GVCs. In particular, the level of backward integration in the country has remained significantly lower than in SEA economies in the 1990s and 2000s. This means that while the middle-income countries in the SEA group have already started integrating into GVCs, South Africa has been slow in linking up into GVCs, similarly to a number of countries in Latin America. In addition, the 'out' phase has not materialized either, as the country's dependence on international trade increased after the end of apartheid in 1994, with China becoming its main trade partner in 2008 (Andreoni and Torreggiani, 2020). On the one hand, the country has relied increasingly on imports of final goods to satisfy its domestic demand; on the other hand, it has served as a gateway and export platform for foreign investors and traders to access the rest of the African continent. This has limited the scope for the localization of high value-added activities and thus for increasing domestic value added (DVA).

In the manufacturing sector, as well as in a number of MHT sectors like chemicals, non-electrical machinery and equipment and automotive, the higher relative levels of DVA in South Africa is due to the country's rich endowment in mineral resources and the historical dominance of the mineral-energy complex within its economy (figure 1). In the case of non-electrical machinery and equipment, this trend is mainly driven by the existence of very strong domestic capabilities in certain specific advanced sectors providing critical inputs to the mining industry (i.e., backward integration from manufacturing to natural resources). For example, domestic mining equipment producers have strong and particularly advanced capacities in offering products and services in certain fields, such as deep-level mining and related areas (Kaplan, 2012; Andreoni and Tregenna, 2020; Andreoni, et al. 2021b).

Figure 1: GVC integration, foreign and domestic value addition, South Africa, 2015.



Source: Authors based on EORA

In the case of the automotive sector, the relative higher levels of DVA along such value chains, are mainly driven by the country's use of its natural resources endowment and by the specific intermediate products it has been able to produce based on that (i.e., forward integration from natural resources to manufacturing). These intermediates include, for example, catalytic converters, which make extensive use of platinum-group metals of which South Africa is the world's largest producer. In the South African automotive sector, value addition is concentrated among OEMs and Tier 1 suppliers, with a limited number of value adding activities performed by Tier 2 and 3 (Barnes and Black, 2017). Given this distribution of value-added activities and the capital expenditure associated with innovation in the sector, OEMs are central to the potential transformation and greening of the sector, hence a shift to electric vehicles and different types of battery technologies.

Notwithstanding these exceptions, the overall failure of South Africa to diversify its economy and integrate the 'in' phase in the 1990s and 2000s has dramatically delayed its progress along the 'in–out–in' industrialization pathway (Andreoni et al. , 2021a). Overall, the stronger performance of upstream resource-based sub-sectors led by coke and refined petroleum products, basic chemicals and basic iron and steel was partially driven by the global commodities boom – with basic non-ferrous metals (mainly aluminium) growing especially strongly to 2008.

Given the increasing global demand for climate transition minerals, this paper maps the battery and fuel cells value chain and analyses how South Africa can potentially leverage its mineral resources to localise and capture value within mining equipment technologies, including leading the building and development of battery and fuel cells regional value chains in Africa.

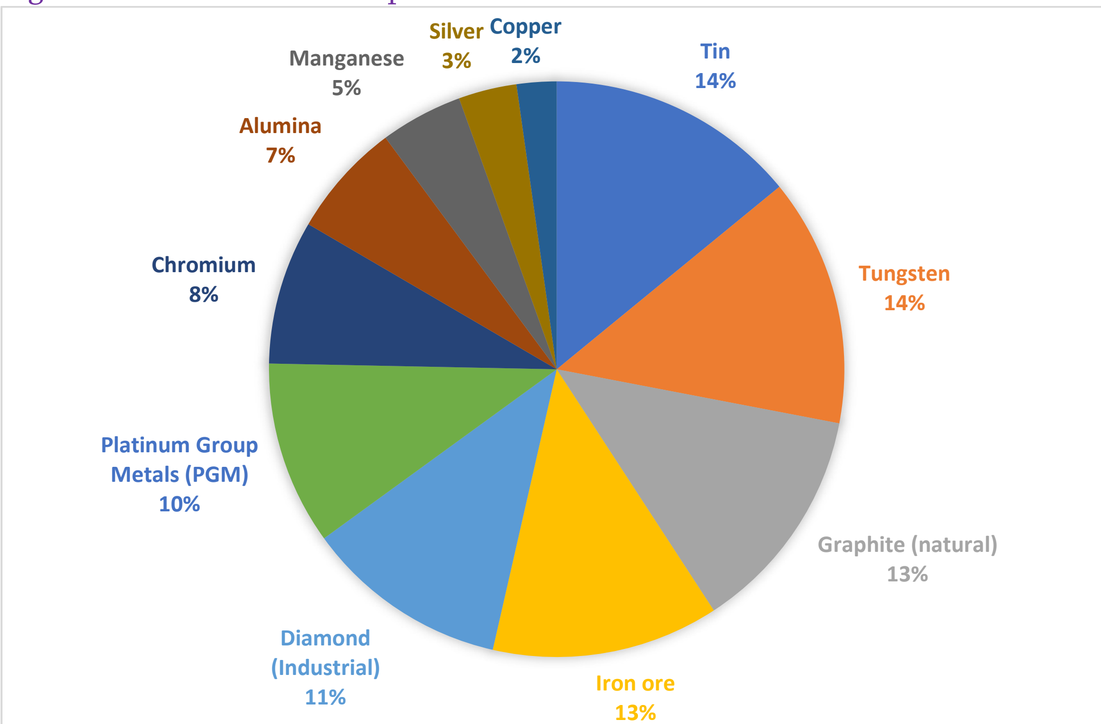
The remainder of the paper is structured as follows. Section 2 presents and discusses the role critical minerals could play in deepening South Africa's industrial diversification and technological capabilities development in the renewable energy sector. Sections 3 and 4 critically discusses two diversification routes for South Africa: batteries and fuel cells and mining equipments. Section 5 concludes the paper with policy recommendations.

