NATIONAL EMPLOYMENT VULNERABILITY ASSESSMENT

METALS VALUE CHAIN

September 2025

TIPS supports policy development through research and dialogue. Its two areas of focus are trade and inclusive industrial policy; and sustainable growth.

info@tips.org.za
+27 12 433 9340
www.tips.org.za

Author
Danae Govender
TIPS Economist

ABOUT THIS REPORT

The impact of climate change and the decisions taken to reduce emissions will have an impact on workers and communities in multiple value-chains. TIPS, with funding from the UK-PACT Programme has undertaken research on five key value chains that will be impacted: coal, petroleum-based transport, tourism, metals, and agriculture.

CONTENTS

ABBREVIATIONS

AMSA	ArcelorMittal South Africa
GDP	Gross Domestic Product
GHGs	Greenhouse Gases
CBAM	Carbon Border Adjustment Mechanism
CO_2e	Carbon Dioxide Equivalent
DRI	Direct Reduced Iron
EMM	Electrolytic Manganese Metal
EU	European Union
EVs	Electric Vehicles
GEPF	Government Employees Pension Fund
ICE	Internal Combustion Engine
IDC	Industrial Development Corporation
IDP	Integrated Development Plan
kWh/t	Kilowatt Hours Per Tonne
KZN	KwaZulu-Natal
PEM	Proton Exchange Membrane
PGMs	Platinum Group Metals
PIC	Public Investment Corporation
SETs	Sectoral Emissions Targets
SJRP	Sector Jobs Resilience Plan
UK	United Kingdom

1. INTRODUCTION

South Africa's metals value chain is under growing pressure as the shift to a low-carbon world exposes its dependence on fossil fuel-based energy. The value chain has long relied on abundant, low-cost fossil fuels, with coal-fired electricity from Eskom being critical to operations. Primary steelmaking is also highly emissions-intensive, due to the use of coking coal that releases greenhouse gases (GHGs) when burned. Opencast mining depends heavily on petroleum products, essentially, diesel for trucks. These energy characteristics leave the value chain vulnerable to policies that target a reduction in emissions, including Sectoral Emissions Targets (SETs), carbon budgets, South Africa's carbon tax, the European Union (EU) Carbon Border Adjustment Mechanism (CBAM), and the transition to electric vehicles (EVs). While physical risks are also present, particularly water shortages, transition risks are likely to impact employment in the value chain before the worst impacts of climate change occur. Failure to respond to these risks could have severe consequences for workers, firms, and communities dependent on the value chain. To inform policy responses that offer social and labour market protection, this report assesses the vulnerability of those reliant on the metals value chain.

Transition-related risks and their impacts evolve with policy measures that typically become more stringent as the world moves towards net zero. That said, early preparation and regular reassessment are essential. In this context, this report updates the National Employment Vulnerability Assessment: Analysis of Potential Climate-Change Related Impacts and Vulnerable Groups (Makgetla, et. al, 2019 – referred to as the 2019 assessment or previous assessment), reflecting key developments since its publication. The findings will be used to inform policy responses in the updated Sector Jobs Resilience Plan (SJRP). While the assessment focuses on transition risks and impacts, it also notes other global and domestic factors that have, or could, impact the value chain.

The first section of the report defines the scope of the value chain, highlighting key processes and products. The following section examines major trends, including the value chain's economic contribution, ownership and control, as well as its energy dependence and sources. This section also highlights factors, outside the transition, that are adversely affecting the value chain. Section four analyses risks associated with the transition, mitigation responses, and key implications. Section five assesses the vulnerability of workers, in terms of their financial, physical, human, and social resources, and the vulnerability of communities dependent on the value chain. The sixth, and final, section concludes the assessment.

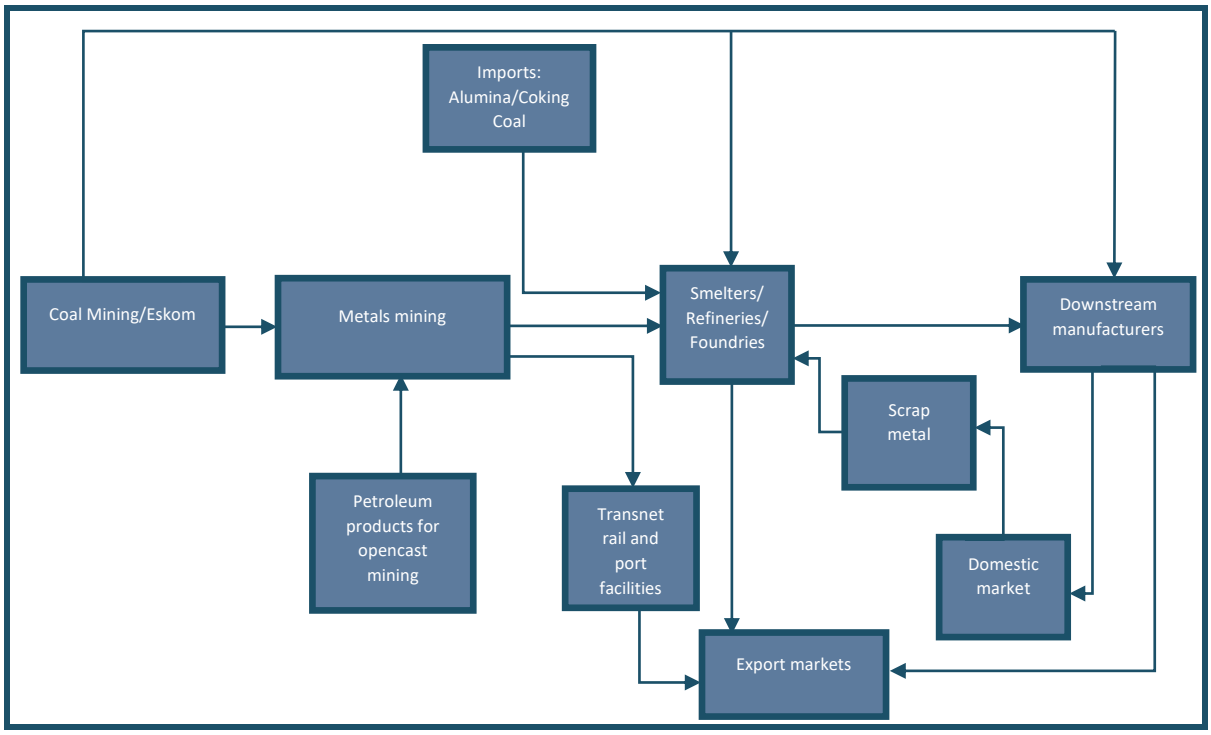
2. SCOPE

As highlighted in the previous assessment, South Africa's metals value chain is made up of multiple sub-value chains. While these subsectors share a broadly similar structure, as illustrated in Figure 1, they differ in scale, complexity, and organisation depending on the mining and manufacturing processes involved, and on whether particular stages are located domestically or abroad (Makgetla et al., 2019).

Mining methods include either opencast (e.g., iron ore, and manganese), which is more fuel-intensive, or underground (e.g., platinum group metals (PGMs), and gold), which is more electricity- and labour-intensive. Some ores, like alumina for aluminium, are imported, and scrap metal is also used as a feedstock. Ores then pass through smelters, refineries, and foundries, which are energy- and emissions-intensive. Some ores are exported with minimal processing. Refined metals are either exported or processed further by downstream manufacturers into finished goods for domestic and export markets. In addition to its importance at the mining stage, energy supply from coal/Eskom is essential across the chain, as highlighted, with imported coking coal being a critical energy source for blast oxygen steel mills. Some components, like petroleum products, are present throughout the value

chain, but are a critical input in opencast mining. Likewise, transport services are important at all stages, but Transnet is highlighted due to its dedicated rail and port facilities for the movement and export of iron ore and manganese.

Figure 1. General structure of the South African metals value chain



Source: Adapted from Makgetla et al., 2019.

The commodities covered in this assessment and their main domestic products are:

- Platinum Group Metals (PGMs): a broad value chain encompassing mining and refining (for both domestic use and export), as well as the fabrication of catalytic converters and other PGM-based products.
- Gold: a comprehensive chain spanning mining, refining, and manufacturing.
- Iron and steel: an extensive chain starting with mining, continuing through local steelmaking for domestic and export markets (including both primary and secondary production), and extending to the manufacturing of steel products.
- Chrome: extensive value chain, involving mining of chromite ores and the production of ferrochrome (primarily used in stainless steel manufacturing).
- Manganese: extensive value chain, involving mining of manganese ores, the production of ferromanganese (used as an alloying agent in steel production), and battery manganese.
- Aluminium: a manufacturing-focused chain beginning with smelting (using alumina imported from Australia for primary production) and extending to the production of aluminium products for construction, transport, and machinery and equipment.

3. MAJOR TRENDS IN THE MINING SECTOR

South Africa's mining sector has undergone significant transformation since the discovery of gold in the 19th century. Gold mining spurred industrialisation and contributed to the Minerals Energy Complex (MEC), describing the strategic alignment between the state and major mining entities. Coordinated investments in infrastructure, energy supply, and industrial development reinforced each other, securing cheap energy, critical minerals, and long-term industrial growth. State-owned

enterprises, such as Eskom, were essential in providing reliable, low-cost electricity for energy-intensive mining and related industries.

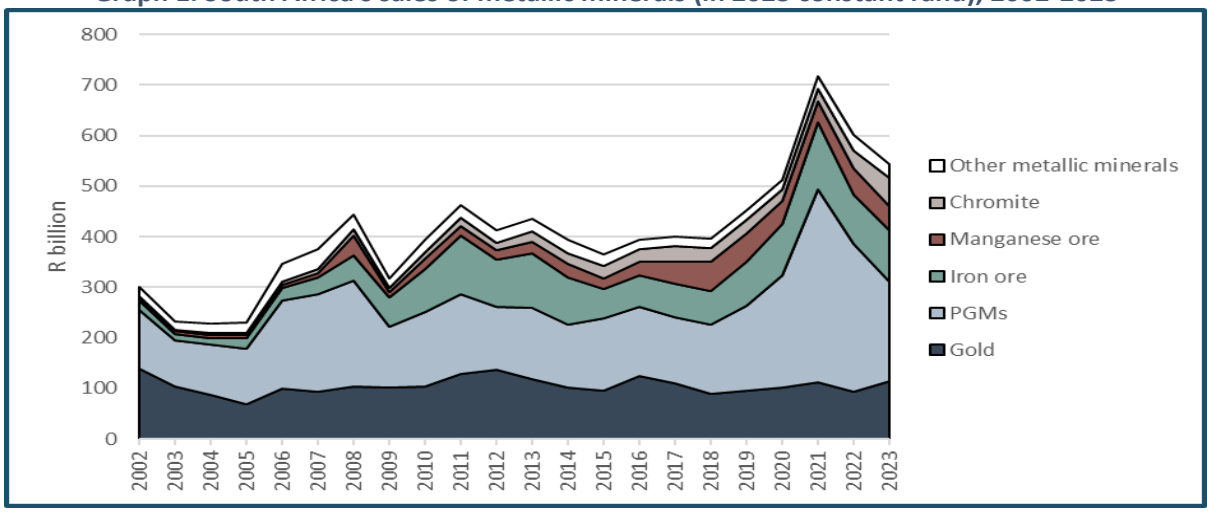
As gold reserves declined and the economy liberalised in the 1990s, mining shifted focus to other commodities, including PGMs, iron ore, chrome, and manganese. While the mining and manufacturing of these and other metals were taking place prior to 1994, the post-apartheid period saw increased policy and investment emphasis.

Partly due to the MEC, and partly due to its physical endowment, South Africa remains unusually dependent on mining for an upper-middle-income country. Mining accounts for almost half of the country's exports, compared to around a third in similar economies. While this emphasises the sector's importance for revenue, and employment, the reliance also amplifies vulnerability to transition risks. This section of the assessment examines the economic contribution of the metals value chain to highlight its importance. In addition, it lists key entities participating in the value chain and outlines instances of public ownership – which has been instrumental in enhancing the sector's importance. The section also unpacks the value chain's energy reliance and sources, which give rise to the risks it's facing. Finally, factors affecting the value chain, outside the transition, are outlined.

a. Production

The metals value chain, driven by a few key commodities, plays an important role in South Africa's economy. In 2023, sales of metal ores were over R540 billion, with gold, PGMS, iron ore, chromite, and manganese ore leading, by value (Graph 1). PGMs and iron ore have tracked global price cycles, with notable peaks during the 2021 commodity spike. It is noted, however, that the elevated sales value resulted primarily from higher US dollar prices, rather than growth in physical sales volume. Sales of manganese have fluctuated while chromite ores have grown steadily (calculated from DMRE, 2024). The relative importance of gold declined since 2002 following a much sharper decline through the 1990s.

