Climate Compatible Growth

POLICY BRIEF

Beyond Extraction: Simulating Increased Battery Mineral Value Addition in Southern Africa

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SUMMARY

Demand for critical minerals is set to rise sharply with the global energy transition. Africa holds vast reserves—especially of battery minerals—but has historically remained at the lower end of value chains, creating an opportunity to expand into refining and manufacturing. Competing approaches of resource nationalism and regional collaboration coexist, yet no comprehensive assessment has examined their implications. This policy brief presents an exploration of potential for mineral value addition under these two scenarios, examining six minerals in the electric vehicle battery value chain (copper, cobalt, graphite, lithium, manganese, and nickel) across 14 Southern African countries. Mining and processing activities, as well as associated implications for infrastructure and environment, are considered. The results identify significant potential to increase net export revenues by diversifying mining activities and moving up the value chain into processing, particularly where there is regional cooperation. However, a regional processing approach would heighten demand for transport and energy infrastructure in order to realise the resulting increased potential for mineral and metal processing in Southern Africa. Delivering a regional approach would also require overcoming political challenges to cross-border trade and benefit sharing. Under either scenario, environmental impacts across Southern Africa would approximately double relative to business-as-usual.

KEY FINDINGS

- Simulations indicate a substantial potential for the scale-up of three minerals with relatively modest production in 2022: graphite, nickel, and lithium.
- Under the simulations, mining of more well-established minerals, including cobalt and copper, stagnates or declines unless additional geological exploration is undertaken to identify new deposits.
- Simulations indicate a high potential for increased net export revenue for many countries by 2040, considering future demand. This includes countries that are currently large exporters (eg DRC, South Africa, and Zambia) but also relative newcomers which, under the simulations, emerge as exporting relatively modest volumes but with a meaningful impact on GDP. These include Namibia, Burundi, Zimbabwe, Madagascar, and Malawi.
- Simulations suggest that regional cooperation leads to substantially higher net export revenues across the region than resource nationalist approaches, mainly driven by cobalt, copper, and lithium.
- There is a tendency for regional cooperation to shift processing activities out of more landlocked countries (such as DRC, Malawi, and Zimbabwe) towards larger and generally coastally situated countries (Angola, Mozambique, South Africa, and Tanzania).
- While the continent stands to gain substantially from regional cooperation in processing, the benefits are not shared equally. Well-designed benefit-sharing agreements are therefore likely to be needed for successful cooperation.

PHOTO: ISTOCKPHOTO.COM

Miners discuss their mining plan in an underground mine – Mwinilunga, Zambia

KEY POLICY RECOMMENDATIONS

- Invest in improved data on geological deposits, processing costs, mineral prices, and trading patterns. Better data would form the foundation of an improved evidence base to inform policy and investment decisions.
- Support a regional processing approach to harness increased economic development benefits, incorporating mechanisms to ensure that mineral processing benefits can be shared across upstream and downstream countries.
- Make targeted investments in energy and transport infrastructure that support the development of mineral value chains, with particular attention to low carbon energy for processing hubs and regional transport linkages.
- Limit environmental impacts of mineral value chain development by avoiding new mining or refining activity in biodiversity-rich areas and water-intensive processing in water-scarce areas.

Introduction

Demand for critical minerals is accelerating due to the clean energy transition [1]. There has been growing international interest in the processing of critical minerals in Africa, given its significant mineral reserves. This trend reflects both growing aspirations for value addition in mineral producing countries [2] and mounting concerns in manufacturing countries about the concentration of global supply chains [3].

However, scaling-up local mineral processing capacity in Africa is hindered by technical, labour, and financial challenges, alongside limited energy and transport infrastructure and significant environmental and social governance concerns [4–8].

Given substantial African mineral endowments of many lithium-ion battery minerals [3], an expansion of critical minerals processing into producing higher-value commodities could be expected to have wide-ranging economic effects in terms of export revenues, local value addition, forwards and backwards supply chain linkages (ie industries and other economic activities feeding in and out of mineral value chains), multiplier effects, and fiscal revenues. However, there are also significant concerns about the potential adverse effects of the mining sector, including environmental impacts and the lack of creation of long-term benefits for local communities [9]. Thus, approaches to deliberately support industrial expansion and manage economic and environmental implications are required.

Some African regional institutions have advocated for a collaborative regional approach to mineral processing, joining cross-border efforts to achieve economies of scale and leverage country comparative advantages [10–11]. These calls are backed by policy studies suggesting benefits could be achieved through a regional approach [12–13]. In parallel, a growing number of African countries have enacted export bans on unprocessed minerals, preferring to pursue a resource nationalist approach [14–17].

To date, there has been limited evidence on which to base such significant policy choices, due to a paucity of underlying data [18] and a lack of geospatial modelling with a regional focus. Most previous studies focus on specific countries or minerals [5–6; 19], without providing a broader strategic roadmap. This policy brief draws insights from a significant new research effort to build a geospatial platform which will enable ‘what-if’ simulations of future mineral processing. This is based on the integration of all available technical and economic data on mining and processing activities, energy and transport networks, as well as environmental and governance constraints [20].

The study currently focuses on the value chain for six battery minerals (cobalt, copper, graphite, lithium, manganese, and nickel) across 14 Southern African countries with relevant endowments (Angola, Botswana, Burundi, DRC, Kenya, Madagascar, Malawi, Mozambique, Namibia, Uganda, South Africa, Tanzania, Zambia, and Zimbabwe). Geographically granular simulations of alternative critical mineral processing futures are undertaken. Modelling inputs include geolocated mines and their production costs; value addition steps along the critical minerals supply chain and their material, energy, and water requirements; supply of and requirement for transport and energy infrastructure; projected future prices of critical minerals and processed products in the international market; and geolocated areas of future water scarcity or rich in biodiversity.