2. Critical minerals in South Africa: pivot for industrial diversification and technological deepening

Over the last decade, the South African government and businesses have increasingly seen the country's rich mineral deposits as well as the country's proximity to other equally resource-rich economies in the region as a route for both upstream and downstream regional integration, as well as an opportunity for diversification and technological innovation. According to the USGS (2022), South Africa is one of the world's leading mining and mineral processing countries, with a diversified portfolio of minerals and large shares of world production. Specifically, in 2017, South Africa's estimated share of world mined rhodium production amounted to 80%; mined platinum, 72%; refined rhodium, 63%; refined platinum, 66%; chromium, 46%; vermiculite, 44%; mined palladium, 39%; manganese and refined palladium, 31% each; ferrochromium, 29%; zircon, 24%; industrial garnet, 22%; vanadium, 11%; refined gold, 7%; diamond, 6%; fluorspar, 5%; coal, iron ore, and mined gold, 4% each; mined cobalt and nickel, 2% each; and aluminium, refined cobalt, mined lead, and stainless steel, 1% each.

If we look at South Africa's export basket of critical minerals, seven minerals account for 80% of total value of the portfolio (figure 2). With the exception of the PGM which is exported completely outside the African continent, there is a significant export of Tin (16%), Tungsten (21%), Graphite (24%), and iron ore (13%) to other African countries. As the network analysis discussed above revealed, South Africa is not only an exporter in the continent but also a significant importer of critical minerals. This is due to the presence of large multinational companies which use South Africa has their basis for Southern and Eastern Africa operation, but also because South Africa has developed significant mineral processing capacity.

Figure 2: Critical minerals export basket of South Africa in 2021



Source: Authors based on UNCOMTRADE

The share of South Africa's export to the rest of the world of processed critical minerals goes from 8% for Tin and 10% for Tungsten, to 74% for Chromium and 75% for PGM, up to 82% for PGM, 99% for Graphite and 100% for Alumina. Mining and mineral beneficiation plays a pivotal part in South Africa's economy. There are important backward linkages into mining equipment technologies, and forward linkages into metal fabrication and automotive (Andreoni et al., 2021b). In fact, South Africa is a major player in the region in terms of supply of mining equipment for extraction, processing and beneficiation for mining houses.

Over the last two decades, given the pivotal role of the mining and mineral sector, the government has developed a regulatory framework for the mining sector which attempts to increase its potential transformative and developmental impact. Mining of minerals and mineral fuels was governed by the Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA), which became effective in May 2004 with the publication of the 'Mining Charter'. With the amendment of the Mining Charter in 2010, the government introduced a Black Economic Empowerment (BEE) programme requiring that black ownership of mining companies reach 26%. Companies are (a) allowed to use the value of their domestic beneficiation activities as credit for up to 11% of their black ownership requirements; (b) required to purchase 70% of their services, 50% of their consumable goods, and 40% of their capital goods from BEE entities; (c) also required to report progress annually on the development of near-mine communities, the sustainability of growth and development, and mineral beneficiation. In 2017, such requirements and provisions were further revised, in view of promoting the local content and ownership. For example, the black ownership requirement was increased to 30% from 26%, and the local content for services increased to 80% from 70% (Andreoni, et al., 2021b).

Alongside these sectoral value chains initiatives, South Africa has been increasingly looking at other diversification opportunities, however, their development has been largely constrained by the dramatic situation in the energy sector (Andreoni et al., 2022). Two diversification scenarios are elaborated below: one related to forward-linked (downstream) industries, focusing on the automotive sector and broader mobility sector; the other in relation to backward-linked (upstream) industries, focusing on the case of advanced mining equipment technologies, including their digitalisation, and industry.

Another central diversification and structural transformation opportunity is related to green hydrogen and the transformation of the current energy-mineral complex into a developmental block connecting green hydrogen production to the greening of the chemical and steel industries, with downstream opportunities for fertilizers and explosives production (with linkages into agriculture and mining) and green steel (with linkages into automotive and other equipment). The production of green hydrogen relies on scaling up dramatically the immense spare renewable energy potential that South Africa and other countries in the region like Namibia have. Domestic availability of green hydrogen could ultimately play a major pulling effect in terms of attracting investments in South Africa and the region in high-emission industrial activity—such as metal smelting. These structural transformation opportunities are discussed in other contributions (see Andreoni and Roberts, 2022; Andreoni et al., 2023).