Graph 1. South Africa's sales of metallic minerals (in 2023 constant rand), 2002-2023

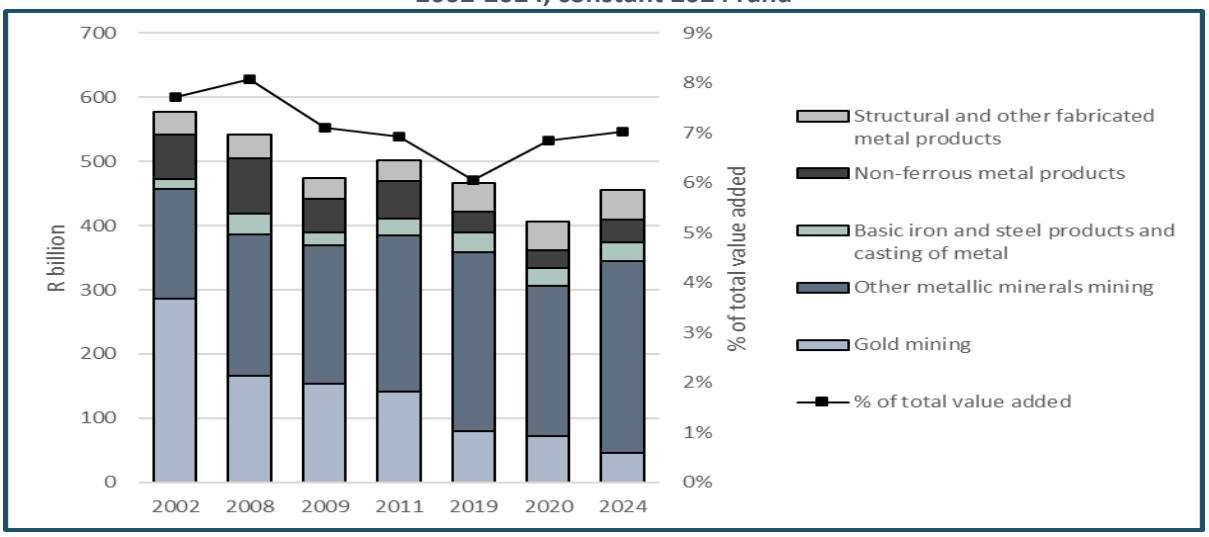


Note: Values are reflated using implicit GDP Deflator, rebased to 2023. *Source*: Sales calculated from Department of Mineral Resources and Energy. B1-2024 Mineral Statistics Tables. Excel spreadsheet. Downloaded from www.dmre.gov.za in May 2025. GDP deflator calculated from Statistics South Africa. GDP P0441 – GDP Time 2024Q4. Downloaded from www.statssa.gov.za in May 2025.

The economic contribution of the metals value chain is shown in Graph 2. In 2024, it contributed R455 billion to total industry value added at factor cost (calculated from Quantec, 2025). In constant 2024 Rand, this represents a decline from R576 billion, in 2002. Much of the decline is the result of reduced value added from gold mining, which fell from R285 billion, in 2002, to R46 billion, in 2024,

as reserves were used up. In the same year, value added from the mining of other metallic minerals (outside of gold) amounted to almost R300 billion, while metals and metal products contributed R111 billion. In percentage terms, the economic contribution of the metals value chain to total industry value added is approximately 7% of total value added at factor cost – relatively unchanged since the undertaking of the 2019 assessment.

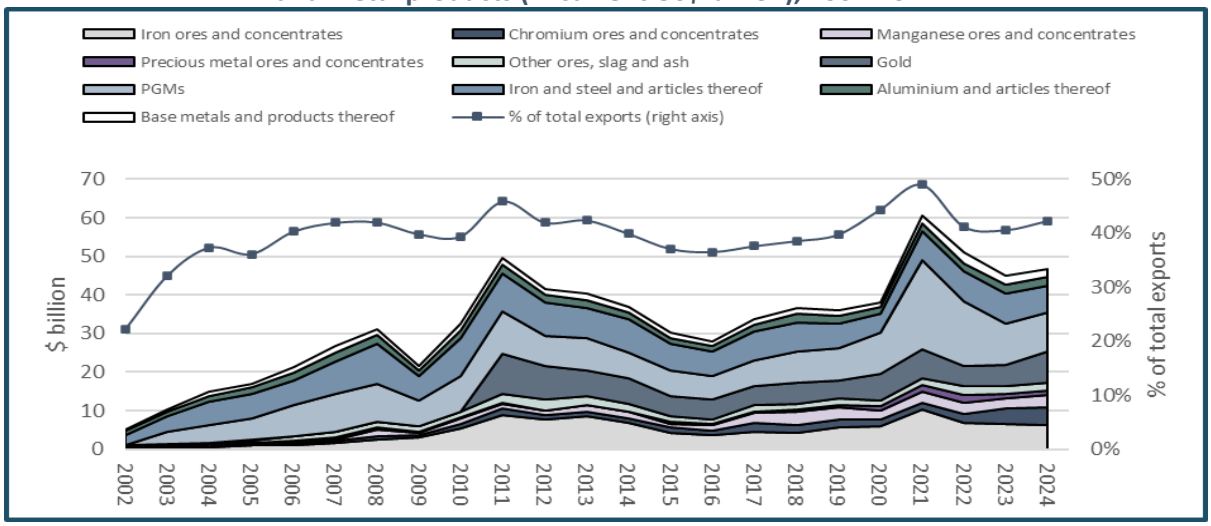
Graph 2. Value added from the metals value chain, for selected years, 2002-2024, constant 2024 rand



Note: Rand values are reflated using implicit deflator, rebased to 2024. Shares are calculated based on the current values for each year. *Source*: Calculated from Quantec. EasyData. Regional Output and GVA at basic prices by industry and 2016 local municipal/ward-based metro region level. Downloaded from www.easydata.co.za in August 2025.

Exports across the value chain are shown in Graph 3. In 2024, South Africa exported almost US$47 billion in metals (including ores and metal products), equivalent to 42% of total exports for the year (calculated from ITC, no date). The structure and pattern of sales and exports remain largely unchanged relative to the findings of the 2019 assessment.

Graph 3. South Africa's exports of selected metallic minerals, and metals and metal products (in current US$ billion), 2002-2024



Note: Gold exports are not properly recorded before 2011. Gold refers to HS7108, and PGMs refer to HS7110
Source: Calculated from ITC. Trade Map. Interactive database. Downloaded from www.trademap.org in May 2025.

b. Ownership and control

The metals value chain, due to its high capital intensity, is dominated by a limited number of large firms in each subsector. Table 1 lists the main players in each of the key commodities considered in this assessment. Changes since the previous assessment include the divesting of AngloGold Ashanti's South African mining assets, and the demerging of Valterra Platinum from Anglo American.

Table 1 also highlights the public ownership that has shaped South Africa's metals value chain. Government institutions have intervened to stabilise the metals sector, and support industrial development. Currently, the Public Investment Corporation (PIC), Government Employees Pension Fund (GEPF), and Industrial Development Corporation (IDC) are notable shareholders in key entities operating in the value chain. While public ownership provides clear benefits, it also entrenches path dependency, with reliance on a small number of state-backed large firms slowing industrial diversification.

Table 1. Ownership of leading firms in South Africa's metals value chain

SUBSECTOR	MINING	MANUFACTURING
Gold	Key players in South Africa's gold mining industry include Harmony Gold (14.72% owned by the PIC), Gold Fields (21.18% by the GEPF), Pan African Resources (10.42% owned by the PIC), and Sibanye-Stillwater (13.96% owned by the GEPF). Other players include DRDGold, and Gold One among others.	Rand Refinery, owned by AngloGold Ashanti (42.41%), Sibanye Gold (33.15%), DRDGold (11.30%), Harmony Gold (10.38%) and Gold Fields (2.76%), is the main primary gold refiner in South Africa. Small refineries process gold from old jewellery, industrial products, coins, and jewellery manufacturing waste.
PGMs	Valterra Platinum (previously Anglo American Platinum, 66.71% owned by Anglo American South African Investments), Impala Platinum (19.78% owned by the GEPF), and Sibanye-Stillwater are key players. Other players include, but are not limited to, African Rainbow Minerals (9.27% owned by the GEPF), Northam (20.09% owned by PIC).	Large mining entities, including Valterra, Implats, and Sibanye-Stillwater, smelt and refine mined ores, which are sold to autocatalyst manufacturers, and jewellery manufacturers, among others. Major autocatalyst manufacturers in South Africa include Benteler (100% owned by Benteler International AG), Tenneco (100% owned by Tenneco Automotive Iberica SA), and Faurecia (100% owned by Faurecia Interior Systems South Africa).
Iron and steel	Kumba Iron Ore (12.88% owned by the IDC and 2.80% by the PIC) and Assmang (owned 50:50 by African Rainbow Minerals and Assore South Africa) are the largest iron ore producers in South Africa. Other producers include the AMSA-owned Thabazimbi Iron Ore Mine, Afrimat, and Ironveld.	The main entities operating in this space include ArcelorMittal South Africa (AMSA) (primary steel producer and 8.18% owned by IDC), Scaw (26% owned by IDC), Columbus Stainless (24% owned by IDC), and CapeGate.
Chrome	Chrome ore mines in South Africa are operated by a few integrated producers, including the Glencore-Merafe Venture (79.5% owned by Glencore Operations South Africa, with the balance controlled by	Production of ferrochrome is handled largely by integrated producers Glencore and Samancor. Also used in the production of stainless steel products.

SUBSECTOR	MINING	MANUFACTURING
	Merafe Resources), and Samancor Chrome (100% owned by Samancor Chrome Holdings). Other operations include Jubilee Metals, Bauba Resources, and Clover Alloys SA.	
Manganese	South Africa's manganese mines are operated by a few large producers, some of which are vertically integrated. Assmang owns the Black Rock Mine in the Northern Cape, the Cato Ridge Works smelter in KwaZulu-Natal (KZN), and 50% of Cato Ridge Alloys, also in KZN. Other operations include Kalagadi Manganese (20% owned by IDC), Tshipi e Ntle Manganese Mining (50.1% owned by Ntsimbintle Mining and 49.9% by Jupiter), and Hotazel Manganese (70% owned by Samancor Manganese and 30% by Anglo American South Africa)	South Africa has one producer of manganese metal products – Manganese Metal Company, which is the only producer of electrolytic manganese metal (EMM) outside of China. It is also the world's largest producer of selenium-free EMM.
Aluminium	No bauxite mining occurs in South Africa. The alumina is imported from Australia by South32.	Primary production takes place at South32's Hillside Aluminium (100% owned by South32 SA Holdings) in Richards Bay. Hulamin (29.17% owned by the IDC), which remelts primary aluminium from Hillside, operates casting facilities in Richards Bay, and facilities for manufacturing in Pietermaritzburg. Wispeco Aluminium produces secondary aluminium, and uses it to manufacture extrusions for the construction, engineering, and durable goods industries.

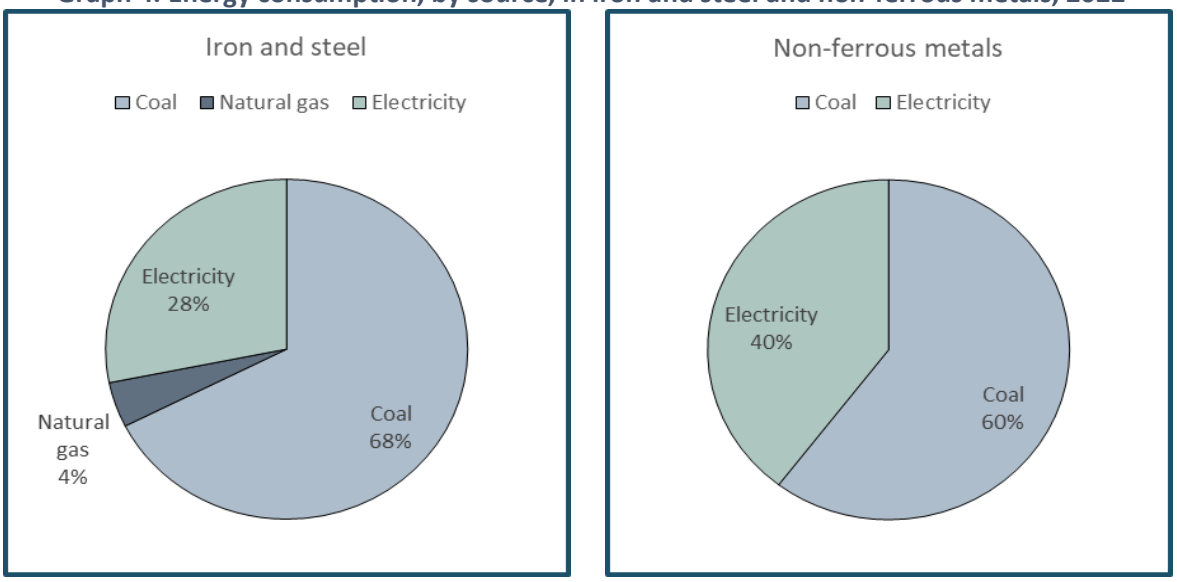
Note: It is noted that the sources of information, in some instances, are not for the most recent year, and ownership structures for the various entities may have changed. *Source*: Makgetla et. al., 2019. For metals, Conradie, 2022, 2023a, 2023b, 2024, 2025. For automotives Felton, 2024. Who Owns Whom. Industries database. Downloaded from www.whoownswhom.co.za in August 2025.

c. Energy dependence and emissions profile

As noted, South Africa's metals sector has historically relied on cheap, fossil fuel-based energy. Currently, this advantage is increasingly challenged by Eskom inefficiencies, and decarbonisation policies. Although there has been a rise in investment in renewable energy (discussed in more detail in the next section), the value chain remains reliant on environmentally detrimental energy sources. The metals industry also accounts for the largest share of South Africa's industrial process and product use GHG emissions, at 51% in 2022, with iron and steel production, and ferroalloys production being the largest contributors to the metals category (DFFE, 2024b).

Graph 4 shows the share of energy sources consumed in the manufacturing of basic iron and steel and non-ferrous metal products.

