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Policy Brief

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Africa Beyond Oil And Gas

Low-Carbon Technologies And The Fourth Industrial Revolution Opportunities For Africa

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Keywords: Low-carbon, green economy, minerals, technology, energy, renewable

Summary:

The drive towards a decarbonized economy is much more urgent in this decade as we have ten years remaining to half emissions and keep global warming to 1.5oC. The increasing pressure to move away from fossils, presents serious risks particularly to emerging fossil fuel producing African countries, hoping to transform their economies with prospects from the sector. However, the increasing demand for metals and minerals needed to produce low-carbon technologies, is opening enormous market opportunities for the mining sector. This holds great promise for Africa, possessing rich deposit of the minerals needed not only for the low-carbon future but also for automated future of the rapidly emerging Fourth Industrial Revolution (4IR). The full spectrum of mineral wealth that African nations hold is sparsely known. There is also a lack of understanding of how countries with significant mineral deposits can take advantage of the low carbon technology and 4IR to support sustainable development. Through an extensive review of literature and synthesis of available data, this paper presents a comprehensive report of the distribution of Africa's mineral wealth and interrogates the development options this present to African countries in a low carbon future. This study reveals that Africa holds 42 of the 66 elements required for the emerging low carbon future and the Fourth Industrial Revolution. The paper also presents some of the appropriate governance mechanisms, African governments can adopt to be rightly positioned to take advantage of the enormous opportunities presented by the low-carbon future to create wealth and explore new opportunities to bolster economic growth.

Fig 1: Geological Map of Africa's mineral resources
Source: SEMS exploration, The African Geological Consultancy Group

[1] The 4IR describes a world where individuals move between digital domains and offline reality with the use of connected technology to enable and manage their lives (Xu et al., 2018)

Transitioning from fossil fuel dependence, towards a low-carbon, automated future is opening up new opportunities for a different set of strategic resources (International Energy Agency, 2019). Low-carbon technologies and the Fourth Industrial Revolution (4IR) will require a substantial increase in the volume of mined minerals and metals than is currently produced (World Bank, 2017a). About six times (6x) increase in iron/steel production is needed to service wind turbines (Addison, 2018), About seventy times (70x) of the current production of copper (Kleijn & Van Der Voet, 2010) is needed to transmit electricity generated from clean energy. This opens up enormous market opportunities-for Africa, holding rich deposits of these minerals (International Energy Agency, 2019).

The rapid transition to low-carbon technologies will result in a rapid decline in demand for fossil fuel resources (Bradley, Lahn, & Pye, 2018) and increase the demand for large quantities of metals and minerals (Vidal, Goffé, & Arndt, 2013;Addison, 2018), including: aluminum, copper, iron ore, lead, lithium, nickel, manganese, silver, steel, titanium and zinc copper, cobalt and chrome , the platinum group metals, Rare Earth Elements (REE) (Woude, 2019;World Bank, 2017). Wind technologies require Copper, Aluminum, Chromium, Iron, Lead, Manganese, Nickel, Zinc, Titanium, Silver, Cobalt, Platinum, Molybdenum and neodymium, Rare earth metals (Rene Kleijn & Van Der Voet, 2010; World Bank, 2017b;The World Bank, 2019). Solar PV Aluminum, Silicon, Silver, Tin, Lead, Copper, Indium, Iron, Nickel, Zinc, Gallium, Cadmium, Chromium, Germanium, Tellurium, Rubidium, Caesium (Achzet, Reller, Rennie, Ashfield, & Simmons, 2011; World Bank, 2017b; The World Bank, 2019). The strong growth in fuel cells to power zero-carbon vehicles, will see a considerable demand growth for lithium, lead, copper, nickel, platinum neodymium, vanadium, cobalt and manganese (International Energy Agency, 2019; García-Olivares, Ballabrera-Poy, García-Ladona, & Turiel, 2012;Rene Kleijn & Van Der Voet, 2010; World Bank, 2017b).