2.1 Diversification route 1: EV batteries and fuel cells manufacturing for off-road vehicles and tracks

The pandemic hit the automotive sector at a time of dramatic technological change and industry organization restructuring globally. Climate change has made decoupling growth from fossil fuels and, thus, the use of cleaner energy sources of mobility a key priority for sustainable structural transformation. Technological solutions so far have mainly relied on alternative energy sources, electric and hydrogen-based technologies. These technologies have created new global demand for natural resources such as lithium for the production of batteries, and platinum-group metal resources for the global fuel cell market. The automotive sector is the driving force behind the technological development and optimization of lithium-ion batteries (LIB). However, these high-energy batteries are currently spreading into a wide range of other mobile and stationary applications (Fraunhofer ISI, 2022).

Several African governments and regional bodies are targeting the battery value chain, for both e-mobility and electricity storage even though so far lithium reserves and production are relatively limited in Africa (Morocco being an exception). A wide array of minerals are used in the production of LIBs, including lithium, cobalt, manganese, nickel, graphite, bauxite, copper, iron, phosphate rock and titanium. South Africa is well endowed in such minerals and can rely on neighbouring Madagascar, Mozambique, and Tanzania who have large reserves of graphite, amongst other critical minerals.

Furthermore, the limited availability of lithium is not necessarily a major constraint given the current evolution in battery technologies and chemistries. A new generation of so-called solid-state batteries (SSB) is under development and could reach the market in larger volumes in the next years. While current LIB are based on liquid electrolytes, SSB rely on solid electrolytes and show promise of improvements in several key performance indicators (KPI) for batteries (Fraunhofer ISI, 2022).

The battery chemistry is also changing, with implication for the critical minerals needed to attract investments in the battery value chain of the future. Most common batteries today are made of lithium, however, we are seeing increasing diversification of battery chemistries across electric car models depending on price, driving range and performance needs. While lithium-ion batteries—like NMC and LFP batteries—will likely dominate for at least the next decade, among manufacturers there is increasing interest for lithium-ion and sodium-ion batteries. While the cobalt content in NMC chemistries is already falling, lithium-ion and sodium-ion chemistries can provide cheaper alternative solutions for mass production (figure 3).

Figure 3: Comparison of key attributes across EV battery chemistries

	LFP	NMC	NCA
Material composition	Lithium	Lithium	Lithium
	Iron	Nickel	Nickel
	Phosphate	Manganese	Cobalt
		Cobalt	
Average cost *US$ per kWh*	$90/kWh	$130/kWh	$130/kWh
Energy density *pack level*	160 Wh/kg	200 Wh/kg	200 Wh/kg
Discharge recommendation	100%	80-90%	80-90%
Discharge cycles *until 80% capacity*	2,500	1,000	1,000

Source: https://zecar.com/resources/what-are-lfp-nmc-nca-batteries-in-electric-cars

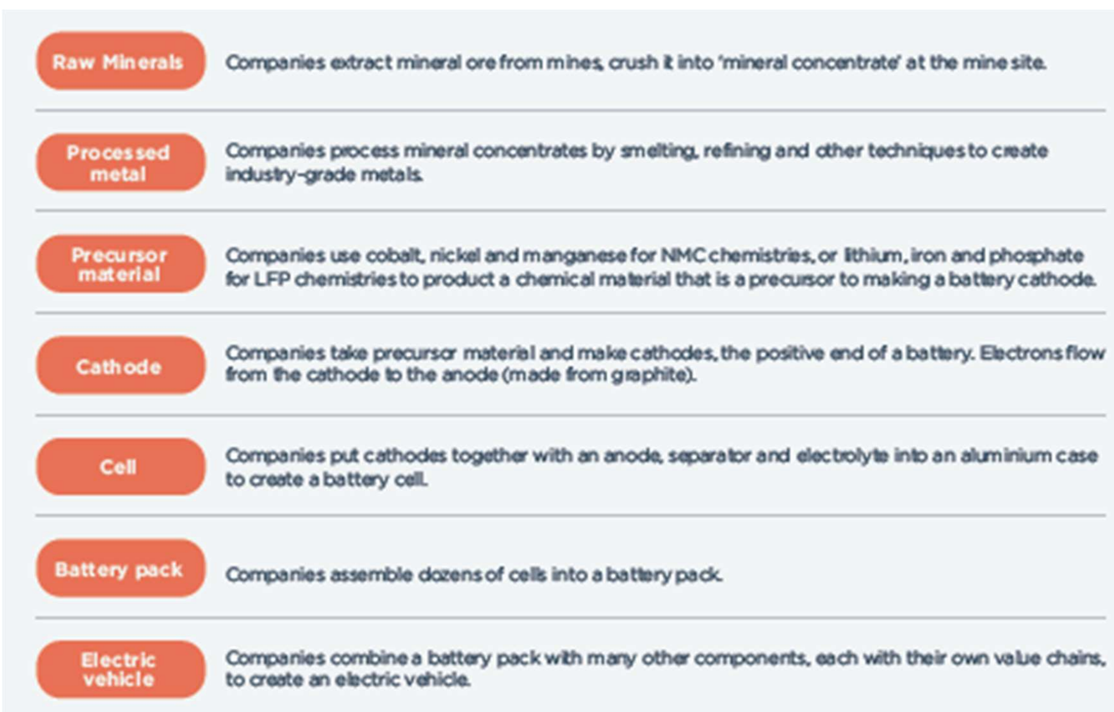
In 2011, South Africa launched the *South Africa's Energy Storage Research, Development and Innovation Programme* with the aim of developing lithium battery value chain for developing storage capacity and proprietary technologies for the automotive sector. The public-private consortium was led by the Department of Science and Innovation, and included strategic players in the industrial-energy-mineral ecosystem such as Council for Scientific and Industrial Research, the University of Western Cape, the University of Limpopo, the University of the Witwatersrand, the Nuclear Energy Council of South Africa, the Nelson Mandela University, and Mintek. The consortium focused on the whole value chain, from precursor and material development to cell and battery manufacturing, to testing and validation, to recycling. Over the last decade, an increasing focus of the consortium has been to build skills and coordinate multi-stakeholders initiatives in the country.