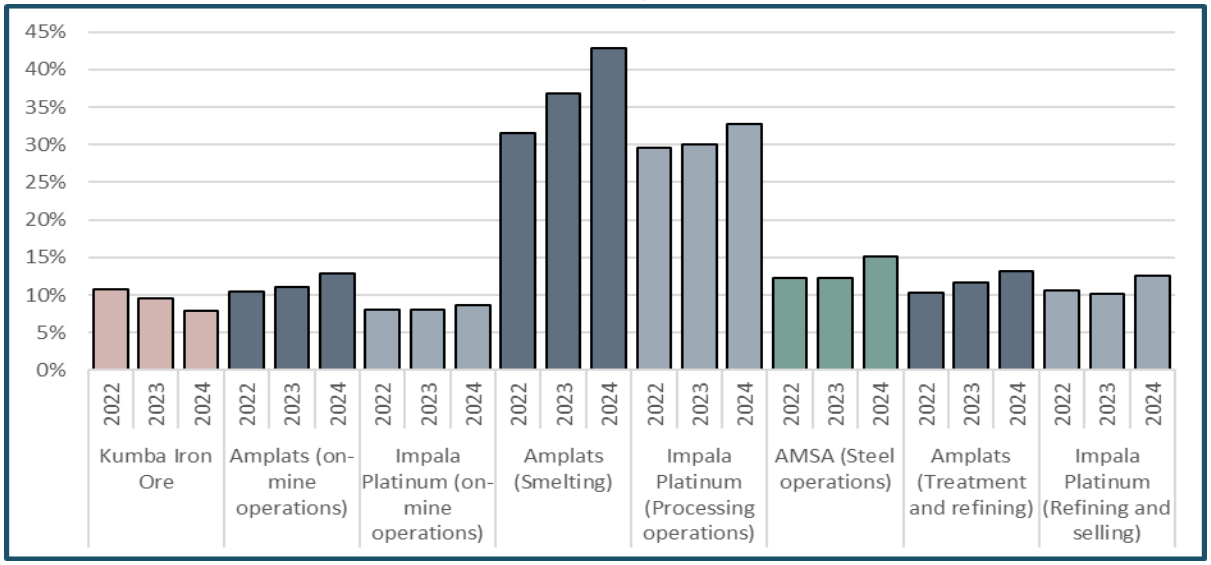
Graph 4. Energy consumption, by source, in iron and steel and non-ferrous metals, 2022



Source: Calculated from Department of Mineral Resources and Energy. Energy Balances 2022. Excel spreadsheet. Downloaded from www.dmre.gov.za in May 2025.

Graph 5 shows the energy intensity of different operations in the metals value chain. In mining, energy-related costs range between 7% and 13% of costs, depending on the nature of the mining operation.

Graph 5. Energy/utilities as a share of cost for selected entities operating in the value chain, 2022-2024



Note: For Kumba, energy includes petroleum costs, and the proportion is calculated as a percentage of total operating expenses. For Amplats and Implats, utilities is calculated as a percentage of the total cost for the respective operation (i.e., mining, smelting/processing, refining). For AMSA, energy intensity is calculated as energy's percentage of the sum of energy, labour, material costs, and other operating expenses in steel operations. For Kumba, values for 2023 were obtained from the 2024 source. *Source*: Calculated from Anglo American, 2022, 2023, 2024a; AMSA, 2022, 2023a, 2024; Implats, 2022, 2023, 2024a; Kumba Iron Ore, 2022, 2024a.

For iron ore mining, a significant proportion of energy-related costs are from petroleum products. For some electricity dependent smelting operations, utility costs reach 43% of production costs. The dependency is less pronounced in coal-based smelting, like primary steelmaking, where energy costs are between 13% to 15% of total costs. At the refining stage, utilities accounted for 13% of production

costs in 2024. The structure of energy consumption across the metals value chain has been maintained since the previous assessment was conducted.

At the firm level, continued reliance on the sources of energy that have historically fuelled the metals value chain translates into emissions intensity. Table 2 shows the emissions and energy intensity of selected value chain participants. While there has been renewable energy uptake by some entities, and plans for further uptake, emissions intensity have not shown notable improvement (reductions). In the absence of drastic reductions, the metals value chain will remain exposed to a myriad of transition risks that will harm its competitiveness, and result in a downturn in production, which will, in turn, lead to retrenchments.

Table 2. Emissions and energy intensity of selected operations in metals value chain

Kumba Iron Ore	**2021**	**2022**	**2023**	**2024**
Emissions intensity (CO2e/tonnes ore)	0.0239	0.0270	0.0275	0.0240
Energy intensity (GJ/tonnes ore)	0.211	0.242	0.253	0.202
Amplats	**2021**	**2022**	**2023**	**2024**
CO_2 intensity/tonnes smelted	3.32	3.55	2.86	2.98
Energy intensity/tonnes smelted	15.3	16.36	13.73	13.99
AMSA	**2021**	**2022**	**2023**	
CO_2 emissions (CO_2eq/t liquid steel)	2.67	3.39	3.38	
Electricity (MWh/tonne of steel)	0.58	0.68	0.59	

Source: Adapted from AMSA, 2023b; Anglo American, 2024b; Kumba Iron Ore, 2024b.

d. Non-climate factors affecting the South African metals value chain

Before unpacking the specific transition-related risks and impacts, it is important to note that they will not materialise (or are not materialising) in isolation. There are several other factors that have harmed the value chain. Globally, commodity prices have declined since the end of the price boom (which ran from 2002 to 2011) and from their peaks in the early 2020s. The economic slowdown in China, which is among South Africa's largest markets for exports from the metals value chain, has led to reduced demand. The United States' 2025 tariff action will also lead to some metals, like aluminium, becoming uncompetitive on the US market.

Domestic structural constraints also continue to erode competitiveness. Eskom's tariffs have risen more than threefold, in real terms, since the early 2000s, placing sustained cost pressure on energy-intensive industries. Similarly, Transnet's crises have undermined the sector, with rail bottlenecks and port inefficiencies.

4. DIMENSIONS OF CLIMATE-CHANGE RELATED IMPACTS

Considering its energy and emissions intensity, South Africa's metals value chain is increasingly exposed to transition-related risks that will affect production, exports, and employment. These risks vary in nature and will materialise over different time horizons, with some already pressing and others likely to unfold over the coming decades. The severity will depend largely on the pace at which firms in the value chain reduce emissions intensity, and the advancement of currently emerging technologies. While decarbonisation over time may reduce exposure, this section outlines the main risks and their likely impacts under a worst-case scenario, drawing on current trends and policy developments. This section also highlights responses by firms operating in the value chain, focusing largely on renewable energy deployment. In addition, it outlines key implications regarding risks and touches on potential opportunities that could result from the transition.

The most important development posing a risk to the metals value chain, since the 2019 assessment, is the signing into law of South Africa's Climate Change Act No. 22 of 2024, which empowers government to set SETs, and allocate carbon budgets to high emitting firms. Other policy risks have evolved, with potential impacts becoming more certain.

a. Types of risks

As illustrated, the high emissions intensity of the metals value chain stems from three main sources:

- Electricity use in mining, where extraction processes remain largely dependent on coal-based grid power;
- Coal and electricity use in smelting and refining;
- Fossil fuel-dependent transport, on-mine as well as within South Africa and internationally.

The energy sources and emissions intensity of metals value chain operations translates into the following supply-side risks.

Climate Change Act – Sectoral Emission Targets and Carbon Budgets: The Climate Change Act establishes regulatory frameworks that affects the metals value chain through SETs and company-level carbon budgets. SETs are a key mechanism outlining the emissions reduction measures needed to bring the country in line with its Nationally Determined Contribution. These measures include renewable power uptake, efficiency improvements, and investment in lower-carbon production technologies. This raises costs in the near term and, in the absence of the necessary technological adjustments, may constrain production for mining, as well as for producers of iron and steel, ferroalloys, and aluminium (DFFE, 2024a).

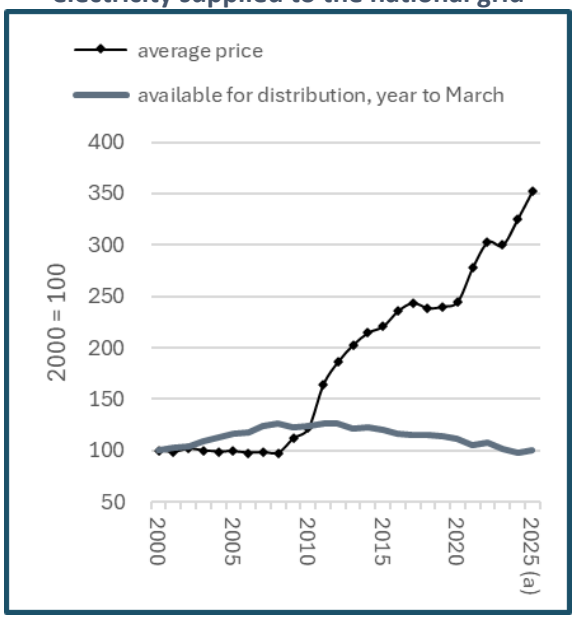
Carbon budgets will be allocated to individual companies whose emissions exceed 30 000 tonnes of carbon dioxide equivalent (CO_2e) a year (Ackermann and Young, 2025). Budgets put a cap on the total allowable emissions for high-emitting companies. For iron and steel, ferroalloys, and aluminium, budgets could force costly technological changes or reductions in output. Companies exceeding their allocated carbon budget will face a higher carbon tax (Brundtland, no date). Non-compliance with reporting requirements carry financial penalties and potential criminal charges. Draft Technical Guidelines for carbon budgets have been published for comment and are expected to become binding in 2026 (Ackermann and Young, 2025). This places immediate pressure on affected entities.

Carbon tax: The carbon tax, introduced in 2019, is scheduled to enter Phase Two in 2026, with proposals including rising rates, and gradually reduced allowances. Primary steelmaking is most at risk from the cost pressures associated with the carbon tax. Proposals indicate that emitters will still be able to reduce 62.5% of tax liability associated with combustion emissions and 72.5% of liability associated with process and fugitive emissions in 2035. However, the declining allowance trajectory, coupled with increasing rates, means, in the absence of decarbonisation measures, costs pressures will mount steadily. Although indirect emissions are currently not penalised under South Africa's carbon tax, potential inclusion, as the carbon tax evolves, will adversely affect electricity-intensive operations, including electric arc furnace steel, ferroalloys, and aluminium.

Rising electricity prices: South Africa's electricity tariffs have more than tripled since the start of the millennium (Graph 6), driven by underinvestment, rising input costs, and maintenance needs at Eskom. As noted in the previous subsection, this is happening outside the realm of the transition, and has already impacted firms in the value chain. However, considering that government's proposal to ensure price neutrality of electricity, under the carbon tax, runs until the end of 2030, the transition (in the form of the carbon tax) could push electricity prices up, thereafter. This will put additional cost pressures on electricity-intensive mining, smelting and refining. As noted, and illustrated in Graph 7,

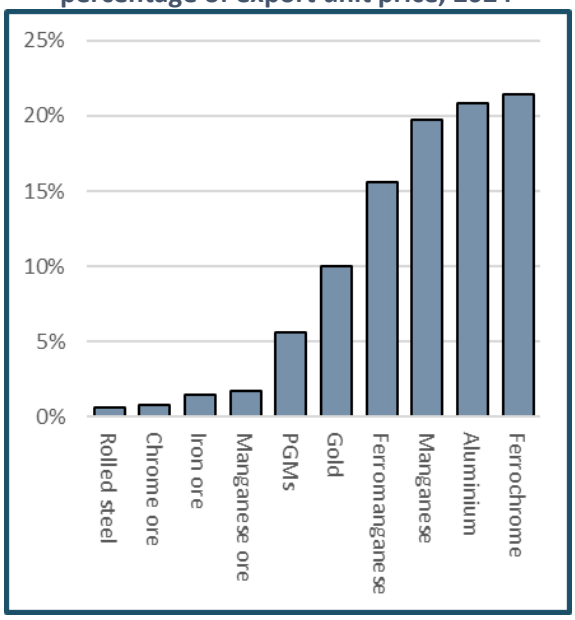
further electricity price increases will prove especially problematic for producers of aluminium, ferroalloys, and manganese metal products. Electric arc furnace steel will also be impacted by higher electricity prices. Ferrochrome is currently experiencing harsh impacts due to soaring electricity prices, and government has proposed beneficial electricity tariffs for smelters (Mthenjane, 2025).

Graph 6. Indices of electricity price and Eskom electricity supplied to the national grid



Note: (a) Based on average increase of 12.74% approved by Nersa. *Source:* TIPS, 2025.

Graph 7. Modelled estimates of electricity as percentage of export unit price, 2024[1]



Source: Calculated from Bleiwas, 2011; Eskom, 2025; ITC, no date.[2]

Increasing transport costs: Bulk commodity transport costs are already rising due to higher fuel prices and stricter environmental regulations, both domestically and globally. Carbon pricing is adding to the cost of petroleum-based fuels, raising input costs for domestic producers. In addition, refinery upgrades to comply with clean fuel standards, like Clean Fuels II regulations, may see costs passed on to consumers. Opencast mining is particularly exposed to higher diesel prices and these costs are expected to rise further as policies evolve or materialise, putting additional pressure on affected entities. Hydrogen-based fuel alternatives are emerging as a viable long-term solution, especially for heavy haul and mine-site operations, but adoption will take time, as deployment is mainly in the form of pilots.

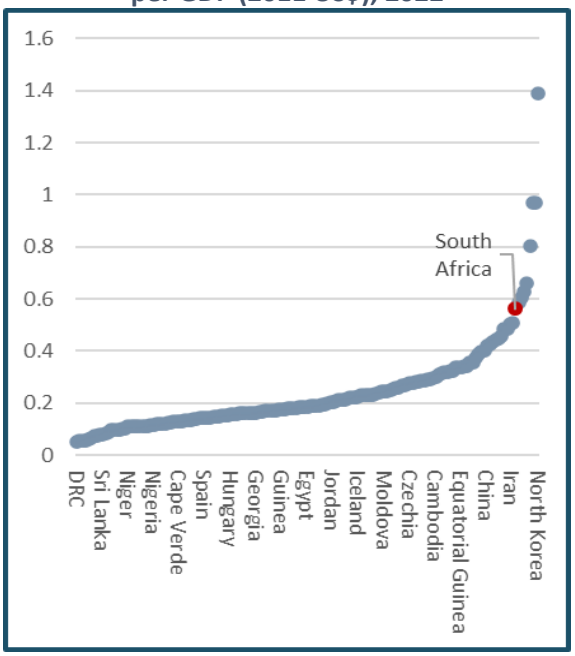
On the demand side, transition risks are also prevalent.