The simulations focus on three illustrative scenarios for 2040 with varying ambitions on the level of mineral processing in Africa prior to export (shown in **Table 1**). Beyond business-as-usual, the two scenarios with processing ambition include advancing to either refined mineral products or battery-precursor inputs to identify the potential for integration with the electric vehicle (EV) value chain. The proportion of each mineral reaching higher levels of refinement under each scenario reflects EV battery global demand estimations. The scenarios can be explored both with and without regional cooperation, as well as with and without the observance of environmental constraints. This work is part of an FCDO-funded project undertaken by Climate Compatible Growth, with key results presented in this policy brief. However, the extensive methodological underpinnings of the analysis are covered elsewhere [20].

This policy brief focuses on ten topical policy questions. The same analysis could in principle be extended to cover (in increasing order of complexity) different policy targets, other value chains for the same minerals, other minerals for the same countries, and other countries in Africa or beyond.

Q1: What is the potential for expanding battery mineral production?

The map below illustrates the potential evolution of battery mineral extraction in Southern Africa from the 2022 baseline year through to 2040, presenting two contrasting narratives (Figure 1).

On the one hand, simulations indicate a substantial potential for scaling up mining of three minerals with relatively modest production in 2022, given Africa's reserves and global demand. These are graphite, nickel, and lithium. Graphite production (shaded green in **Figure 1**) increases twelvefold, primarily concentrated in Malawi, Mozambique, and Tanzania, as well as Madagascar. Nickel production (shaded dark orange in Figure 1) increases almost sixfold, with growing production in South Africa and Madagascar, as well as significant new entry from Tanzania and Burundi. Lithium production (shaded violet in Figure 1) triples, driven by expansion in Zimbabwe and Namibia and continued production in DRC.

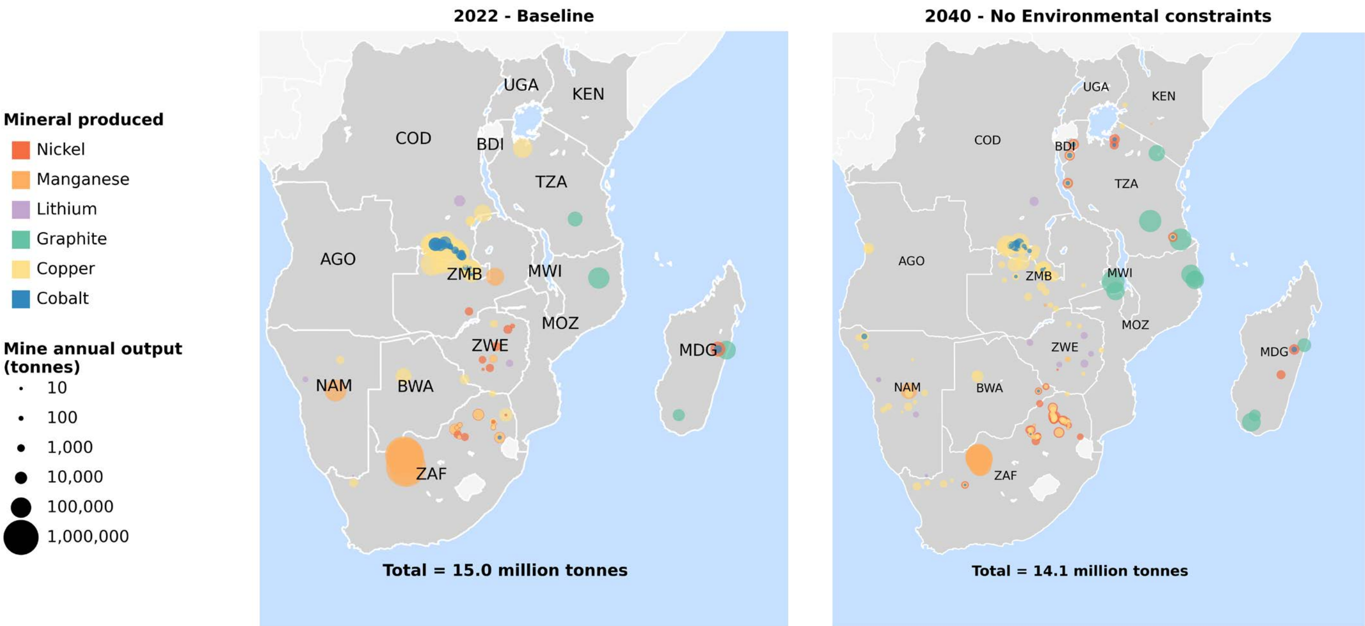
By contrast, the simulations suggest that mining of more well-established minerals experiences stagnation (in the case of cobalt) and even significant decline (in the cases of copper and manganese). This is due to the dependence of mineral extraction simulations on current information regarding geological deposits, where production based on known deposits is expected to peak before 2040 unless further geological exploration is undertaken to identify new deposits (mainly for copper, cobalt, and manganese). While such exploration is likely to occur in practice, the outcomes cannot be anticipated at this stage.

The mining expansion translates into distinct processing patterns by scenario. In the Business-as-Usual scenario, mineral beneficiation increases 10% compared to 2022. Early Refining scenarios shift emphasis to intermediate processing, more than doubling baseline volumes primarily for copper, nickel, and cobalt. Precursor scenarios simulate the highest processing activity, expanding advanced processing tenfold, led by copper, nickel, and cobalt

***Table 1:** Scenarios considered in the study*

2040 Scenario	Description
Business-as-Usual (BAU)	A pessimistic scenario in which no additional mineral processing capacity is developed in Southern Africa beyond what existed in the baseline year 2022. Most countries would at least conduct beneficiation of minerals, namely producing a concentrate. This is preserved in the scenario.
Early Refining	A challenging scenario in which most minerals produced in 2040 would undergo an intermediate stage of processing prior to export. Products include copper metal (cathode, 100% conversion share), cobalt hydroxide (100%), spherical graphite (30%), lithium carbonate (100%), manganese oxide (10%), and nickel matte (100%). Conversion shares from extraction assumed for each product are reflective of projected global battery demand.
Precursor-Related Product	A very ambitious scenario in which a significant share of minerals produced in 2040 would be processed into inputs to battery precursor manufacturing prior to export. Products include copper sulphate (50% conversion), cobalt sulphate (60%), lithium hydroxide (100%), manganese sulphate (10%), spherical purified graphite (40%), and nickel sulphate (25%). Conversion shares from extraction assumed for each product are reflective of projected global battery demand.