Despite this early move and several research experimental pipelines, South Africa has not managed to develop commercial production of battery cells in the country and the feasibility of developing an industrial vertical on lithium battery is still to be proven (South African Low Carbon Transport Report, 2021). Furthermore, despite mineral processing capabilities are well developed in South Africa, apart from manganese and aluminium, there is little beneficiation of minerals to battery grade in the country (nickel and lithium are in the pipeline). Downstream in the value chain, other battery manufacturing activities have however developed building on imported cells (TIPS, 2021). Firms have developed IP and expertise in the manufacturing of specific components, parts and systems (most notably battery management systems) as well as the assembly of battery packs and re-manufacturing second-life batteries for the domestic and regional markets. There is however no recycling facility in place.

The multi-stakeholders report (South Africa Low Carbon Transport Report, 2021) identifies four possible pathways: 1) mineral refining; 2) cell manufacturing; 3) battery manufacturing and assembly; and 4) battery recycling. The viability of these pathways largely differs in the short term; similarly, industrial development associated with these options is at different levels of maturity. Developing battery manufacturing and mineral refining are the two routes ready for scale-up. There are several constraints to the feasible development of these value chain, that South Africa and other countries in the regions face, as identified in a recent report by the Natural Resource Governance Institute (NRGI) called 'Triple Win' (Diene, et al. 2022) (see figure 4).

First, as highlighted in the case of Morocco's solar power technologies case, economies of scale drive competitiveness in the battery value chains. Production processes are continuous, and plants need to operate constantly at near full capacity. These processes are also energy intensive, hence a reliable supply of energy is needed. Furthermore, battery manufacturing requires a large, reliable and well coordinate supply of intermediate industrial inputs. In Africa these inputs are spread among different countries, even South Africa does not have all the minerals needed. This means that countries will need to pool mineral supply to achieve the minimum scale and reliability in case supply from a mine stops.