[1] Estimates are derived by multiplying the electricity requirement, in kilowatt hours per tonne (kWh/t), for each product by the Eskom unit price, in Rand per kWh, in 2023/2024 to obtain the electricity cost per tonne. This cost is then expressed as a share of the export price (in Rand per tonne) for each product. Gold and PGMs include electricity used in various stages of the value chain. Ore stages used the price of electricity for mines, most manufacturing stages used the price for industry. Gold and PGMs used the average of the two prices. Electricity requirements are calculated as the mid-point of the given ranges. The purpose of these estimates are to provide insight into the differences in electricity requirements across different stages of the value chain, rather than to provide precise figures. The analysis does not account for differences in production methods for individual metals. For manganese, estimates are for lump ore, not sintered ore.

[2] Electricity requirements calculated from Bleiwas (2022 Open File Report 2011), Unit export prices from ITC. Trade Map. Interactive dataset. Downloaded from www.trademap.org in August 2025. Electricity prices calculated from Eskom Historical average price increase. Excel Spreadsheet. Downloaded from www.eskom.co.za in August 2025.

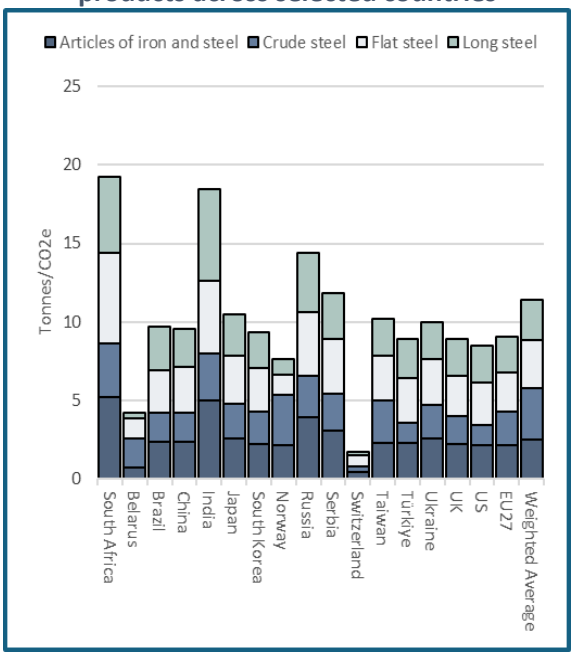
EU CBAM: The EU CBAM will apply carbon pricing to carbon-intensive imports from 2026. For metals, the EU CBAM covers iron and steel, including certain ferroalloys, and aluminium. Considering the carbon intensity of the South African economy (Graph 8), and particularly steel (Graph 9), South Africa's steel exports are highly exposed. Aluminium is less affected in the short term due to the current scope of CBAM penalties. However, there is the potential for other types of emissions to be penalised as the CBAM evolves. In addition, other countries, including the United Kingdom (UK), Japan, and Canada are considering the implementation of similar mechanisms (Maimele, 2025). Potential solutions include reducing the carbon intensity of exports, through low-carbon alternative energy sources, or increasing the domestic carbon tax. However, both these solutions will translate into higher costs for affected operators. The carbon intensity of the affected products remains high by global standards, necessitating substantial investment in low-carbon technologies. In addition, the domestic carbon tax is far lower than the price of carbon applied in the EU, meaning it will have to increase by much more than what is outlined in its current trajectory.

Graph 8. Carbon intensity by country CO_2e per GDP (2011 US$), 2022



Source: Global Carbon Budget, 2024; Bolt and Van Zanden - Maddison Project Database 2023 – with major processing by Our World in Data. Downloaded www.ourworldindata.org in July 2025.

Graph 9. Carbon intensity of steel products across selected countries



Source: Maimele, 2025.

Demand shifts due to low-carbon innovation: The PGMs value chain faces declining demand as EVs are anticipated to replace internal combustion engine (ICE) vehicles, reducing demand for PGMs for catalytic converters. This risk will begin materialising in about 10 years, considering the timeline for the phase out of the sale of new ICE vehicles in major export destinations, like the EU and UK. Impacts are likely to worsen as EV uptake increases. Increased use of recycled PGMs could add to these pressures, as it will reduce demand for newly mined ores.

b. Responses

In response to mounting transition pressures, firms in the metals value chain have adopted a variety of mitigation strategies to reduce their vulnerability. These initiatives are centred on renewable energy uptake, although other sustainability-related measures also prevail. Since the previous assessment, a key development has been the removal of the licensing requirement for embedded

electricity generation projects. Table 3 outlines some of the most recent projects/announcements from key players.

Table 3. Existing/planned decarbonisation projects by major firms in the metals value chain

COMPANY	PROJECTS
Kumba Iron Ore	• 11 MW wheeled renewable energy offtake agreement finalised for Kolomela. • Predevelopment work done for 63 MW solar plant at Sishen Exploring: • Electrification of light delivery vehicles • Hybrid electric shovels • Rolling resistance reduction on roads
Amplats (now Valterra Platinum)	• Concluded offtake agreement for 460 MW renewables
Implats	• Evaluating funding options for 140 MW solar at Goedegedacht • Bankable feasibility study completed for 30 MW onsite solar at Marula • Signed five-year renewable energy agreement for Impala Refineries – expected to provide 90% of needs from 2026
AMSA	• Seen progress around 200 MW embedded solar at Vanderbijlpark Works. Expected to be commissioned end-2025.
Samancor Chrome (Tubatse Ferrochrome smelter)	• Planned 100 MW solar in Limpopo
Glencore-Merafe Resources JV	• Entered into 20-year power purchase agreement for up to 100 MW solar energy
Manganese Metal Company	• Entered into renewable energy supply agreement to source 70% of electricity from renewables

Source: AMSA, 2023b; Anglo American, 2024b; Glencore, 2024; Implats, 2024b, 2025; Kumba Iron Ore, 2024b; Hakeenah, 2025; Parker, 2025.

The broader South African steel industry has also seen a growing number of mini mills, supported by a series of policy developments, and aligning with global trends. When powered by renewable energy and reliant on scrap or direct reduced iron (DRI), these mini mills offer the potential for much lower GHG emissions (Maimele, 2025). Within this context, the use of scrap results in the fewest carbon emissions, followed by DRI. In South Africa, however, mini mills are on grid, and are thus exposed to rising electricity prices and potential charges on indirect emissions. Nevertheless, they offer cleaner alternatives to processes using coking coal.

c. Key implications

Implications for the metals value chain depend on several factors, including the adoption of low-emissions technology, the pace of renewable energy uptake – both on the national grid and by firms in the sector – and the advancement of the production of renewable energy components, green hydrogen, and battery technologies.

By segment, smelting operations face the highest exposure to transition risks. Mining is relatively less vulnerable, given its lower electricity and emissions intensity. By commodity, steel, ferroalloys, and aluminium are highly exposed to risks due to their high carbon intensity and energy dependence. South Africa's primary steelmaking industry is already under strain, as shown by the (anticipated at the time of writing) closure of AMSA's Newcastle facility. Ferroalloy producers are also under strain due to soaring electricity prices. Gold mining is in long-term decline due to resource depletion, and it is unclear whether climate-related pressures will further affect employment in the industry. PGMs

(in both mining and manufacturing) risk demand losses as demand for ICE vehicles decline in key export destinations.

A shift from local beneficiation to exporting unprocessed ores would lower exposure to risk, helping to preserve upstream mining jobs. However, this would likely lead to losses in downstream manufacturing and processing. In addition, extraction-only areas could still be affected by shifts in market demand.

While the transition poses risks for operations in the metals value chain, it also presents an array of opportunities. For example, the decline in demand for PGMs could be offset by advancements in hydrogen fuel, which uses PGMs in proton exchange membrane (PEM) electrolysers and as a catalyst in fuel cells. In addition, iron and steel, which covers ferroalloys, will be needed for the manufacture of renewable energy components and other infrastructure. Aluminium will also be required in this case. Manganese could benefit from the transition, considering its use in batteries. Outside the transition, beneficial electricity tariffs, like that proposed for ferrochrome smelters, may offer some reprieve. However, the ability of these developments to offset the impact on employment that could result from the transition depends on the speed and scale at which they advance.

5. VULNERABLE GROUPS

Vulnerable groups include those directly employed in the metals value chain, workers in related industries, communities reliant on these activities for livelihoods, and local service providers.

In the short term, high-risk workers include those directly employed in the production of steel, ferroalloys, and aluminium. These operations are energy- and emissions-intensive and face transition-related risks in the near term. Workers in these segments often have fewer financial, human, and social resources, compared to mining, meaning job losses would have a deeper and more immediate impact. They are, however, located in more economically diversified regions, which implies the availability of work opportunities outside the metals value chain. Nevertheless, reemployment will depend on additional factors, including qualifications and experience, as well as the prevailing economic conditions.

Mining segment workers are relatively less vulnerable in the short term due to lower electricity and emissions intensity of operations, as well as generally stronger financial, human, and social capital. In many mining-dependent regions, however, particularly those outside of Gauteng, economic diversification is limited, with most local businesses serving nearby mines, implying fewer economic opportunities for potentially displaced workers. The geographic concentration makes relocation difficult, and as businesses in mining regions tend to set up in service of the mine and its workers, potential mine closures would adversely affect broader communities, even if mineworkers are relatively safe. In addition, regions where mining and smelting are co-located face considerable risk in the near term. In the long term, workers and communities dependent on PGMs are at risk due to a decline in demand for the finished product (catalytic converters) associated with their sub-value chain.

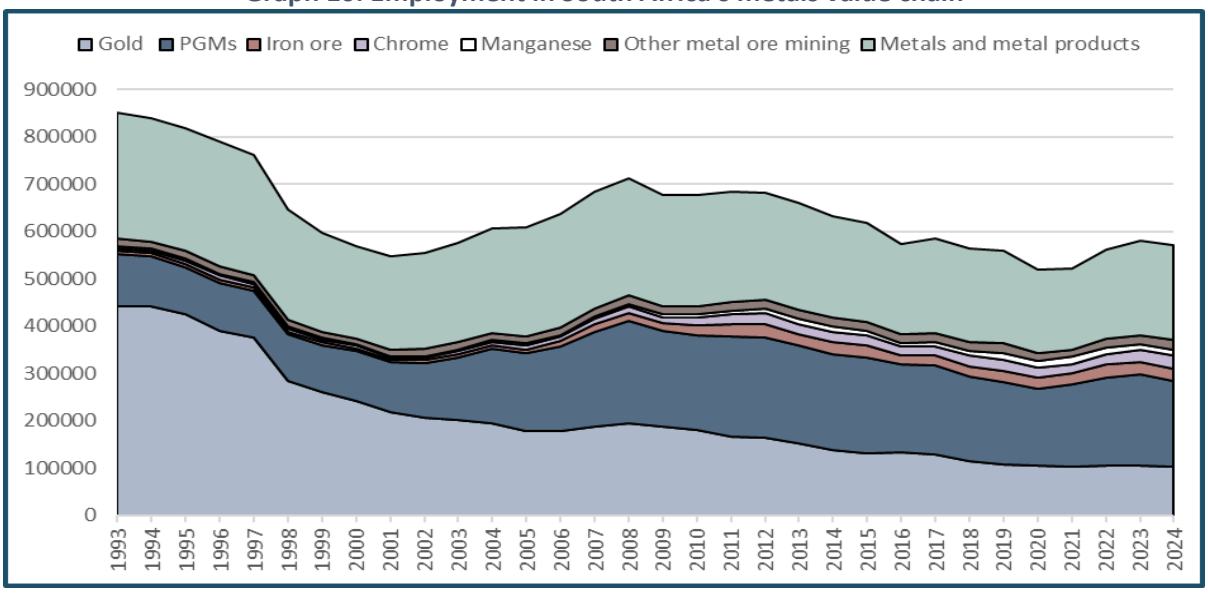
Indirect employment is also significant. A wide range of activities, such as electricity generation, transport and logistics, industrial maintenance, and ancillary services like catering, security, and cleaning, depend on the metals value chain. Outside of small businesses, notably Eskom and Transnet are integral to the operations of South Africa’s metals value chain and could experience workforce reductions if related industries contract. However, employment trends at these entities are also influenced by other factors, including ongoing theft and vandalism, the legacy effects of State Capture, and, in Eskom’s case, the closure of power stations as they aged out.

This section of the report assesses the vulnerabilities of workers and communities reliant on the metals value chain, with findings remaining, largely, unchanged from the 2019 assessment.

a. Employment

In 2024, the metals value chain employed 570 000 people, down from 850 000 people in 1993, as shown in Graph 10 (calculated from Quantec, 2025). Mining accounts for almost two thirds of employment in the value chain, and a significant proportion of the decline in employment is linked to the gold mining industry, which shrank from around 440 000 in 1993 to 100 000 in 2024. Employment in the manufacturing segment of the value chain also fell, albeit significantly less than gold, from 266 000 to 200 000 over the same period, with a notable fall following the global financial crisis, which hit heavy industry. By contrast, employment in other metallic minerals mining increased from 140 000 at the start of the period to almost 270 000 at the end of the period. Overall, within the context of the metals value chain considered in this assessment, the structure of employment remains, largely, unchanged since the previous assessment.