***Figure 1:** Simulated evolution of battery mineral production in Southern Africa between 2022 baseline and simulations for 2040. ISO3 country codes are used for each country, namely: AGO: Angola, BWA: Botswana, BDI: Burundi, COD: Democratic Republic of the Congo, KEN: Kenya, MDG: Madagascar, MWI: Malawi, MOZ: Mozambique, NAM: Namibia, ZAF: South Africa, TZA: Tanzania, UGA: Uganda, ZMB: Zambia, ZWE: Zimbabwe.*



Q2: How could processing contribute to export revenues?

Export revenues provide a simple metric to gauge the economic scale of the opportunity, although these are sensitive to highly uncertain projections of future absolute and relative prices in 2040. Moreover, mineral export revenues alone do not reflect the full scale of potential economic benefits to a country, as they do not include forwards and backwards linkages and associated multiplier effects. To include the cost of importing unprocessed minerals as they are moved across borders, net export revenues were evaluated.

The countries with the largest absolute annual net export revenues from battery minerals in 2040, according to the simulations, continue to be largely the same as in 2022, notably DRC (US$71 billion), South Africa (US$22 billion) and Zambia (US$10 billion). Notable newcomers in 2040 are Tanzania (US$16 billion), which emerges as a major producer of graphite and nickel, and Zimbabwe (US$11 billion) with lithium production.

Furthermore, several other countries emerge as producers of battery minerals by 2040. While the absolute value of their exports remains small relative to the top four countries mentioned above, when normalised relative to their national income, it becomes clear that these relatively modest exports could still be economically significant for them. Net export revenues as a percentage of projected 2040 GDP in environmentally unconstrained scenarios reach 17–32% for Burundi and Namibia, 10–17% for Zimbabwe, and around 10% for Madagascar and Malawi, with some variation across scenarios.

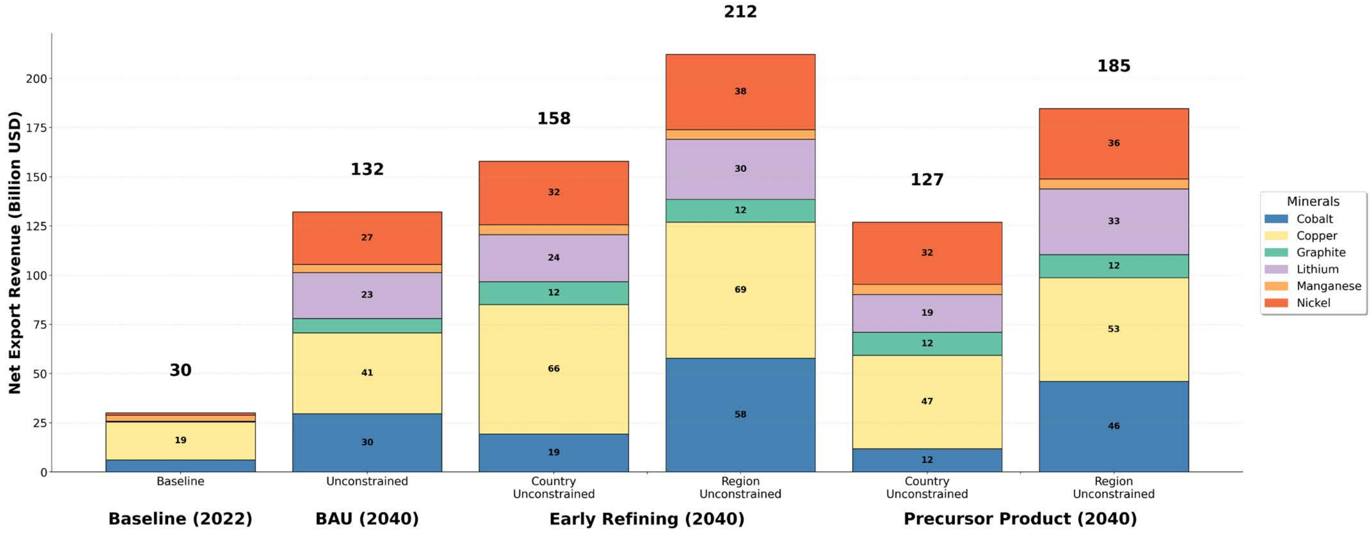
Q3: How would regional cooperation affect the potential for increased processing in Southern Africa?

Both resource nationalism and regional cooperation for mineral processing are simulated. In the nationalist approach, minerals are processed domestically as long as production meets minimum observable scale thresholds and otherwise exported unprocessed. In the regionalist approach, minerals are allowed to move across African borders to achieve economies of scale at regional processing hubs.

The regional approach reconfigures trade patterns by allowing more unprocessed minerals, mainly copper and cobalt, to cross borders, permitting more processed minerals such as lithium carbonate and cobalt hydroxide to be produced. Simulations suggest that regional cooperation leads to substantially higher net export revenues across the region than resource nationalist approaches, which offer only modest improvements on business-as-usual exports of mainly unprocessed ores (**Figure 2**).

Overall, regional cooperation leads to regional net export revenues 34–46% higher than under resource nationalism. These results are mainly driven by cobalt, lithium, copper, and nickel, all of which see a significant expansion in net export revenues as a result of regional cooperation.