Figure 4: A battery value chain



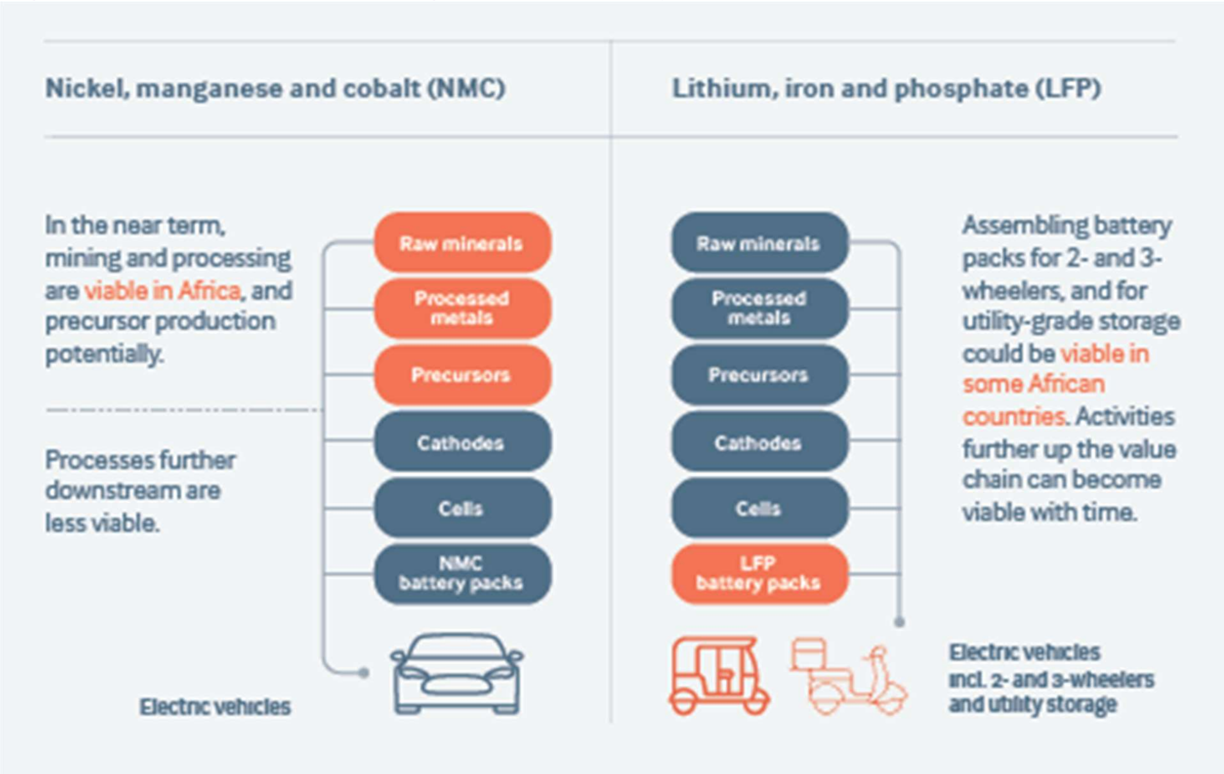
Source: Diene et al., 2022

Second, the geography of a battery value chain is determined by different factors. While early stage of processing and beneficiation are bound to be localised close to the mining sites, due to high transport costs, the more mineral are processed the more this cost declines. Processed metals are indeed relatively easy and inexpensive to transport (TIPS, 2021). As an example, Zambia has developed locally copper smelting and refining capability to reduce the weight of exports. However, further downstream developments using copper have not materialised. The location of precursors materials, that is, chemicals that are a precursor to making battery cathodes, tend to co-locate in countries with clusters of other chemical plants. South Africa is perhaps the only country in the region with a developed chemical industry, and could in fact leverage that to develop such manufacturing capability for precursors.

The next higher value stages of the value chain – battery cathodes and cell production – tend to be co-located, and cluster around EV manufacturers to benefit from quicker, more flexible delivery to customers. Again, South Arica could have an advantage given its domestic automotive industry, however such industry has stagnated in terms of total volumes, its competitiveness its affected by upstream industry constraints, and depends dramatically on the European market (Andreoni et al., 2021c). The development of a regional market for battery-powered vehicles would be essential to attract large scale investments in cathodes and cells manufacturing. From the bottom end of the value chains, battery pack assembling capabilities are already well developed in the country, especially in relation to battery packs for mining equipment and refrigeration.

A regional market for battery-powered vehicles in Africa is not going to be the same as the one in Europe or other advanced industrial economies. EV vehicles are still too expensive and the energy infrastructure – grid and charging station – is nowhere yet. The African market might resemble the one emerging in India, dominated by electric two- and three-wheelers. These light vehicles use lithium, iron, and phosphate (LFP), a type of battery chemistry also widely adopted for stationary power storage. The latter are particularly useful for providing off-grid electricity, a solution that is widely popular in Africa given its dispersed population.

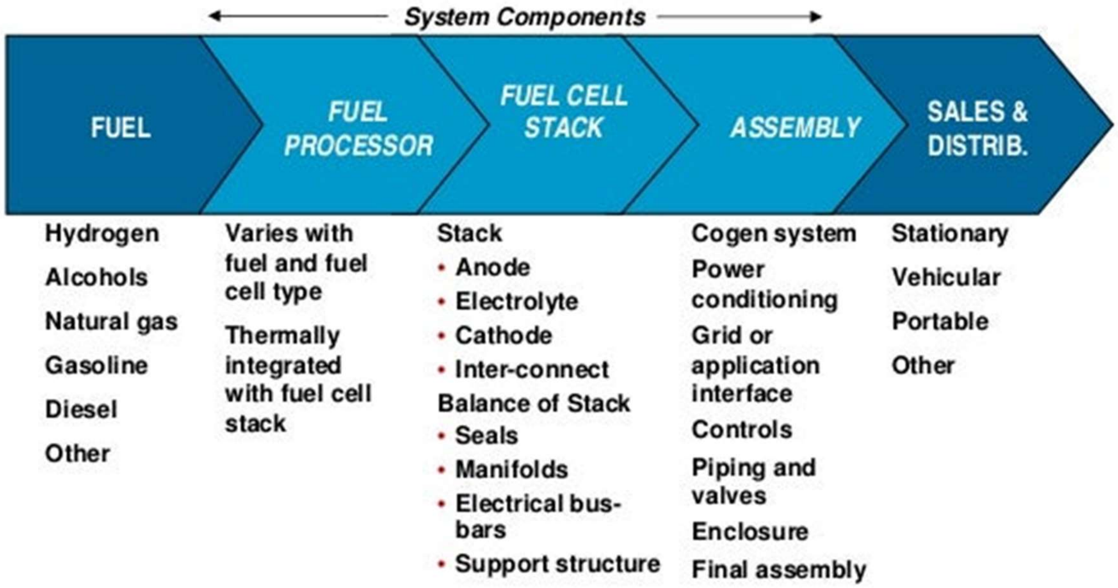
Figure 5: Two options in locating parts of a battery value chain in Africa.