Solar Panels	Wind Technology	Battery Storage/Fuel Cells	4IR materials
Cd, Cu, Si, Te, Cu, In, As, Al, Ge, Ni, Se, Sn, Fe, Zn, Pb, Ag, Ti, K, Ni, Zn, Ga, Cr	Al, Fe, Mo, Cd, Pb, Co, Mn, Zn, Cu, Cr, Ni, Ti, Ag, Pt, Nd and other REE	H, Li, C, Li, REE, Co, Cu, Fe, Mn, Si, Cu, Pb, Ni, Ti, Ca, Pt, Nd, V	Co, Al, Ga, Ti, In, Ni, Li, W and REE

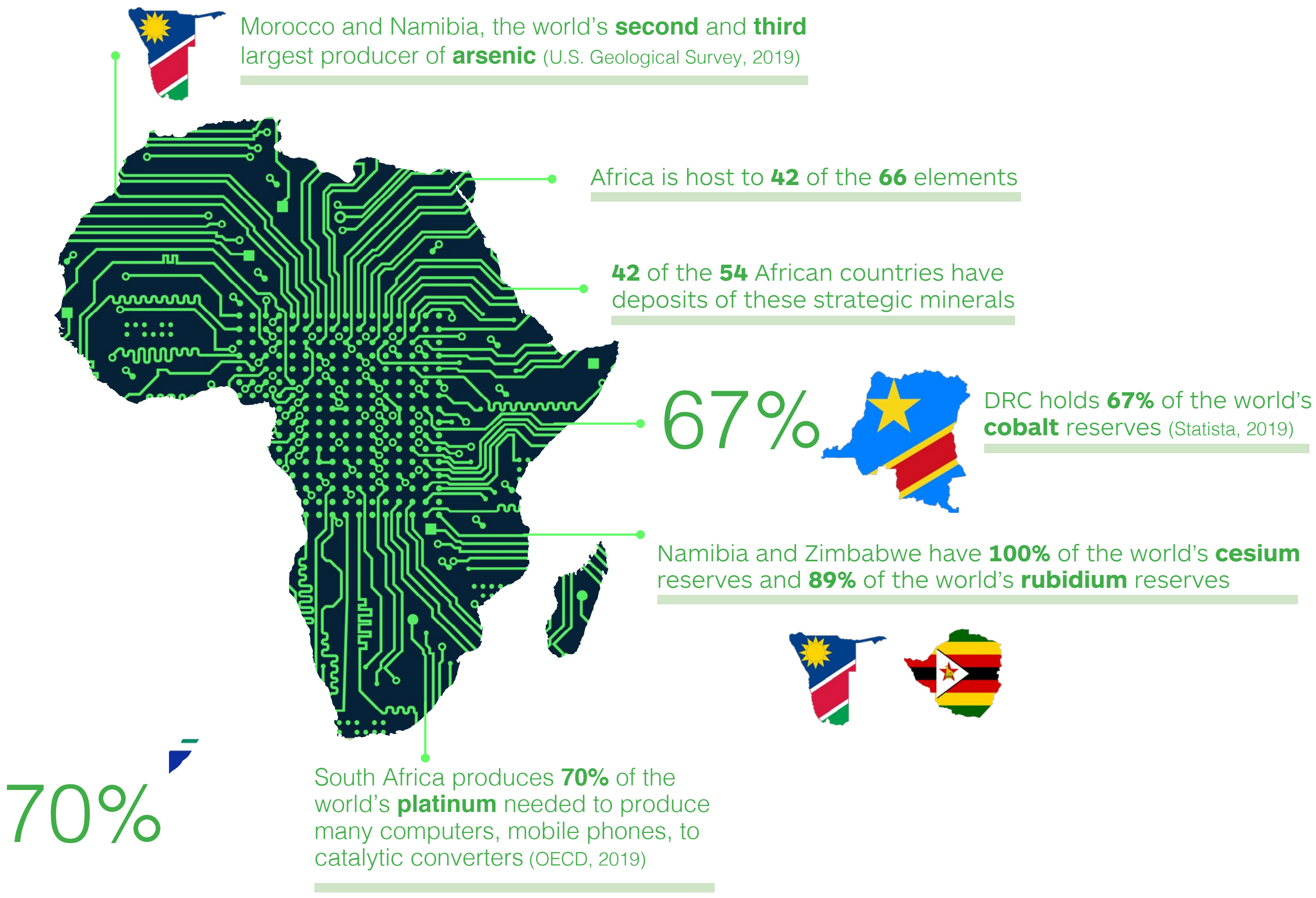
Table 1: Minerals needed for solar technology, wind technology, electric vehicles and energy storage.
Source: Author compiled from various sources