***Figure 2:** Simulated evolution of battery mineral net export revenues in Southern Africa under selected scenarios regarding the extent of regional cooperation. BAU refers to Business-as-Usual. These scenarios are all without environmental constraints (thus the Unconstrained label accompanying the type of approach). Net export revenues refer to export revenues minus import costs.*



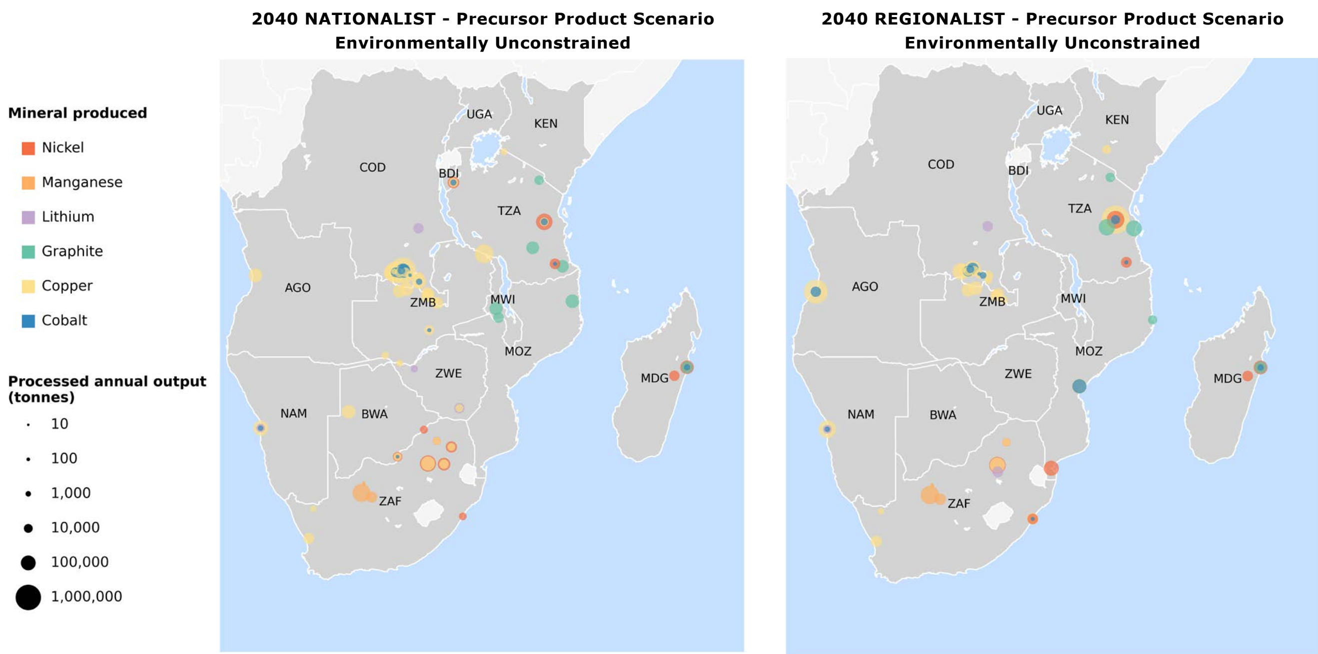
Q4: **How does regional cooperation affect specific countries?**

Regional cooperation entails a shift of processing activities across borders, in order to reap economies of scale and optimise infrastructure inputs. Overall, there is a systematic tendency for regional cooperation to shift processing activities out of more landlocked countries (such as DRC, Malawi, and Zimbabwe) towards larger and generally coastally situated countries (Angola, Mozambique, South Africa, and Tanzania) (see **Figure 3**). The countries that undertake additional processing activities through regional cooperation also tend to perform somewhat better in terms of environmental and social governance indices such as the Environmental Performance Index [21], Positive Peace Index [22], or Resource Governance Index [23] (despite governance not being a factor for selecting locations in the model).

This section describes simulated shifts in processing activity between the nationalist scenario and the regional cooperation scenario for specific minerals. For copper, the main shift in processing activity is from DRC, towards Tanzania (c. 1.1–1.7 million tonnes per year), with a much smaller shift from Zambia (c. 0.04–0.1 million tonnes per year) towards Angola and Namibia. Processing of cobalt at early refining also shifts from DRC (c. 0.2 million tonnes per year) towards Tanzania and in smaller amounts to Mozambique. When it comes to graphite, regional cooperation brings about a shift of processing activities away from Malawi and Mozambique (c. 0.2 million tonnes per year combined) towards Tanzania, particularly for early refining. Regarding lithium, regional cooperation moves 0.05 million tonnes of product away from Zimbabwe towards South Africa. In the case of nickel, regional cooperation shifts 0.1 million tonnes of processing activity away from South Africa, while for manganese, there are no substantial differences between the regional and national scenarios.

Whether or not these shifts in processing activities translate into economic losses for landlocked countries ultimately depends on the benefit-sharing arrangements that are put in place as part of any regional cooperation agreements. However, the results suggest that, without careful design of benefit-sharing arrangements, there is a risk that these economic losses could occur, which may dilute incentives for regional cooperation.

***Figure 3:** Simulated evolution of battery mineral processing in Southern Africa between Precursor-Related Product scenarios based on resource nationalist and regional cooperation in 2040. ISO3 country codes are used for each country, namely: AGO: Angola, BWA: Botswana, BDI: Burundi, COD: Democratic Republic of the Congo, KEN: Kenya, MDG: Madagascar, MWI: Malawi, MOZ: Mozambique, NAM: Namibia, ZAF: South Africa, TZA: Tanzania, UGA: Uganda, ZMB: Zambia, ZWE: Zimbabwe.*