Source: Diene et al., 2022

There are, however, other more viable routes for diversification, as shown in figure 5. South Africa could leverage its large platinum-group metal resources to develop forward linkages in a number of emerging and innovative sectors, and become an exporter of value added technologies based on its natural resources. Almost all the fuel cells sold to date use platinum as a catalyst, with smaller amounts of ruthenium. Fuel cells can be deployed in portable power generation, stationary power generation, and power for transportation (DMR, 2013). Fuel cell technology (see figure 6) is a pollution-free electricity generation technology. Because fuel cells have no moving parts and do not involve combustion, they can achieve up to 99.99 percent reliability. Fuel cells have also another advantage. Like batteries, fuel cells generate electricity from an electrochemical reaction – that is, converting chemical potential energy into electrical energy and, as a by-product of this process, into heat energy. However, while batteries need to be recharged using electrical source of energy, a fuel cell uses an external supply of chemical energy and can run indefinitely. Fuel cells use a variety of feed streams such as hydrogen, ammonia and liquid petroleum gas to generate electricity. Unlike internal combustion engines, the fuel is not combusted; the energy is instead released through a catalyzed chemical reaction. This allows fuel cells to be highly energy efficient, especially if the heat produced by the reaction is also utilized for other purposes.

Figure 6: Fuel cells value chain



Source: Heydorn, 2010

South Africa could develop several stages of the fuel cells value chain on the back of the catalytic converters industry for automotive, and its currently installed capacity for coating of PGMs. Given the transition in the automotive sector, companies involved in the production of auto catalysts could re-purpose their capabilities to enter the fuel cells value chain, with positive implications in terms of jobs retention and sustainability. Jobs creation opportunities could also arise from maintenance of various installations.

Given that the power output from a single cell is relatively low, these technologies are more likely to find industrial applications where stack arrangement of cells is possible. Three broad areas of application can be identified: portable power generation, stationary power generation and power for transportation. Transport fuel cells provide propulsive power to vehicles, directly or indirectly (as range-extenders). Specifically, fuel cell technologies offer South Africa an opportunity to develop its mining equipment industry, including underground equipment such as locomotives in mines. Using the platinum-based hydrogen-powered fuel-cell locomotives would reduce energy costs for mining activities. Mining houses are expected to increasingly look at this technology and South Africa is an ideal country for their development. In May 2022, Anglo American unveiled in South Africa the prototype of what it claims is the world's largest hydrogen-electric mining vehicle. The vehicle is being tested at the Mogalakwena mine in north-western South Africa where platinum is also mined. Anglo American has collaborated with other groups such as Engie, First Mode, Ballard and NPROXX.

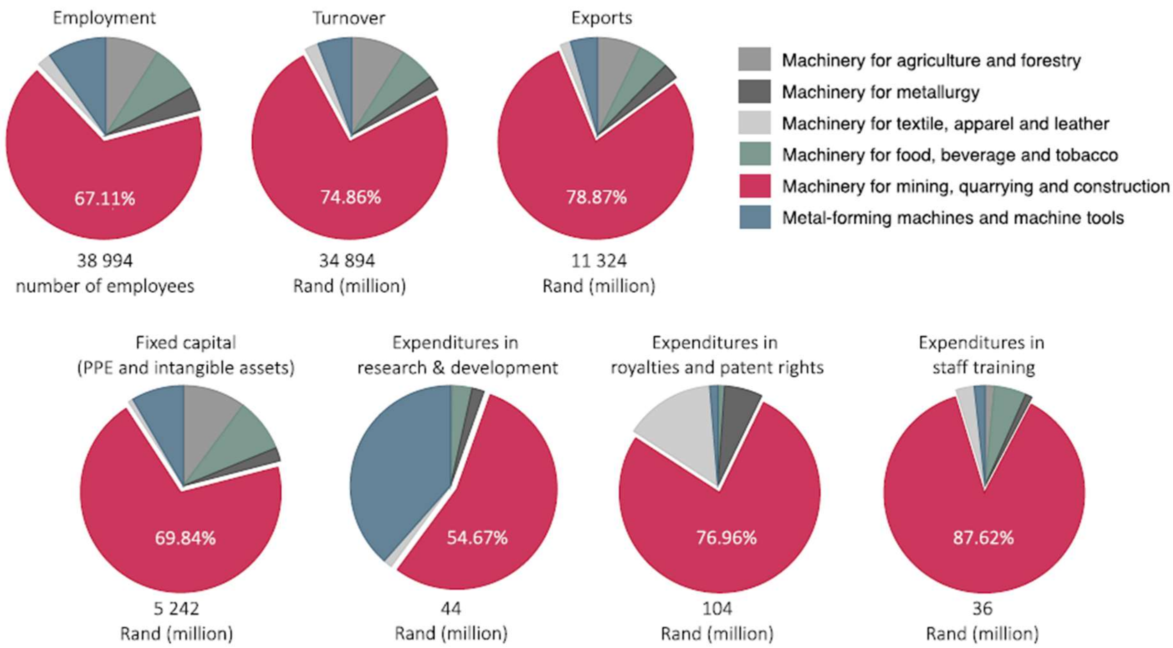
2.2 Diversification route 2: Pivoting the mining industry backward through supply of mining equipment

The second route to diversification for South Africa is indeed not new. South Africa is already a leader in mining equipment technologies. However, retaining such leadership position require investing in new mining solutions – such as the one integrating fuel cells technologies – as well as developing regional value chains anchored around its local industrial ecosystem. Critical minerals in the continent could be a major pull for upstream and downstream mining equipment development in South Africa. Recent developments in the global mining equipment value chains present both opportunities and challenges for South Africa.