The Fourth Industrial Revolution (4IR) a term coined by Klaus Schwab, founder and executive chairman of the World Economic Forum, describes a world where individuals move between digital domains and offline reality with the use of connected technology to enable and manage their lives (Schwab, 2015). Digitization and automation are the foundation of the 4IR, rapidly revolutionizing every aspect of modern society (Komatsu Mining Corp., 2019). The 4IR is leading to breakthroughs, in: (1)artificial intelligence (AI) robotics (such as machine learning); (2) nanotechnology; (3) biotechnology; (4) quantum computing; (5) blockchain; (6) the Internet of Things (IoT); (7) 3D-printing, etc (Humphreys, 2019;Effoduh, 2016; Xu et al., 2018;Dilberoglu, Gharehpapagh, Yaman, & Dolen, 2017). Material requiremets of the 4IR include: Cobalt, Aluminium, Gallium, Cobalt, Titanium, Indium, Nickel and lithium, Tungsten, REE (Addison, 2018; Dilberoglu et al., 2017). (Table 1).

[2] Rare Earth Elements (REE) are a group of 17 chemically similar metallic elements including the 15 Lanthanide series elements, plus **yttrium** and **Scandium**. is found in most REE deposits and so sometimes classified as an REE. They range from atomic numbers 51-71 (King, 2019;BGS, 2019b).

The rapid changes being brought about by low carbon technologies and the 4th industrial revolution (Xu et al., 2018) offers great opportunities for Africa being host 42 of the 66 elements needed for 4IR. (Fig 1). Forty-two (42) of the 54 African countries have deposits of these strategic minerals. Africa holds two-thirds of global cobalt production, 80 % of platinum, half of manganese production (International Energy Agency, 2019) and 32 % of the world's bauxite resources (U.S. Geological Survey, 2019). The Democratic Republic of the Congo is the world's leading source of cobalt (U.S. Geological Survey, 2019), accounting for two-thirds of global cobalt production (65 %) (Statista, 2019) . Rwanda and DR Congo both produce tantalum (about 30 % and 40 % of the global supply respectively) critical for electronics. Namibia and Niger are producers of uranium (World Nuclear Association, 2019) critical for nuclear power plants (International Energy Agency, 2019). Morocco and Namibia, the world's second and third largest producer of arsenic (U.S. Geological Survey, 2019). Congo (Kinshasa) and Rwanda accounted for 66 % of estimated global tantalum production in 2018 (U.S. Geological Survey, 2019). Namibia and Zimbabwe hold 100 % of the world's Cesium reserves and 89 % of the world's Rubidium reserves (U.S. Geological Survey, 2019)-needed for the manufacture of photoelectric cells. Africa is also home to rare earth elements with rich deposits in South Africa (Steenkampskraal, 2019)

Minerals for low carbon technologies
and the **4th** industrial revolution



Africa holds **two-thirds** of global **cobalt** production, **80%** of **platinum**, **half** of **manganese** production (International Energy Agency, 2019) and **32%** of the world's **bauxite** resources (U.S. Geological Survey, 2019)

Elements Of A Smartphone

Elements colour key:

- Alkali Metal
- Alkaline Earth Metal
- Transition Metal
- Group 13
- Group 14
- Group 15
- Group 16
- Halogen
- Lanthanide