Graph 10. Employment in South Africa's metals value chain

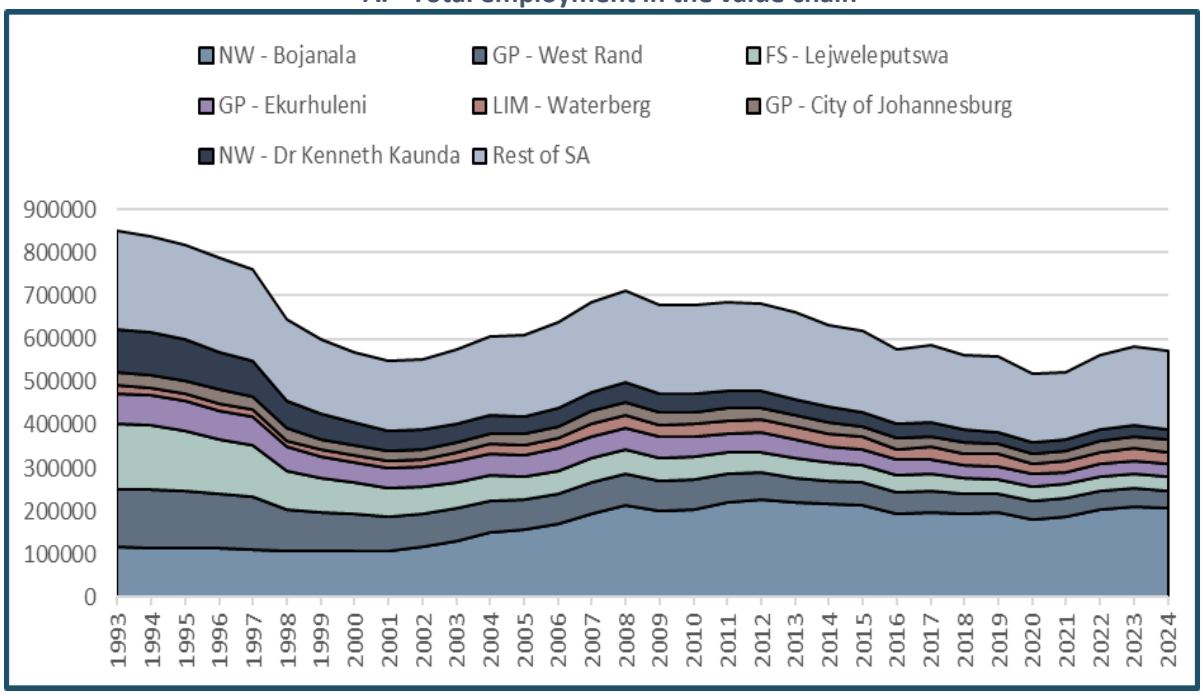


Note: Apart from Metals and metal products, categories refer to mining. *Source:* Calculated from Quantec. EasyData. Industry Service. Industry Trends. Downloaded from www.easydata.co.za in August 2025.

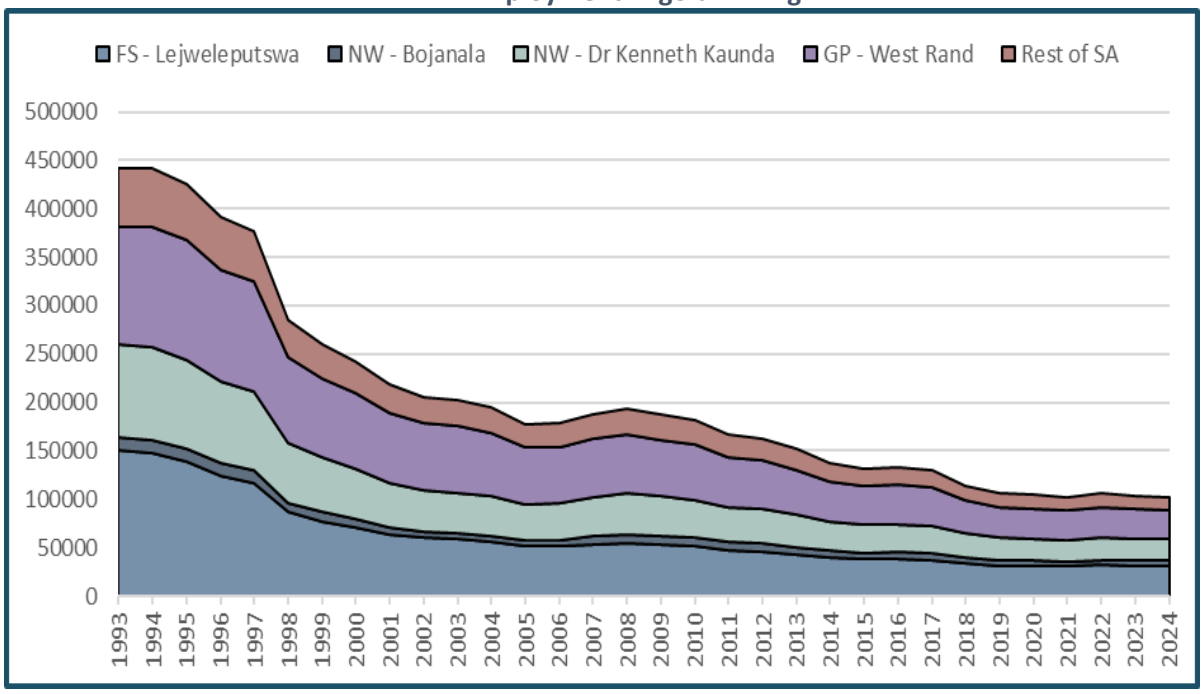
Employment in the metals value chain is concentrated in four municipalities for gold mining, five for other metallic minerals mining, and nine for metals and metal products (Graph 11). The top seven district municipalities host over two thirds of the metals value chain. City of Johannesburg, City of Cape Town, and eThekwini feature among the top hosts for employment in the manufacturing segment.

Graph 11. Employment in South Africa's metals value chain by municipality

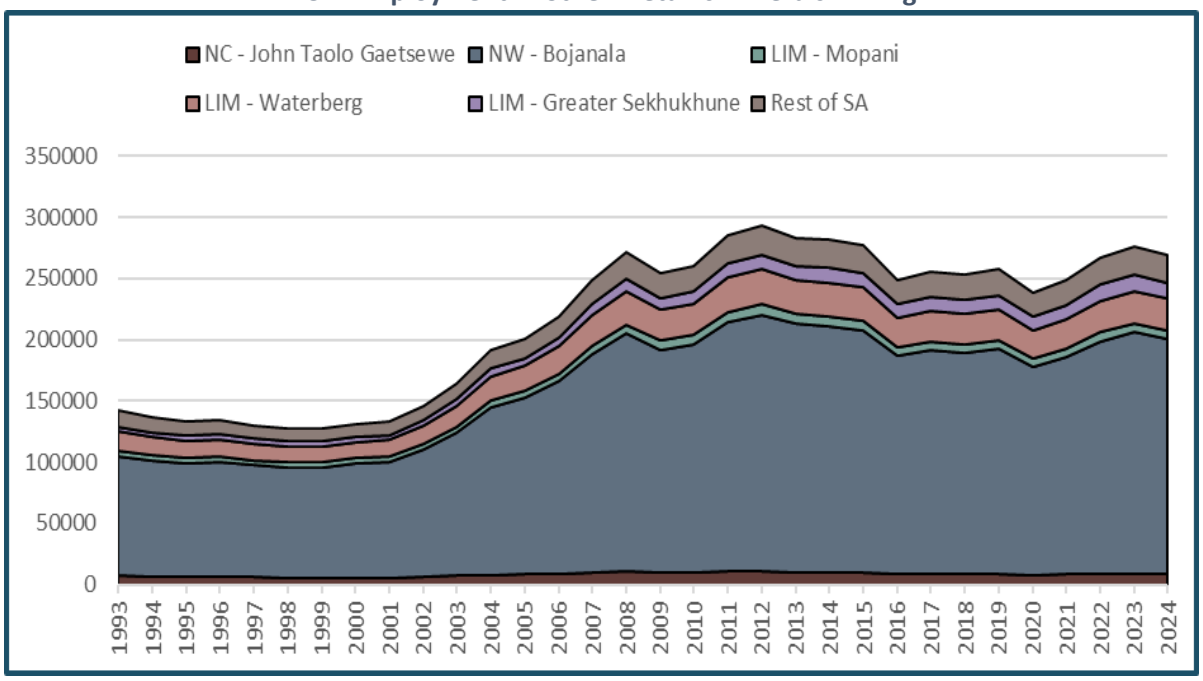
A. Total employment in the value chain



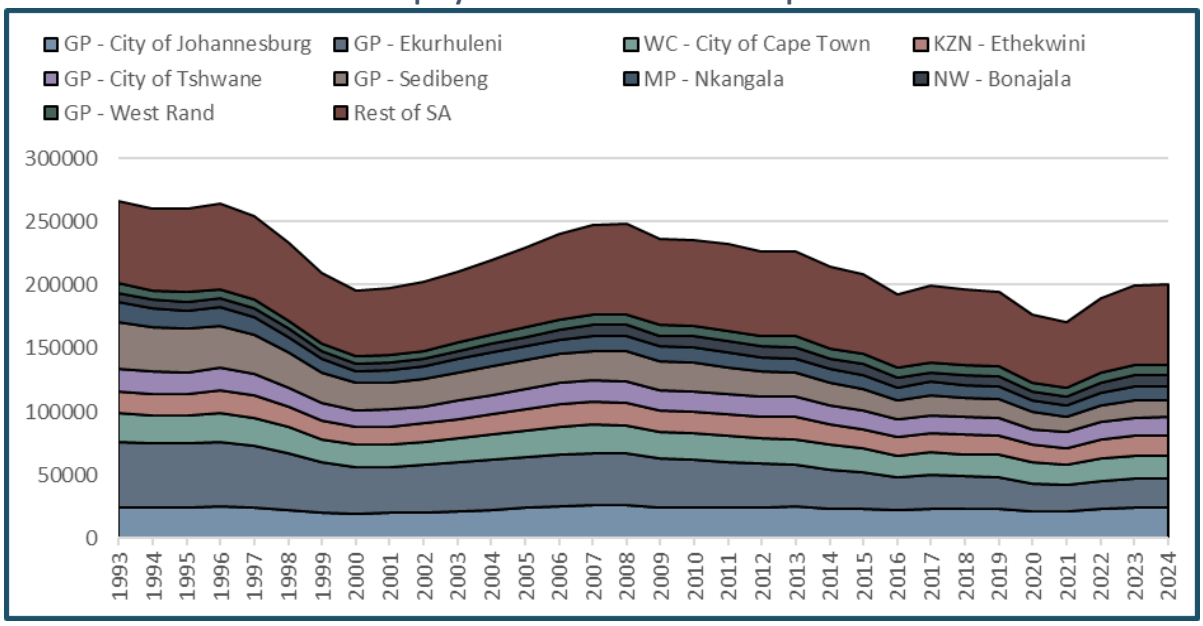
B. Employment in gold mining



C. Employment in other metallic minerals mining



D. Employment in metals and metal products

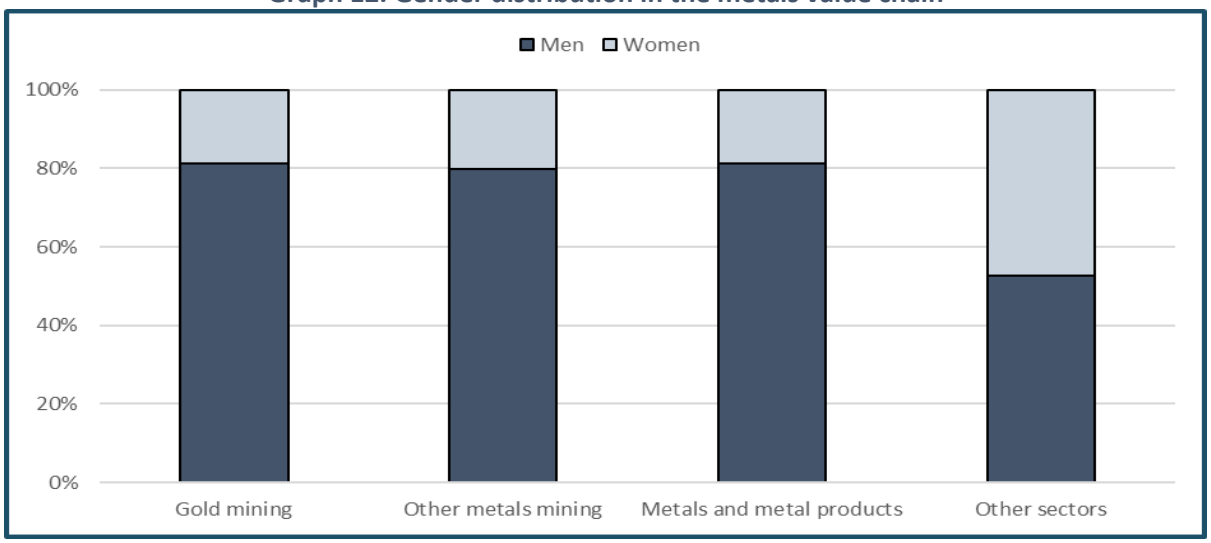


Source: Calculated from Quantec. EasyData. Dataset on Employment and compensation by skill level, industry and 2016 local municipal/ward-based metro region level. Downloaded from www.easydata.co.za in July 2025.

b. Workers

In terms of the gender split, as shown in Graph 12, men dominate employment in the metals industry, accounting for around 80% of workers across the value chain. This contrasts with the rest of the economy, where the distribution is relatively more even, with men accounting for 53% and women at 47% (calculated from Stats SA, 2025b).