The impact of the Covid-19 crisis across different geographies has put new pressure on traditional mining global supply-chain structures, which are concentrated around a few equipment vendors from the US, Europe, Japan, and China. According to a recent exploratory analysis conducted by international professional services organizations (Ernst & Young, 2020), mining companies are actively exploring alternative and broader sources of supply to reduce reliance on a small number of overseas vendors. On the one hand, this will open up opportunities for local or regional companies with the right level of technology and production capabilities to enter into such value chains. On the other hand, foreign multinationals supplying mining equipment and other critical inputs to mining houses might decide to progressively relocate part of their production activities closer to their clients' operations, through subsidiaries or collaborative partnerships with local companies. The South African mining equipment sector is well positioned to seize both these opportunities in the domestic and regional mining markets.

Mining equipment production and services are the today's most relevant and technologically advanced segments of the broader special purpose machinery industry in South Africa (Andreoni and Torreggiani, 2020). Specifically, the mining machinery and equipment sector represents the largest contributor to employment, turnover and exports of the special purpose machinery industry, and it also stands out with respect to total plant, property, equipment (henceforth referred to as PPE) and intangible assets, expenditures in R&D, royalties and patent rights, and staff training. According to the South African Revenue Service (SARS) data, in 2017, South Africa-registered companies producing equipment and machines for mining, quarrying and construction, contributed to more than 67% of the total employment in the special purpose machinery sector (e.g., around 39,000 employees), and to around three fourth of its total turnover (75%) and exports (79%), accounting to around 35,000 million Rand (about $ 1,799,337,820) and 11 300 million Rand (about $5,8092,9067,60), respectively. The development of a mining equipment ecosystem in the Gauteng province – two thirds of the employment and turnover are concentrated there – has driven processes of technological capabilities development and diffusion. Indeed, this sub-sector also makes a heavy contribution to the total non-current assets (70%) and spending in capabilities development undertaken in the specialised machinery and equipment industry, as proxied by expenditures in R&D (55%), royalties and patent rights (77%) and spending in staff training (88%) (figure 7) (Andreoni and Torreggiani, 2020 based on SARS Data).

Figure 7: Relevance of mining equipment in the South African specialised machinery industry, 2017



Source: Andreoni and Torreggiani, 2020

The proximity to the mines, the demand for customized and niche technology solutions well-suited for the peculiar geological conditions of South Africa have been critical drivers of learning and, thus, global competitiveness for local companies that, over the years, have developed production and services operations across major extractive industries and countries, actively engaging with the technological race in the global mining value chain. However, although a number of these companies are large by local standards, they are still significantly smaller than the leading multinationals operating in South Africa and their expertise and competencies are particularly advanced and at the global frontier only in specific product segments (e.g., deep level mining and related areas).

We can distinguish between three main clusters of companies adopting different business models and controlling different capabilities:

(a) international OEMs mainly importing assembled machines from abroad with limited manufacturing facilities in the country and weak linkages with the local supply chain (notable examples are Sandvick and Epiroc in the underground segment, Caterpillar and Komatsu in the surface equipment segment and Outotec and Metso (now combined) in mineral processing);
(b) international OEMs with significant production and assembling activities in South Africa and relatively stronger relationships with local suppliers (notable examples are Joy Global – recently acquired by Komatsu – in underground equipment and FLSmidth and Weir Minerals for mineral processing)
(c) domestic OEMs and local suppliers with high local content and export capabilities (notable examples are AARD, Rham and Fermel for underground equipment, Bell Equipment for surface equipment and Kwatani, Vibramech and Multotec for mineral processing).

These different clusters of companies operate across various stages of a mine's lifecycle and specialize on three main different product segments – i.e., underground equipment, surface equipment and mineral processing.

3. Concluding remarks and policy direction

Over the last decades, South Africa's global competitiveness in the mining equipment sector has been on the decline due to a combination of factors including both domestic bottlenecks like the shrinking domestic mining industry among others, and global threats such the increasing foreign competition faced by local players. The country has experienced a decline in its export shares of mining machinery and equipment to traditional markets in the aftermath of the global financial crisis (Andreoni and Torreggiani, 2020), and it is losing its appeal for leading multinationals as a preferred and strategic location in which to undertake research, product development, engineering and production activities.