Battery

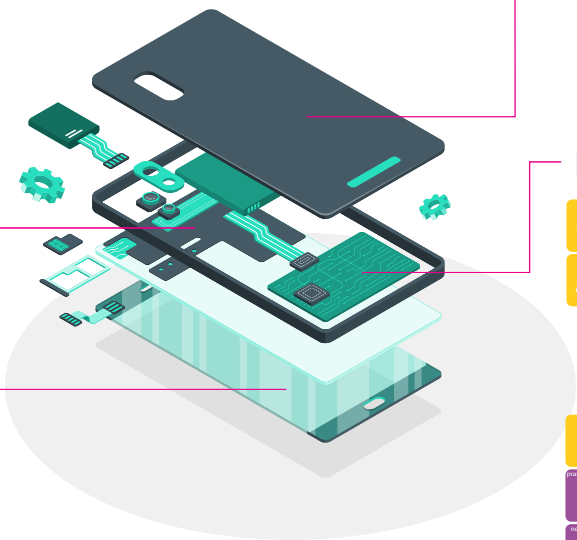
Li Co C Al O

The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminum.

Casing

C Mg Br Ni

Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electro-magnetic interference.



Electronics

Cu Ag Au Ta

Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which micro-electrical components are fashioned. Tantalum is the major component of micro-capacitors.

Ni Dy Pr Tb Nd Gd

Nickel is used in the microphone as well as for other electrical connections, Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.

Si O Sb As P Ga

Pure silicon is used to manufacture the chip in the phone. It is oxidized to produce non-conducting regions, the other elements are added in order to allow the chip to conduct electricity.

Sn Pb

Tin & led are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.

Screen

In Sn O

film in the screen that conducts electricity. This allows the screen to function as a touch screen.

Al Si O K

Th glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina (Al_2O_3) and silica (SiO_2). This glass also contains potassium ions, which help to strengthen it.

Y La Tb Pr Eu Dy Gd

A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone's screen. Some compounds are also used to reduce UV light penetration into the phone.

Fig 2: Different minerals and metals found in mobile phones
Source: Compound Interest 2014

[3] https://www.techwalla.com/articles/what-materials-are-used-to-make-cell-phones
[4] https://www.compoundchem.com/wp-content/uploads/2014/02/The-Chemical-Elements-of-a-Smartphone-v2.png
[5] Digitization is the process of converting non-digital information into digital data.