Graph 12. Gender distribution in the metals value chain

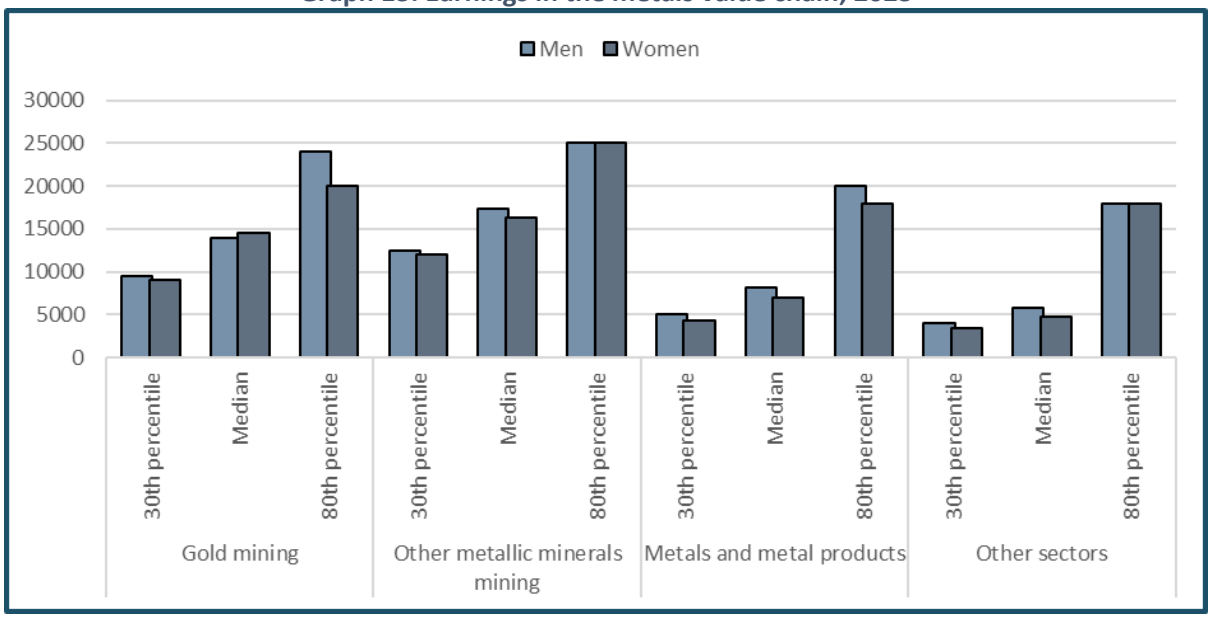


Note: Mining is a clustered industry, and thus might not have been adequately captured in the survey sample. Gold mining includes mining of uranium ore, which is a by-product of gold mining in South Africa. Gold mining is used as a shorthand in this graph and other graphs in this section. Graphs 12-24 also focuses on employees in the value chain, not own-account workers or employers. In addition, "Other sectors" in these graphs refer to industries outside the metals value chain. *Source:* Calculated from Statistics South Africa. Quarterly Labour Force Survey Q1 2025. Isibalo Data Portal. Electronic database. Downloaded from www.isibaloweb.statssa.gov.za in June 2025.

i) Financial resources

Workers in the metals industry are generally better paid than workers in other sectors. Within the industry, however, the mining segments of the value chain are significantly better paying than the manufacturing segments (Graph 13). Median pay across gold and other metallic minerals mining are notable, with the latter being the highest median pay, for both men and women, in the value chain, at around R16000 to R17000. By contrast, median pay in the manufacturing segment – ranging between R7000 to R8000 – is significantly lower than mining, but notably higher than in the rest of the economy (calculated from Stats SA, 2024).

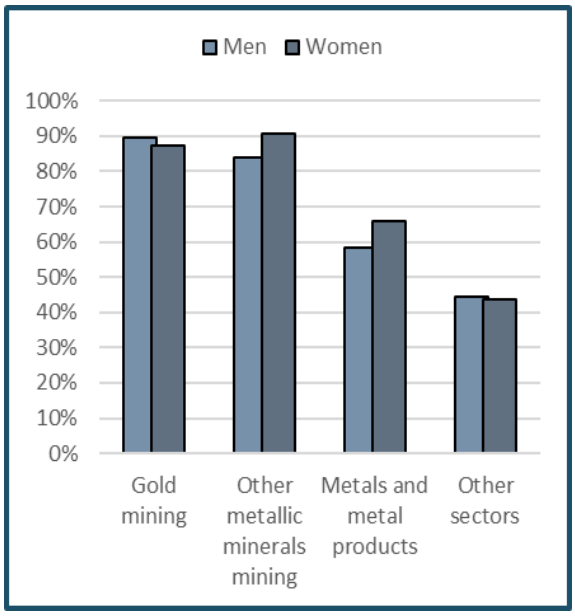
Graph 13. Earnings in the metals value chain, 2023



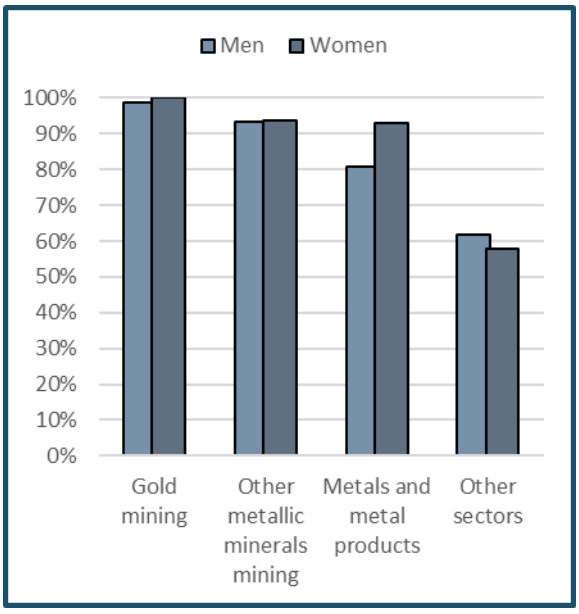
Source: Calculated from Statistics South Africa. Labour Market Dynamics Survey 2023. Isibalo Data Portal. Electronic database. Downloaded from www.isibaloweb.statssa.gov.za in June 2025.

Workers in the industry also have higher access to retirement funds and Unemployment Insurance Fund (UIF) benefits than workers in the rest of the economy, as shown by Graph 14 and Graph 15. Once again, this is particularly true in the mining segment of the value chain, but workers in metals and metal products also fare well for UIF. This provides greater job security and financial cushioning, helping workers better absorb the impact of job losses.

Graph 14. Contribution to a retirement fund in the metals value chain



Graph 15. Contribution to UIF in the metals value chain



Source: Calculated from Statistics South Africa. Quarterly Labour Force Survey Q1 2025. Isibalo Data Portal. Electronic database. Downloaded from www.isibaloweb.statssa.gov.za in June 2025.

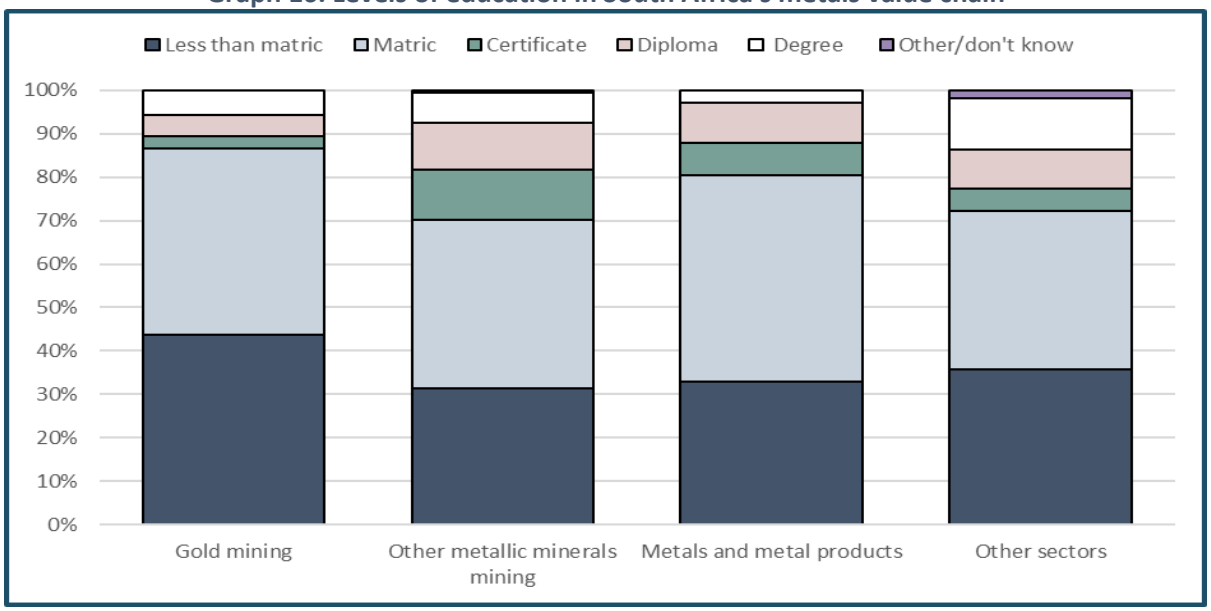
ii) Physical assets

Information on physical assets by occupation is generally lacking. However, studies indicate that, in the case of platinum mining regions, small rural towns often do not allocate adequate land or infrastructure for decent housing for mineworkers. Even those earning relatively good wages have frequently ended up living in informal settlements, with living conditions well below what would typically be expected for their income level (Makgetla et al., 2019). Nonetheless, many workers reported having houses elsewhere (North-West University, 2018). The poor living conditions in communities surrounding platinum mines is confirmed by the Integrated Development Plan (IDP) of Thabazimbi and research from other platinum regions (HSRC, 2025; Thabazimbi Local Municipality, 2025). By contrast, the IDP for the Joe Morolong Local Municipality, an iron ore and manganese ore region, shows that around 86% of the population own their homes. It also shows that only 11% of dwellings are traditional and informal dwellings, while almost 89% are formal dwellings (Joe Morolong Local Municipality, 2024).

iii) Human capital

In keeping with the trends uncovered above, those in other metallic minerals mining have higher levels of qualifications, when compared to gold mining and the manufacture of metals and metal products (Graph 16). Other metallic minerals mining also has a greater proportion of degrees and a lower proportion of workers with less than matric. However, there is a greater proportion of workers with degrees in the rest of the economy.

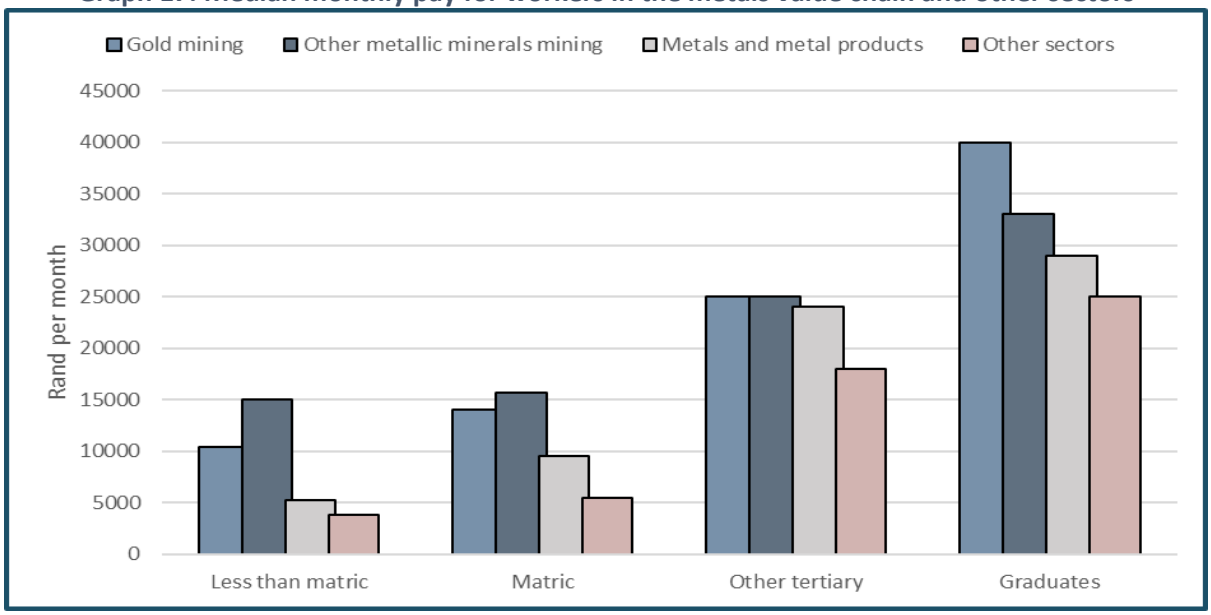
Graph 16. Levels of education in South Africa's metals value chain



Source: Calculated from Statistics South Africa. Quarterly Labour Force Survey Q1 2025. Isibalo Data Portal. Electronic database. Downloaded from www.isibaloweb.statssa.gov.za in June 2025.

The median monthly pay for workers in the metals value chain was higher than for workers across other sectors with the same level of education (Graph 17). Median pay for workers in other metallic minerals was higher than the rest of the value chain for those with lower levels of education. However, those in gold mining with other tertiary qualifications had the same median earnings as those in other metals mining and, for graduates, gold mining had the highest median monthly earnings across all categories.

Graph 17. Median monthly pay for workers in the metals value chain and other sectors



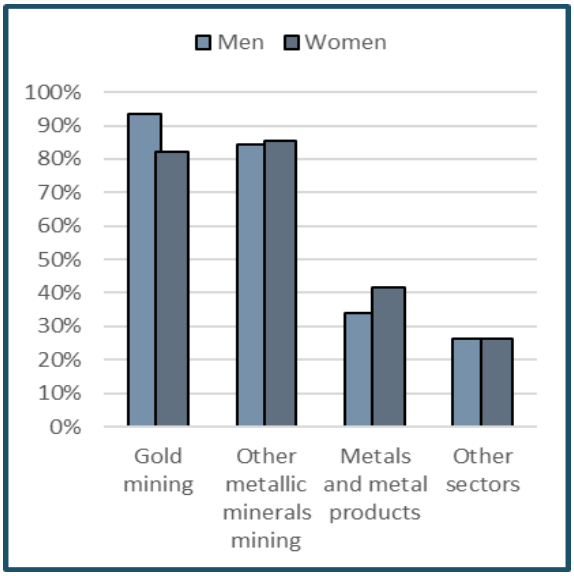
Source: Calculated from Statistics South Africa. Labour Market Dynamics Survey 2023. Isibalo Data Portal. Electronic database. Downloaded from www.isibaloweb.statssa.gov.za in June 2025.

iv. Social capital

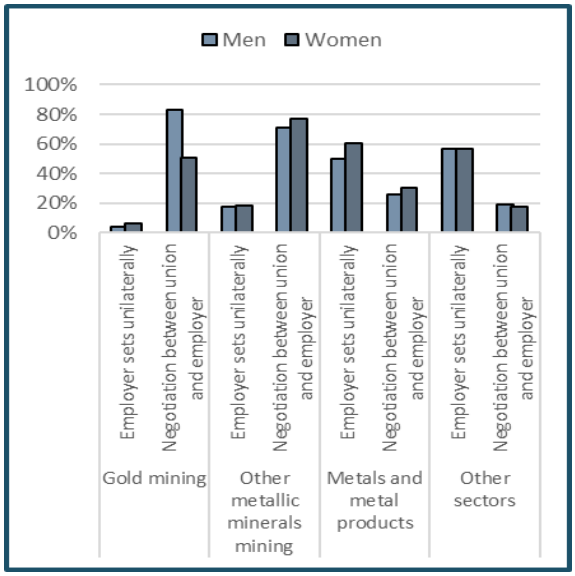
High levels of worker organisation in mining mean that workers virtually invariably get an annual raise. Moreover, salaries are more likely to be negotiated between employers and unions than in other

industries (Graph 18 and Graph 19). In contrast, metals manufacturing is in line with the rest of the economy.