These downturns are expected to be reversed as new and emerging opportunities in the green energy transition offers South Africa new prospects for sustained industrial development. This is because South Africa is endowed with critical minerals essential for the large-scale manufacturing of clean energy transition technologies. However, evidence suggests that the mining sector has so far played a limited structural transformation role in South Africa, despite the diversified ecosystem of technologically advanced mining equipment companies (Andreoni et al., 2021b). Taking advantage of the green windows of opportunity, therefore, requires targeted policies that address the 'resource curse' and builds a developmental agenda for structural transformation in South Africa.

First, the case studies discussed bring to fore the need for South Africa to implement sector-specific policies that position the country to leverage its unique strengths towards playing lead roles in the development of battery and fuel cells and mining equipment regional value chains in Africa. As noted, South Africa is well positioned, in terms of abundant critical mineral resource endowment and technological expertise, and can leverage their current industrial capacity, skilled workforce, and growing experience in renewable energy to become a regional leader in manufacturing and assembly and industrial battery cell production. For instance, South Africa is one of the countries on the continent where some of these opportunities – namely the development of a lithium-ion battery (LIB) value chain for sustainable mobility and just transition – are materialising rapidly.

Second, local content requirements can help protect existing jobs and increase the share of the work force directly hired, assuming that the skill of domestic human capital is adequate. For instance, South Africa can implement policies and regulations that aim to localise critical parts of the battery cell product production chain and encourage the adoption of locally produced products through South Africa's localisation policy, for instance. If properly formulated, implemented, and monitored, these policies can effectively reduce competitive pressure from imported inputs for local suppliers and create immediate employment opportunities. Otherwise, the risk is that they can end up undermining these objectives in the long-run: on the one hand, if poorly designed and enforced, they might lead to potential distortions penalizing many leading local companies and creating pockets of unproductive rents-capture for a small group of players; on the other hand, if their enforcement along the entire supply chain is not properly monitored, they can prove simply ineffective. To avoid such shortcomings, localisation conditionalities should be developed focusing on their 'policy functions' – i.e., inclusive and sustainable industrialisation – more than simply their 'policy form' – i.e., a certain undifferentiated threshold of local content. These requirements are meant to influence the procurement strategies of mining companies and parts manufacturers and create incentives for local companies to get involved in the supply chain (Andreoni and Roberts, 2022).

These policy instruments have been aimed at increasing local use of locally available products and services in the traditional mining industry, and could be further adapted and developed for critical minerals if purposefully designed. For example, as part of its 2018 Mining Charter, South Africa required mining companies to have 70% of their total mining goods procurement to be spent on domestic manufactured goods (Ramdoo and Cosbey, 2019). In line with this, the local procurement and content policy framework could be reformed along two main directions (Andreoni and Torreggiani, 2020).

The first one would consist in the introduction of a list of specific categories of procurement reserved for local suppliers. The definition of such list would require a thorough assessment of the products and services to target, and the extent to which these products and services meet quantity, quality and price competitiveness parameters. The second option (also in combination with the former) could be introduced in view of linking compliance with local procurement and content requirements with export promotion. Specifically, this option would offer domestic companies the opportunity of contributing to increasing domestic value addition either by increasing the local content of their products and services in the domestic market or by increasing the value of their products and services in the international export market. In a nutshell, companies would be allowed to import more of the products their need, to the extent that they also increase the local content value of the exported products.

This policy could appeal several international OEMs with or without a local footprint as well as domestic OEMs who are affected by the local content requirements in their production expansion and price competitiveness. International OEMs willing to invest in South Africa would now have a new development pathway. They would be allowed to increase their import from their global supply chain for a number of products and services, to the extent that they link up local companies to their exclusive global supply chains and allow them to export internationally. By doing so, local companies would be opened enormous export market opportunities and would potentially become the main supplier of the international OEMs in other major mining countries such as Australia, Canada, Russia and Brazil.

The international OEMs could also link back the local company into their exclusive supply chains, thus 'powering' the local company. Of course, a limited number of domestic companies might be technologically and operationally ready to seize this opportunity. The development potential and growth scope however would be extremely significant. This measure would also create some competitive pressure in domestic backward industries. Local OEMs would have some alternative ways to reach local content requirement, that is, by increasing their export instead of accepting uncompetitive prices.

Moreover, given its central role in the Southern African Development Community (SADC) region, there is potential for regional industrial integration of these minerals notably through the implementation of the SADC Industrialization Strategy and Roadmap 2015-2063, and the recent implementation of the African Continental Free Trade Agreement (AfCFTA). Indeed, SADC is endowed with critical minerals such as graphite (Mozambique and Tanzania), nickel (Botswana, and Zimbabwe), and titanium (Mozambique, Madagascar). Governments in the region, however, will have to closely develop and reinforce regional partnerships to create robust regional value chains. The AfCFTA and other existing sub-regional free trade agreements need to facilitate coordination of these activities. However, it is important to recognise that the location and benefits of activity will not be equal, particularly as some countries already have more capacity than others. Those with the most minerals but the least potential to benefit could block efforts to coordinate. As a failed attempt at establishing a regional coltan refinery in South Africa showed, regional authorities must explore mechanisms for sharing not just the profits from an activity but also the wider economic benefits with producer countries. Given South Africa's economic structure and political economy, how these happen is the 21st century mission and industrial policy question.

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