Periodic table highlighting elements relevant for the 4IR

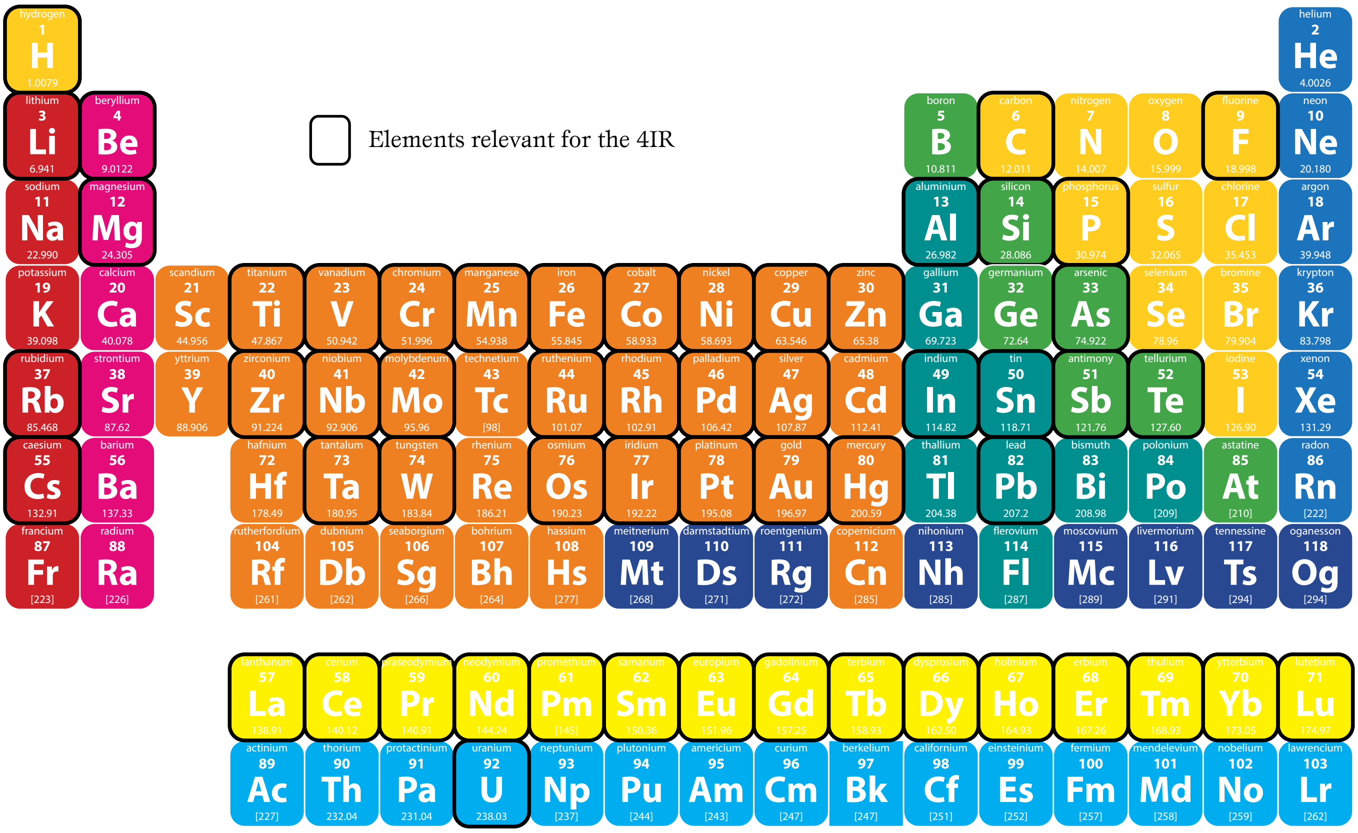


Fig 3: Periodic table highlighting elements relevant for the 4IR
Source: UNU-INRA

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^{3}Li-Lithium ^{35}Br-Bromine Be^{4}-Beryllium ^{24}Cr-Chromium ^{25}Mn-Manganese Fe-Iron
^{27}Co-Cobalt W-Tungsten ^{40}Zr-Zirconium ^{4}Nb-Niobium ^{42}Mo-Molybdenum ^{46}Pd-Palladium
^{76}Os-Osmium ^{21}Sc-Scandium ^{47}Ag-Silver ^{63}As-Arsenic ^{44}Ru-Ruthenium ^{28}Ni-Nickel
^{30}Zn-Zinc ^{15}P-Phosphorus ^{6}C-Carbon ^{92}U-Uranium ^{60}Nd- Neodymium ^{9}F-Fluorine
^{50}Sn-Tin ^{57}La-Lanthanum ^{55}Cs- Cesium ^{45}Rh-Rhodium ^{37} Rb-Rubidium ^{49}In-Indium
^{79}Au-Gold Cd-Cadmium ^{78}Pt-Platinum ^{52}Te-Tellurium ^{59}Pr-Praseodymium ^{82}Pb-Lead
^{8O}-Oxygen 19K-Potassium ^{29}Cu-Copper ^{65}Tb-Terbium ^{66}Dy-Dysprosium ^{39}Y-Yttrium
^{14}Si-Silicon 63Eu-Europium ^{37}Ho-Holmium ^{31}Ga- Gallium ^{64}Gd-Gadolinium ^{51}Sb-Antimony
^{77}Ir-Iridium 73Ta-Tantalum ^{13}Al-Aluminum ^{22}Ti-Titanium ^{12}Mg-Magnesium ^{23}V-Vanadium