Graph 18. Union membership in South Africa's metals value chain



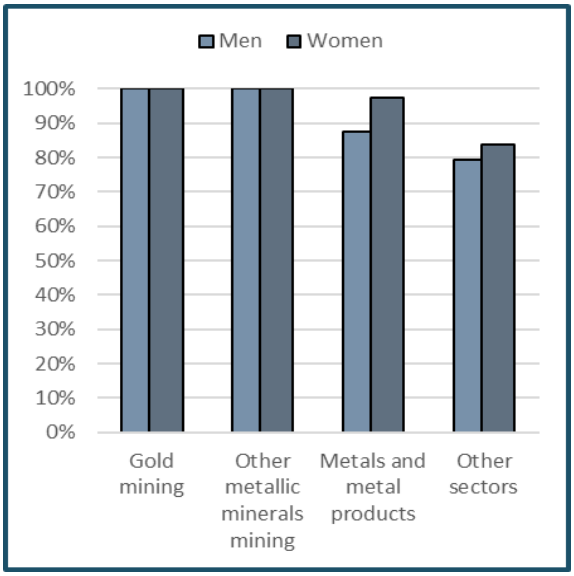
Graph 19. Mechanism to determine annual salary increment in South Africa's metals value chain



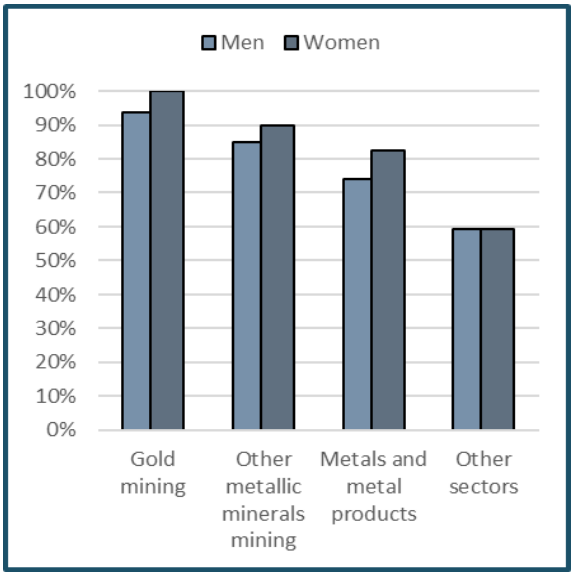
Source: Calculated from Statistics South Africa. Quarterly Labour Force Survey Q1 2025. Isibalo Data Portal. Electronic database. Downloaded from www.isibaloweb.statssa.gov.za in June 2025.

In line with the above, employees in the metals value chain have better protection under the labour laws, with a higher degree of written contracts as well as permanent employment (Graph 20 and Graph 21). Once again, workers in the mining sector fare better than those in other stages of the metals value chain as well as the rest of the economy. Nevertheless, metals and metal products perform well in this regard.

Graph 20. Share of written contracts in South Africa's metals value chain



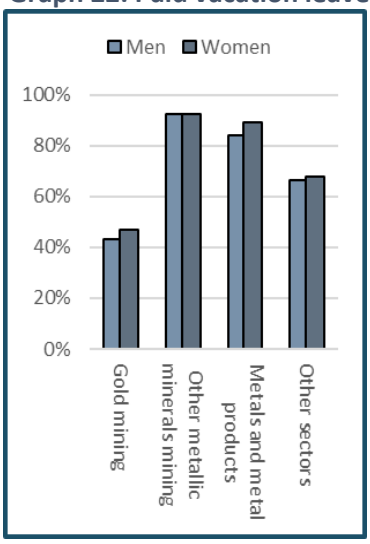
Graph 21. Share of permanent contracts in South Africa's metals value chain



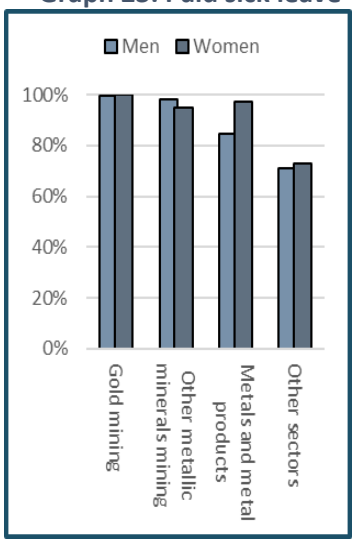
Source: Calculated from Statistics South Africa. Quarterly Labour Force Survey Q1 2025. Isibalo Data Portal. Electronic database. Downloaded from www.isibaloweb.statssa.gov.za in June 2025.

As depicted in Graph 22, Graph 23 and Graph 24, employees across the metals value chain have relatively strong access to paid leave of all kinds, which is a legal requirement. It is noted, however, that access to paid vacation leave in gold mining is unusually low.

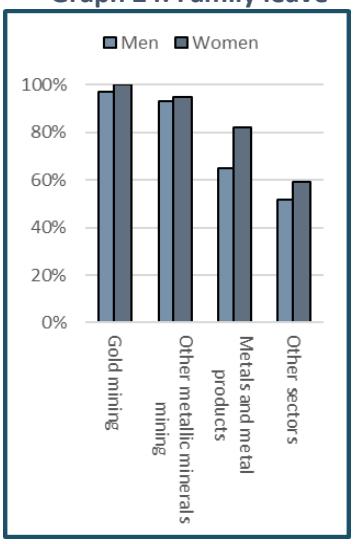
Graph 22. Paid vacation leave



Graph 23. Paid sick leave



Graph 24. Family leave



Source: Calculated from Statistics South Africa. Quarterly Labour Force Survey Q1 2025. Isibalo Data Portal. Electronic database. Downloaded from www.isibaloweb.statssa.gov.za in June 2025.

c. Communities

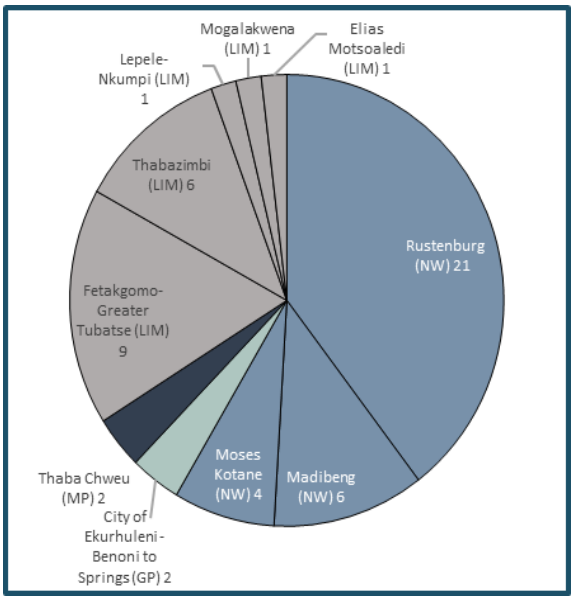
As mentioned, in many mining communities, if the dominant producer downsizes, they will see a general economic decline affecting the small businesses that depend on sales to the company or its workers. While mineworkers may have protections, such as UIF and retirement funds, broader communities may not have access to such. Although it is noted that mines are relatively safe in the short term, impacts are likely to be felt in regions where mining and smelting are co-located. In the long term, as noted, both workers and communities dependent on PGMs face significant risk due to the anticipated phase out of vehicles that require catalytic converters. Within this context, workers face relatively lower vulnerability due to having access to UIF and retirement funds, while communities, whose local economies depend on mining activity, may experience lasting adverse impacts.

Based on Quantec data, the number of mines for the metals considered in this assessment remain unchanged relative to the previous assessment. Graph 25 highlights the number of mines and their location for key metallic minerals in South Africa. Mines are concentrated geographically in the following provinces:

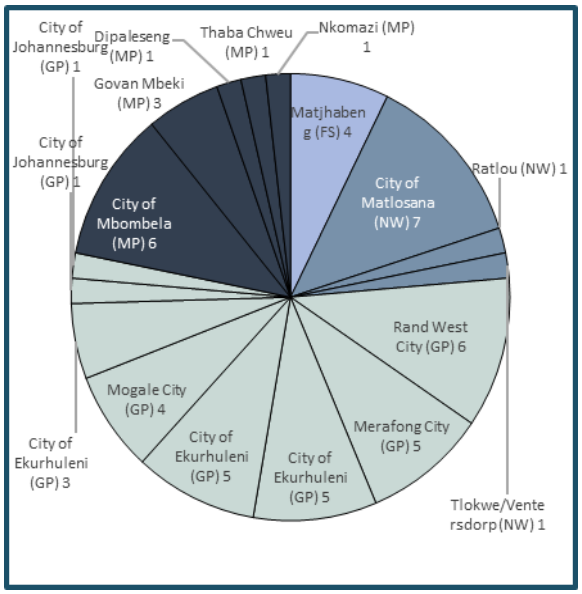
- North West and Limpopo for PGMs;
- Gauteng, Mpumalanga, North West and Free State for gold;
- Northern Cape and Limpopo for iron ore;
- North West and Limpopo for chrome; and
- Northern Cape for manganese.

Graph 25. Geographical location of South Africa's mines for key metallic minerals

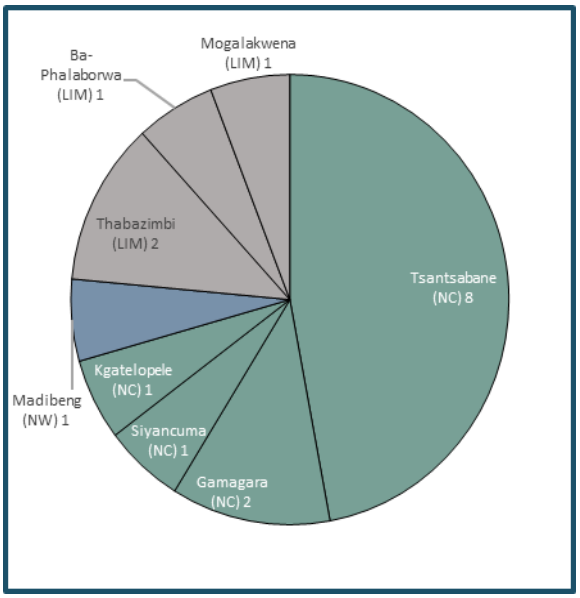
PGMs: 53 mines



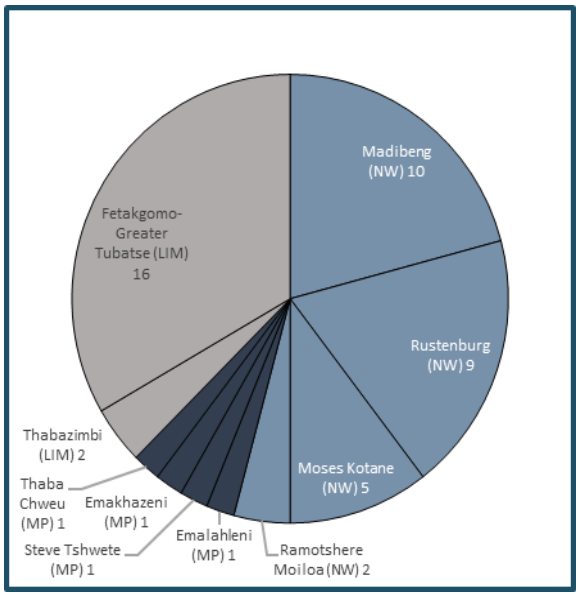
Gold: 55 mines

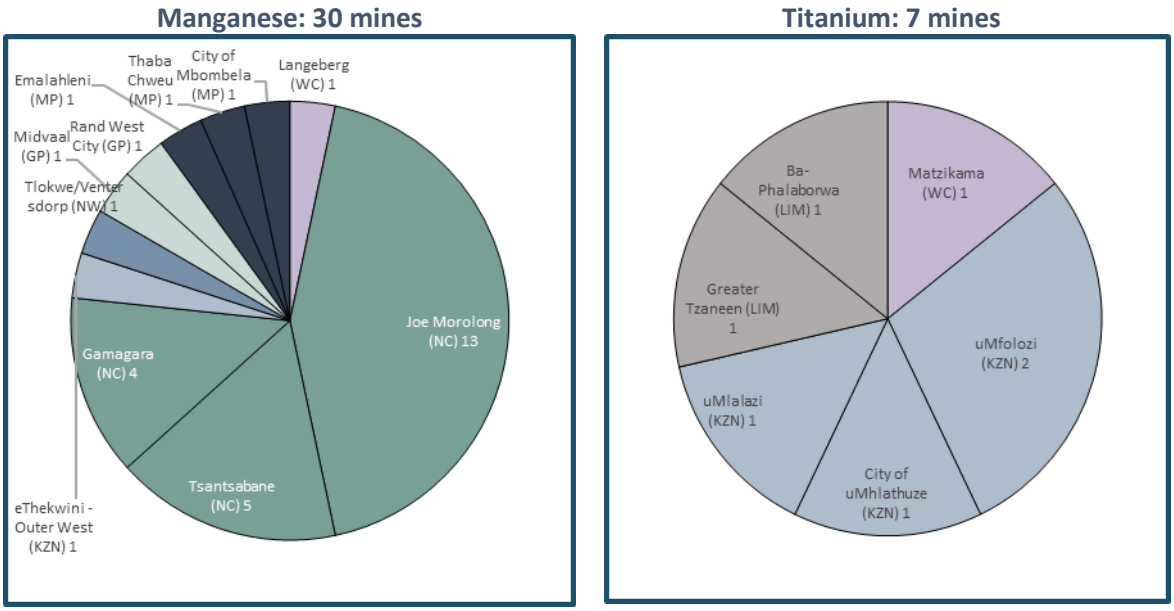


Iron ore: 17 mines



Chrome: 48 mines





Source: Calculated from Quantec. EasyData. Operating Mining Entities By Entities, Types and Commodities Downloaded from www.easydata.co.za in July 2025.