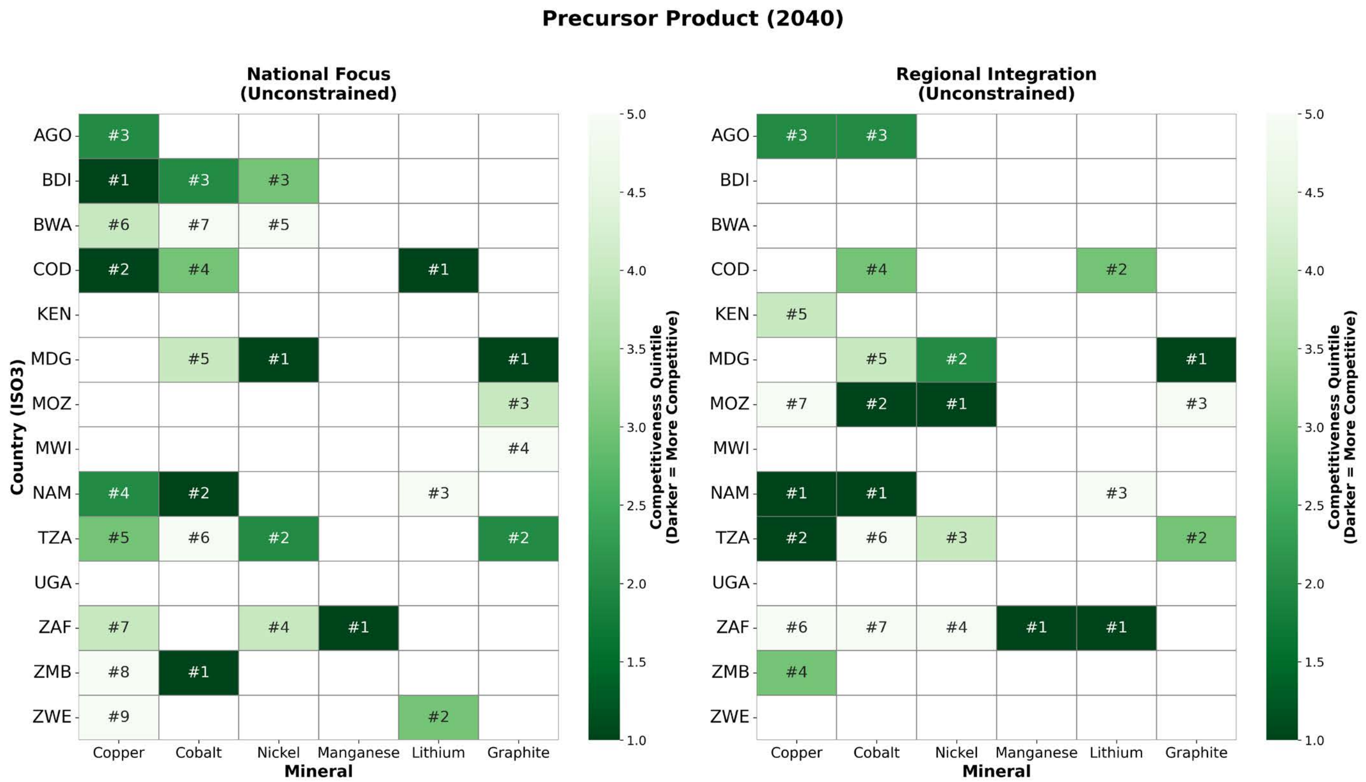
Q5: How competitive is Southern Africa's mineral production?

Fully evaluating the absolute competitiveness of Southern Africa's battery mineral production and processing by 2040 would require projecting the associated costs of doing so across other regions of the world, which is beyond the scope of this exercise. The simulations for this analysis assume that Southern Africa could preserve its existing market share of global production of traditional minerals such as copper and cobalt while increasing the share of minerals of recent interest such as graphite and lithium, assuming current levels of global competitiveness.

Nevertheless, the geospatial platform sheds light on the relative competitiveness of different countries in Southern Africa as producers of a given mineral and allows for the construction of regional supply curves, identifying the unit costs of specific products. Country-specific production costs reflect the scale of processing activity, as well as the local costs of energy and transport infrastructure (**Figure 4**). In the scenario with the highest processing ambition, the most competitive countries are Mozambique (graphite), Namibia (lithium), South Africa (manganese), Madagascar (nickel), Zambia (cobalt), and Burundi (copper) under resource nationalism. Regional collaboration results in some of these countries preserving their competitiveness (for example Madagascar for nickel and South Africa for manganese); however, increased competitiveness of coastal countries such as South Africa (lithium) or Tanzania is also observed.

Q6: How much energy will be needed?
Meeting the ambitious mineral processing targets simulated can be expected to place significant additional demands for electricity (among other sources of energy). Given the magnitude of the loads, simulations suggest that it would be economic to meet this almost entirely from grid (as opposed to off-grid) electricity. Intermediate stage copper processing is by far the most

***Figure 4:** Relative competitiveness of Southern African countries for production of processed minerals in 2040 in the Precursor-Related Product Scenario under resource nationalism and regional collaboration. Colours show within-mineral quintile rankings. Darker green means more competitive and therefore lower cost. Costs considered for the ranking are cumulative unit costs of production, transport, and energy for all processing stages up to the scenario target. ISO3 country codes are used for each country, namely: AGO: Angola, BWA: Botswana, BDI: Burundi, COD: Democratic Republic of the Congo, KEN: Kenya, MDG: Madagascar, MWI: Malawi, MOZ: Mozambique, NAM: Namibia, ZAF: South Africa, TZA: Tanzania, UGA: Uganda, ZMB: Zambia, ZWE: Zimbabwe.*



electricity-intensive of the cases considered. Nonetheless, intermediate stage processing of cobalt, graphite, and nickel also generates significant demands.