Mineral Production/Deposits in Africa

Country	Mineral Resources
Botswana	Fe, U, Ni, Cu, Co, Pt, Au, Pd, Ag, Graphite, Cr, Mn
Mozambique	Bauxite, Au, Graphite, Ta, Ti, Zr, Cu, Fe, V, Al, Pb, Nb
Namibia	As, U, Rh, Zn, Au, Cu, Pb, Mn, Li, Ag, Graphite, Fe, F, Cs, Rb
Zambia	Cu, Co, Au, Pb, Rh, Fe, Zn, Mn, Ni
Zimbabwe	Pd, Pt, other PGM's, Cr, Rh, Au, Co, Au, Graphite, Li, Ni, Phosphate, Cu, W, Cs, Rb, Ag
Angola	Fe, Cu, U, Pb, Zn, Sn, V, Ni, Au,
DRC	Co, Cu, Au, Ag, Sn, Zn, W, Ta, Li, Pb, Nb
Congo	Au
Tanzania	Au, Al, Cu, Graphite, Ag, Ni, U, Ti, Phosphate, Sn
Niger	Au, Ag, Sn, U, Ni
Burkina Faso	Au, Zn, Mn, Cu, Mo, Pb, Ag
Mali	Au, Phosphate, Al, Cr, Cu, Fe, Pb, Li, Mn, Ni, Ag, Ti, U, W
Kenya	Ti, Zr, Au, Mn, Zr, F
Senegal	Phosphate, Ti, Zr, Au, Fe, Ag
Ghana	Bauxite, Au, Mn, Li, Ag, Al
Gabon	Mn, Au,
Egypt	Phosphate, Al, Au, Fe, Mn, Sn, F
Ethiopia	Pt, Pd, Nb
Togo	Phosphate, Au
Morocco	As, Co, Phosphate, Cu, Au, Fe, Mn, Ni, Ag, Zn, F, Pb
Ethiopia	Ta, Au, Ag
Nigeria	Ta, Sn, Al, Au, Fe, Pb, Zr, Ag, Zn, Nb, W
Rwanda	Ta, Sn, W, Au, Be, Nb

Sierra Leone	Ti, Bauxite, Au, Fe, Zr
Guinea	Al, Fe, Au
Madagascar	Graphite, Cr, Co, Au, Ni, Zr, Cu, Be, Ti
Cameroon	Al, Au
Sudan	Cr, Au, Fe, Mn, Ag, Zn
Uganda	Co, Au, Fe, Ta, Sn, W
Benin	Au
Central African Republic	Au,
Equatorial Guinea	Au
Ivory Coast	Au, Mn, Ni, Ag
Liberia	Au, Fe
South Sudan	Au
Algeria	Au, Fe, Ag, Zn
Burundi	Au, Ta, Sn, W, Nb
Eritrea	Au, Ag, Zn
Mauritania	Au, Fe
Malawi	Fe, U
Swaziland	Fe
Tunisia	Fe, Zn, P

Table 2: Mineral Production/Deposits in Africa
Source: Author based on British Geological Survey, 2017;U.S. Geological Survey, 2019; World Bank, 2017b and Global Business Reports, 2016

South Africa's Mineral Resources for the 4th Industrial revolution

South Africa holds greater promise for these prospects, with 35 of the key minerals and currently producing 25 (Minerals Council South Africa, 2019). (Table 2). South Africa has the largest deposit (70 %) of PGM`s (used both in internal combustion engines and fuel cells) and second largest deposits and the leading global producer of chromium (U.S. Geological Survey, 2019), South Africa produces 70 % of the worlds platinum, 45 % of the chromium (used in wind turbines) and a third (74 %) of the world's manganese (a vital element for steel and advanced batteries) (International Energy Agency, 2019; U.S. Geological Survey, 2019). South Africa also has rich deposits of platinum, vermiculite, chromium, palladium, zirconium, vanadium, rutile, ilmenite, manganese, and gold, including the exceptionally rare PGM's among others (Global Business Reports, 2016). South Africa, mines at least five of the 16 minerals/metals used to produce solar panels, namely iron ore, lead, phosphate rock, silica and titanium oxide (Harvey, 2019).

Mineral	% of Worlds Production
Antimony	16.7
Chromium	45
Copper	2.4
Gold	12.7
Iron	0.8
Lead	2.1
Manganese Ore	80
Nickel	5.2
PGM's	87.7
Phosphate	5.3
Titanium	9.8
Uranium	8
Vanadium	32
Zinc	3.3
Zirconium	25
Silicon	1
Fluorspar (F)	17
Cobalt	1.6
Aluminum	*
Silver	*
Rhodium	*
Tellurium	1.6
Rare Earth Metals	*

Table 3: South Africa's Mineral Resources for the 4th Industrial revolution
Source: Author compiled from a variety of sources

South Africa has the highest-grade rare earth's metal mine in the world useful for cell phones, computer memory, wind turbines and cell phone batteries. (Fig 4)

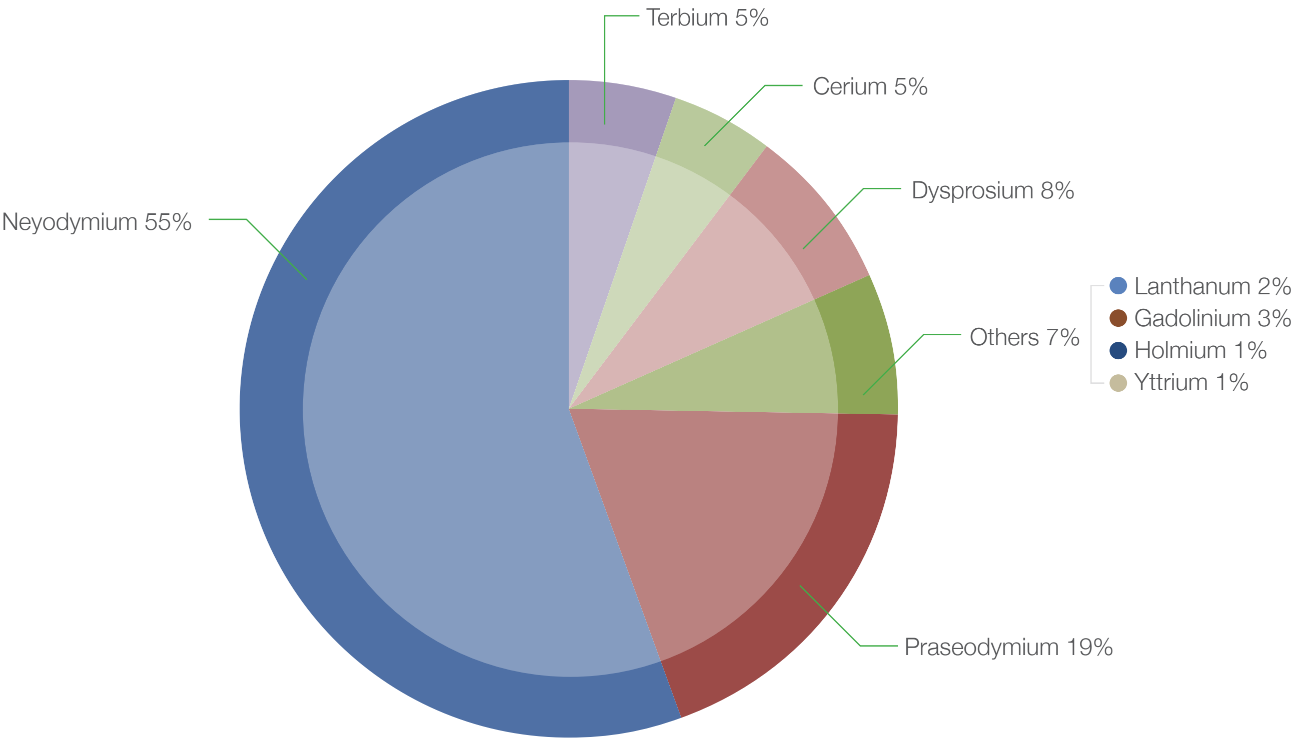

Fig 4: Relative economic value of the rare earth metals at Steenkampskraal mine in Western Cape South Africa. Source: Steenkampskraal (2019)

Next steps

There is a particular concern about growing economic importance and high risk of supply shortage of some of these critical metals", delivering new low-carbon energy, transport and digital technologies (MineralsUK, 2017; Living With Environemental Change, 2015). Among these are: antimony, beryllium, cobalt, gallium, germanium, graphite, indium, magnesium, niobium, platinum group metals, rare earth elements, tantalum, tungsten. This calls for efficient use and recycling of these materials (BGS, 2019a).