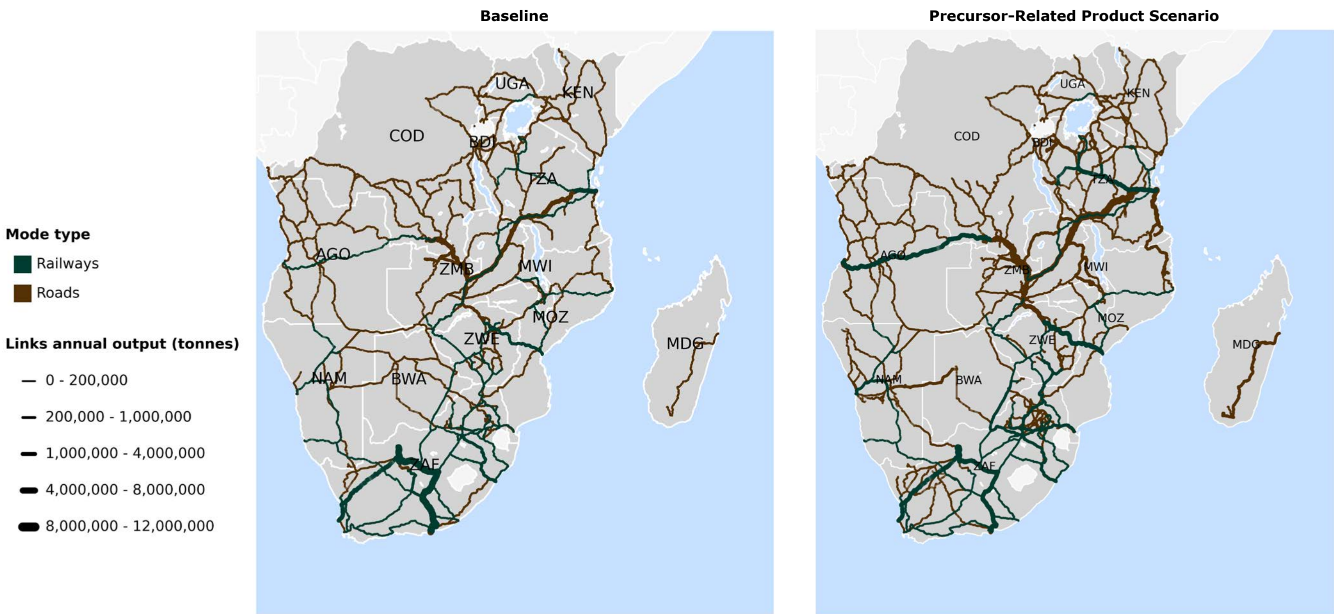
For some countries, the impact of increased mineral processing on national power systems would be very large, raising concerns about the feasibility of infrastructure expansion. DRC and Namibia, in particular, stand out as needing to expand national generation capacity by as much as 30% to accommodate the processing targets considered here under regional scenarios—with DRC also needing this expansion in nationalist scenarios. Other countries that could need to substantially expand national generation capacity (by 10–20%) include Botswana (under nationalist scenarios), as well as Burundi and Tanzania (both under regionalist scenarios). Countries such as Angola, Madagascar, Malawi, Mozambique, and Zambia would face smaller expansions of the order of 5% of national power generation capacity regardless of the approach considered.

In general, regional cooperation entails greater investment in energy infrastructure due to the concentration of processing activities in certain countries, which places a greater strain on their national energy development plans.

Q7: What are the implications for transport infrastructure?

Transport demand is affected by the bulkiness of minerals at different stages of processing and the geographical locations of mines, processing facilities, port infrastructure, and destination markets. Depending on routes, either road or rail infrastructure may be used (shown by red and black lines respectively in **Figure 5**). Simulations assume that existing trading patterns are preserved into the future (ie that whatever future minerals were produced by a country,

***Figure 5:** Simulated evolution of battery mineral freight traffic across Southern Africa's multi-modal transport networks to maritime gateways, illustrating the 2022 Baseline (left) and the 2040 Precursor-Related Product Scenario (right) under regional collaboration. ISO3 country codes are used for each country, namely: AGO: Angola, BWA: Botswana, BDI: Burundi, COD: Democratic Republic of the Congo, KEN: Kenya, MDG: Madagascar, MWI: Malawi, MOZ: Mozambique, NAM: Namibia, ZAF: South Africa, TZA: Tanzania, UGA: Uganda, ZMB: Zambia, ZWE: Zimbabwe.*



they are sent in the same shares to the same destination markets as currently).

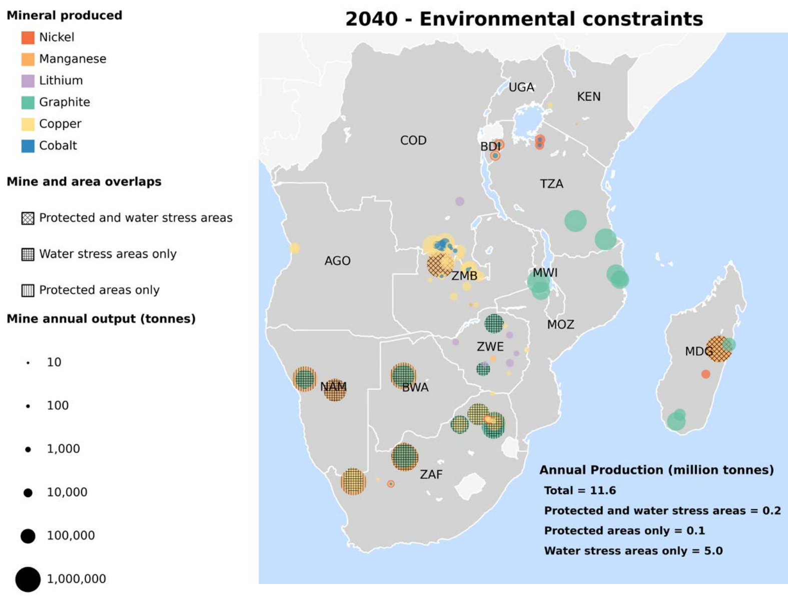
As mining production expands there is a growing density of associated roads as new mines open-up more outlying locations. In addition, two areas experience particularly marked traffic growth and increasing use of transport infrastructure. One is the corridor from the Copperbelt on the DRC–Zambia border, both eastwards towards Dar es Salaam in Tanzania (doubling in some parts of the transport network and reaching 6–8 million tonnes of traffic per annum by 2040) and, to a lesser extent, westwards towards Lobito in Angola (increasing the use of rail and almost tripling volumes on some routes up to 4 million tonnes of traffic per annum by 2040). The other is the corridor linking the Northwest province of South Africa to Cape Town (on the southwestern side) and Port Elizabeth (Gqeberha) (on the southeastern side), with traffic volumes along these routes simulated to reach 8 million tonnes per annum by 2040.

Q8: What are the environmental risks from increased mineral processing?

Many parts of Southern Africa present environmental sensitivities that carry risks for biodiversity and/or water availability. These sensitivities could potentially restrict the extent of mining development and mineral processing. The countries at the southern tip of the continent (Botswana, Namibia, and South Africa, as well as parts of Angola, Mozambique, and Zimbabwe) are arid and affected by varying degrees of water scarcity. Countries in the equatorial belt have significant reserves of land rich in biodiversity (notably DRC, Tanzania, and Zambia, as well as parts of Mozambique and Zimbabwe). Overall, almost two-thirds of the land area of Southern Africa is affected either by biodiversity or water scarcity factors.