African countries enriched with these strategic minerals must develop strong governance structures and the right capacities and strategies to enable them realize maximize the benefit of these resources. African government must apply the right fiscal policies to enhance their competitiveness and attract investments (Dobbs et al., 2013). About 37% of reserves of minerals and metals are in countries with weak resource governance (Tilley & Manley, 2017). Though global poverty is falling, many mineral-rich African countries like the DRC, Zambia, and Zimbabwe have rising poverty levels (FERREIRA, LAKNER, & SÁNCHEZ-PÁRAMO, 2017;Arndt, McKay, & Tarp, 2016). Zimbabwe's output of lithium is far below other producing countries, despite having much larger reserves). Fragile states like the DRC risk missing the many development benefits of a future in which low-carbon pathways generate a rising demand for their metals and minerals (Addison, 2018).

37%

About **37%** of reserves of minerals and metals are in countries with weak resource

(Tilley & Manley, 2017)

African governments must prepare to provide critical infrastructure-road/rail facility, water supply and power. This can be done in synergy with the development plans of the community to enable development of not only the natural resources but also enable greater community engagement in economic activity associated with mining and by that promote development of local communities and diversification of the economy (Dobbs et al., 2013). African government expecting to be relevant in metals and minerals market for the low carbon future must begin to decarbonize their energy system by increasing the share of renewables in the power supplied to mines, and in the transport system which serves them reducing their own GHG emissions (Addison, 2018).

African governments must be well prepared by building their capacity on contracting (Dobbs et al., 2013; UNECA, 2011). governments' interactions with extractive companies, it is particularly important that they have strong market intelligence that encompasses prices, trends, investment dynamics, the economics of exploration, and the drivers of domestic competitiveness (Dobbs et al., 2013)

African governments must begin to diversify their economies to be less dependent on fossil fuel and begin to design policies and approaches to take advantage of the emerging markets of the low carbon future and the 4th Industrial revolution.

Governments must develop a mineral beneficiation strategy to enable them realize the full potential of their mineral wealth. In the resources sector, this often means creating new industries that process a country's resources rather than export raw materials.(refining and manufacturing processes) makes substantial contributions to economic development through employment, skills development, and supply chains (Dobbs et al., 2013). a resources boom can also be an opportunity to create a step change in agricultural productivity. A rapidly growing resources sector can create rising prosperity and therefore increase the demand for food. At the same time, a resources boom can reinforce urbanization through the migration of people from rural areas to cities by creating demand for local services and potentially public-sector employment. Higher demand for food and fewer people working on farms is an opportunity to adopt new techniques to improve agriculture productivity—indeed, doing so is a necessity.

Policy Considerations

1. Africa's knowledge of the scale and distribution of these mineral and metal resources remains is limited. There should be increase investments in mineral mapping and exploration to provide sufficient data on the deposits and reserves of these resources.
2. Governments need to develop an industrialization strategy to take advantage of the opportunities associated with the 4th industrial revolution such as electric vehicles and robotics.
3. Restructure their governance structures and be well placed to benefit from the resource boom that is emerging from the low-carbon transition Weak resource governance deters the investment necessary to develop the sector and provide the revenues. (Addison, 2018).
4. African governments should put in place measures to ensure sustainable production, consumption and recycling of critical metals.

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Institute for Natural Resources in Africa

About UNU-INRA

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The United Nations University Institute for Natural Resources in Africa (UNU-INRA) is one of the 15 research and training centres of the United Nations University (UNU) and is the only one focusing predominantly on Africa. We provide cutting-edge solutions and knowledge outlets for natural resource planning and management from an African perspective.

UNU-INRA serves as a platform to amplify African voices and showcase made-in-Africa solutions. We harness the incredible talent on the continent and also strengthen and develop capabilities by equipping African researchers, entrepreneurs and policy actors with the requisite knowledge to sustainably manage natural resources. We deliver research, capacity development and policy advice, and we convene spaces for knowledge sharing.

Our operating units across 5 countries in Africa (Senegal, Ivory Coast, Cameroon, Zambia and Namibia) give us on-the-ground knowledge, while our global network of experts and the wider UNU group give us a comparative advantage in the production and export of knowledge.

It is our vision for Africa to realise the transformational potential of natural resources in the context of sustainable development and deliver a prosperous, fair and resilient future.

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