To explore the sensitivity of mining and processing to such considerations, an environmentally constrained scenario is used to simulate a strict prohibition of activities in all areas either affected by water scarcity or exhibiting rich biodiversity (**Figure 6**). The results

***Figure 6:** Simulated mineral production areas and their environmental impact categories resulting from applying environmental constraints in 2040 Scenarios in metal content units (or mineral in the case of graphite). Environmental impacts refer to either water scarce- or biodiverse-rich areas (labelled as protected). ISO3 country codes are used for each country, namely: AGO: Angola, BWA: Botswana, BDI: Burundi, COD: Democratic Republic of the Congo, KEN: Kenya, MDG: Madagascar, MWI: Malawi, MOZ: Mozambique, NAM: Namibia, ZAF: South Africa, TZA: Tanzania, UGA: Uganda, ZMB: Zambia, ZWE: Zimbabwe.*



suggest that this would reduce simulated battery mineral production in 2040 by almost 20%.

However, the effects would be highly concentrated in certain countries and mineral value chains. Notably, nickel is the most exposed mineral, with production declining by 3 million tonnes annually, a 64% reduction, followed by manganese with a smaller decline of 1.2 million tonnes annually (33%) and copper with a decline of 0.5 million tonnes annually (11%). This leads to significant reductions in net export revenues, ranging from 70–90% for Namibia, and South Africa, and 30–35% for Tanzania. Mining volumes are the same irrespective of resource nationalism or regional collaboration, which only affect processing.

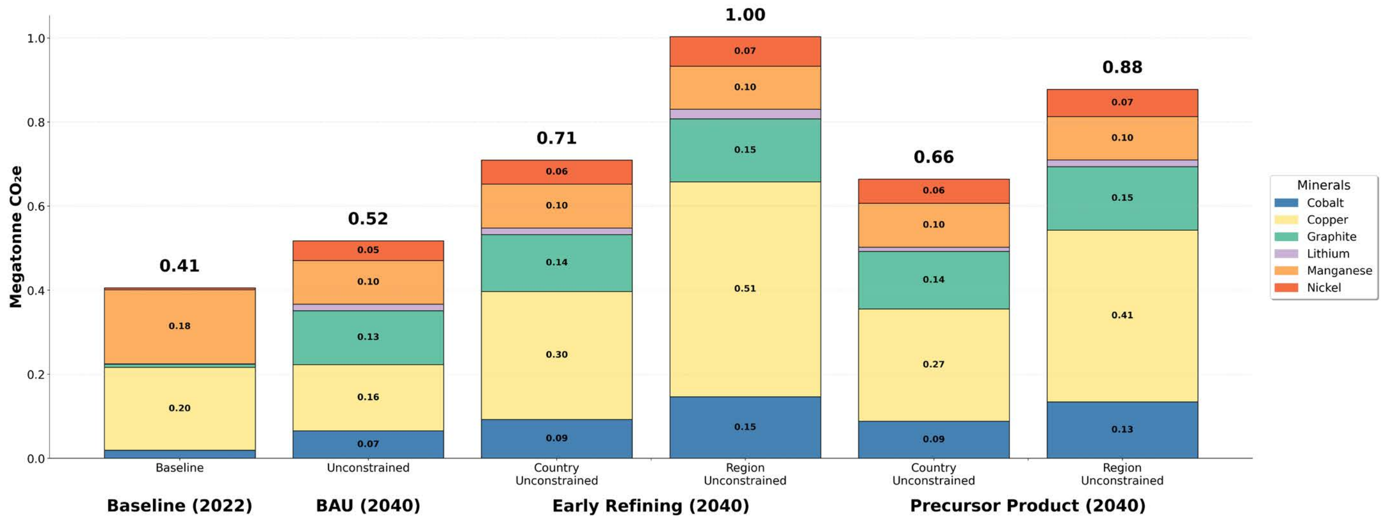
While the effects on projected mining cannot be mitigated due to deposit locations, export revenues are less affected under regional cooperation due to the model's flexibility in relocating processing activities to less environmentally sensitive areas. In fact, export revenues under environmentally constrained regional cooperation are still about 25% higher than those under resource nationalism without regard for environmental concerns.

Q9: What are the implications for carbon emissions?

Carbon emissions arise from the electric and thermal energy consumption associated with mineral production and processing, as well as the motive energy associated with transportation of minerals at different stages of processing. The carbon intensity of energy systems varies across countries in Southern Africa. Hydro-dependent countries such as DRC, Angola, Mozambique, Tanzania, and Zambia have a carbon intensity well under 100 grammes of CO_2 equivalent per kilowatt-hour, whereas coal-dependent countries such as South Africa, Zimbabwe, and Botswana have a carbon intensity of 300–400 grammes of CO_2 equivalent per kilowatt-hour.

Relative to the 2022 baseline, carbon emissions from mineral production and processing are simulated to increase 30% even without additional mineral processing activity, reflecting a shift in the composition of mineral production towards energy intensive graphite and to a lesser extent nickel (**Figure 7**). When higher levels of processing are additionally factored in, carbon emissions increase by between 60% (nationalist scenario) and 110% (regionalist scenario) over

Figure 7: *Simulated evolution of carbon emissions from battery mineral production and processing in Southern Africa under different scenarios.*



2022 baseline levels, with copper being the main driver of higher emissions, followed by graphite, manganese, and nickel.

In general, carbon emissions are somewhat higher under regional cooperation scenarios. This partly reflects 40–50% higher transport emissions, due to the need to transport bulkier unprocessed minerals over longer distances to regional processing centres. To a lesser extent, it also reflects 10–20% higher energy emissions as a result of the increased energy needed for higher amounts of processing.

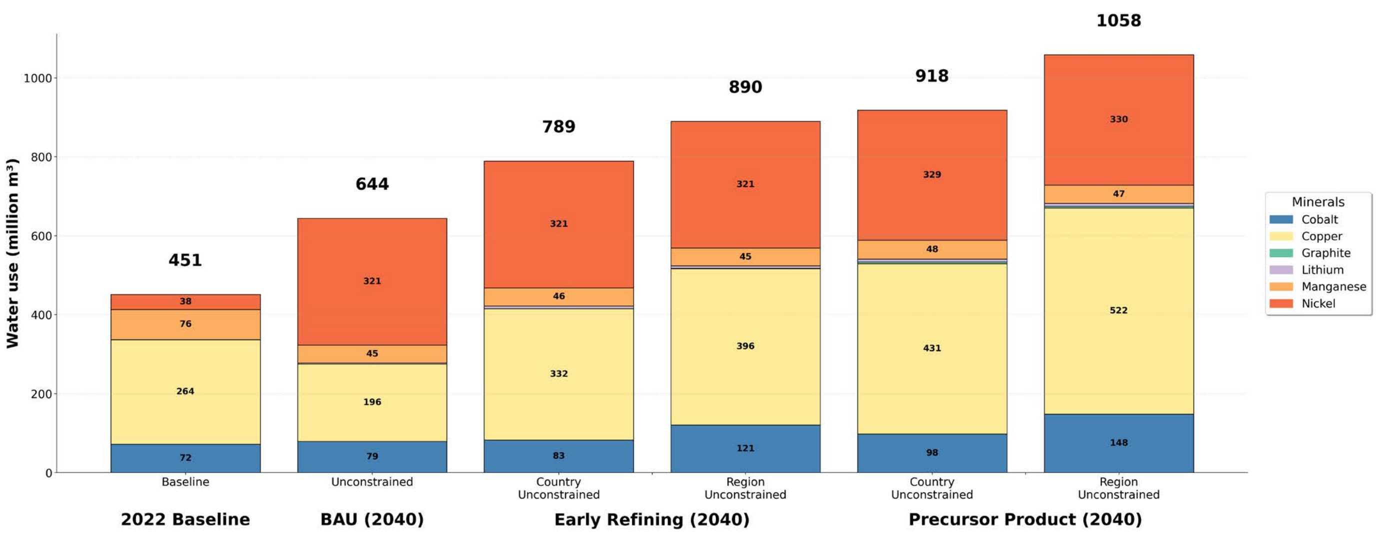
Overall, total carbon emissions from battery mineral production and processing are simulated to grow from 2022 baseline levels of 0.4 Mt of carbon dioxide equivalent to 0.7–0.9 Mt of carbon dioxide equivalent under increased processing scenarios. The increases suggest decarbonising transport and energy systems is paramount.

Q10: How will water consumption be affected?
Water requirements vary by mineral and processing activity. Intermediate stages of copper processing stand out as being three times more water intensive than any of the other processes considered here. Nevertheless, significant water consumption is entailed by early-stage production of nickel, late-stage processing of graphite and lithium, and various stages of cobalt production and processing.

Total water consumption from battery mineral production and processing is simulated to grow from 2022 baseline levels of 451 million cubic metres to around 790–1,058 million cubic metres under increased processing scenarios.

Relative to the 2022 baseline, water consumption from mineral production and processing is simulated to increase by 43% even without additional mineral processing activity (**Figure 8**). This is largely due to the almost eightfold expansion in water-intensive nickel mining. When higher levels of processing are additionally factored in, water consumption increases 75–135% over 2022 baseline levels, depending on the scenario. The principal driver of this increase is the processing of copper to higher stages. Unlike carbon emissions, water consumption is barely affected by the adoption of regional cooperation along mineral value chains, but the locations of increased water change.

Figure 8: *Simulated evolution of water consumption from battery mineral production and processing in Southern Africa under different scenarios*



Conclusions

These illustrative simulations of battery mineral processing futures in Southern Africa enhance the potential for evidence-based exploration of different processing futures. The findings could usefully inform the development of policy frameworks and investment strategies to enable national and regional value addition.

The findings in this brief give rise to the following policy recommendations.

1. **Invest in improving the knowledge base underpinning policy decisions** on the development of critical mineral value chains in Africa. This includes improving African geological data, international trade classifications, processing costs, and tracked commodity prices and characteristics to name a few.

2. **Regionally collaborative approaches appear to offer greater promise**, with the potential to significantly increase export revenues and to mitigate water stress and biodiversity impacts. However, appropriate benefit-sharing arrangements will be needed to create the right incentives for collaboration. To facilitate successful regional cooperation, it will also be important to consider cross-country harmonisation on fiscal regimes, cross-border revenue configurations, trade mechanisms, and overall institutional coordination.

3. **The simulations highlight the importance of supporting the sector's early development stages through an enabling environment**, including regulatory clarity, infrastructure readiness, and strategic partnerships. Tanzania illustrates this potential, with results suggesting it could emerge from playing a minimal role to become a major battery mineral producer in Southern Africa over the next 15 years.

4. **Policy attention should include emerging smaller producers** (Burundi, Madagascar, Malawi, Namibia, Zimbabwe) where local economic impacts may be particularly significant, alongside major producers (DRC, Zambia, South Africa).

5. **Infrastructure is an important enabler of further critical mineral processing** in Southern Africa. The simulations suggest that priority areas for investment are clean power infrastructure in coastal countries with potential to act as processing hubs and transport corridors strengthening linkages with landlocked mineral-producing countries, particularly those running east and west from the Copperbelt to the oceans.

6. **Mitigating environmental impacts will be important and requires collaboration between governments and investors** to establish protocols and coordinate on environmental standards across countries to avoid causing further harm. Key aspects to be considered are biodiversity, water scarcity, and carbon emissions.

7. **Promoting the battery materials sector could create opportunities for new and existing industries in other sectors.** Construction, energy, transport, and related services will be required to expand battery material production, and its outputs could support additional manufacturing and industrial activities. Although these broader opportunities were not evaluated in the study, industrial policies could explore the implications of different manufacturing pathways, building roadmaps or supplier development programmes that consider national and regional capabilities and support benefit sharing.

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