Value added from the metals value chain is concentrated in a few localities. At the provincial level, the Free State (45%) and Gauteng (37%) accounted for the majority of value added (at factor cost) for gold mining, in 2024. For the mining of other metals, North West (37%) and Limpopo (35%) held the lion's share of value added.

In terms of the manufacturing segment, provinces with major metros hold much of the segment's value added. In 2024, Gauteng accounted for 40% of value added from the manufacture of metals and metal products, while KwaZulu-Natal accounted for 21%. The concentration of value added from the metals value chain remains largely unchanged since the previous assessment (Calculated from Quantec, 2025).

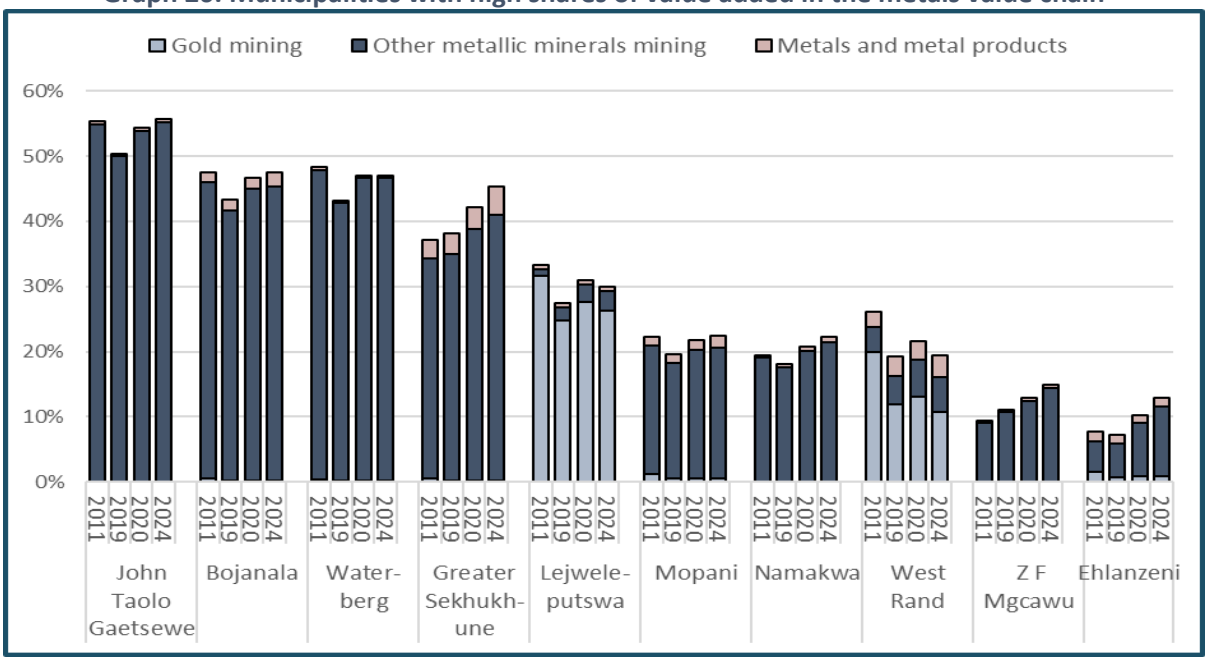
Eight of the 10 municipalities displayed in Graph 26 would be especially hard hit by a decline in mining, considering their particularly high share of value added from the value chain, particularly mining.

As illustrated, these municipalities include:

- Northern Cape: John Taolo Gaetsewe (iron ore, manganese ore);
- North West: Bojanala (PGMs, chrome ore)
- Limpopo: Waterberg (iron ore, PGMs), Sekhukhune (PGMs, chrome ore);
- Free State: Lejweleputswa (gold); and
- Gauteng: West Rand (gold).

In the long term, Bojanala, which hosts a significant proportion of metal mining workers and most PGM mines, could see widespread devastation from transition-led mining closures. Waterberg and Greater Sekhukhune face similar risk.

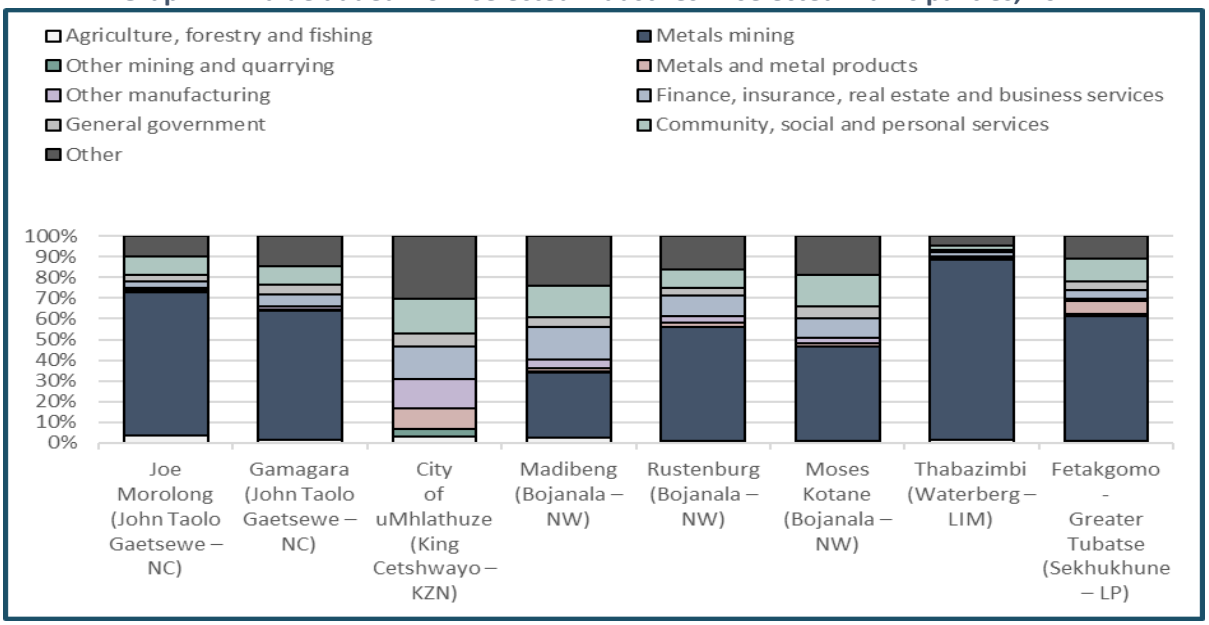
Graph 26. Municipalities with high shares of value added in the metals value chain



Source: Calculated from Quantec. EasyData. Regional Output and GVA at basic prices by industry and 2016 local municipal/ward-based metro region level. Downloaded from www.easydata.co.za in July 2025.

While Bojanala, Waterberg, and Greater Sekhukhune face notable risk, potential declines in other mining regions could be devastating for workers, businesses, and communities, alike. In many metals mining areas, outside Gauteng, virtually all economic activity depends on the metals value chain. Other economic activity essentially serves the people (and households) that work in the value chain. Agriculture and other manufacturing activities are virtually non-existent, as illustrated by Graph 27, for a number of municipalities. This implies limited economic opportunities, outside of mining, for potentially displaced workers, and severe risks for businesses centred on the value chain and its workforce. By contrast, uMhlathuze, which hosts Richards Bay's aluminium smelter, has limited mining activity, but displays a more diversified value added.

Graph 27. Value added from selected industries in selected municipalities, 2024

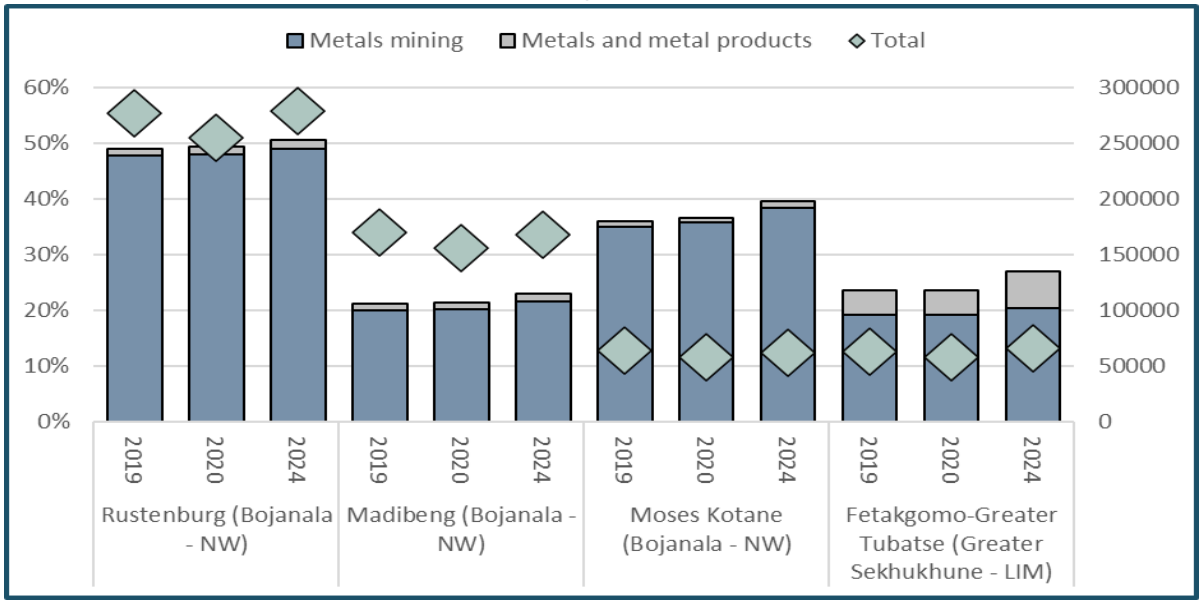


Source: Calculated from Quantec. EasyData. Regional Output and GVA at basic prices by industry and 2016 local municipal/ward-based metro region level. Downloaded from www.easydata.co.za in July 2025.

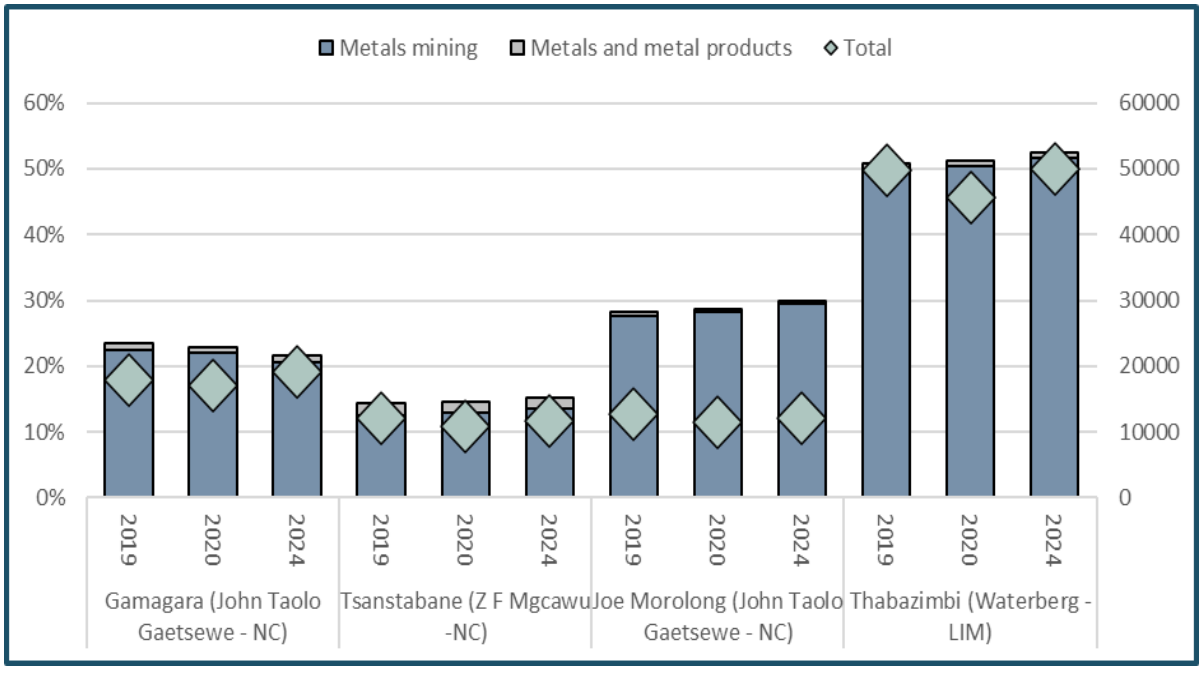
The concentration of value added in mining, in mining regions, is reflected in employment proportions (Graph 28). The share of employment in the metals value chain is particularly significant for Thabazimbi (in Waterberg in Limpopo) with 52% in 2024, Rustenburg (in Bojanala in North West) with 51% and Moses Kotane (also in Bojanala) with 40%, which are also regions facing particularly high risk over the longer term. Job losses of these proportions would, in addition to workers, devastate host communities as people lose their spending power and can no longer support local businesses/employers.

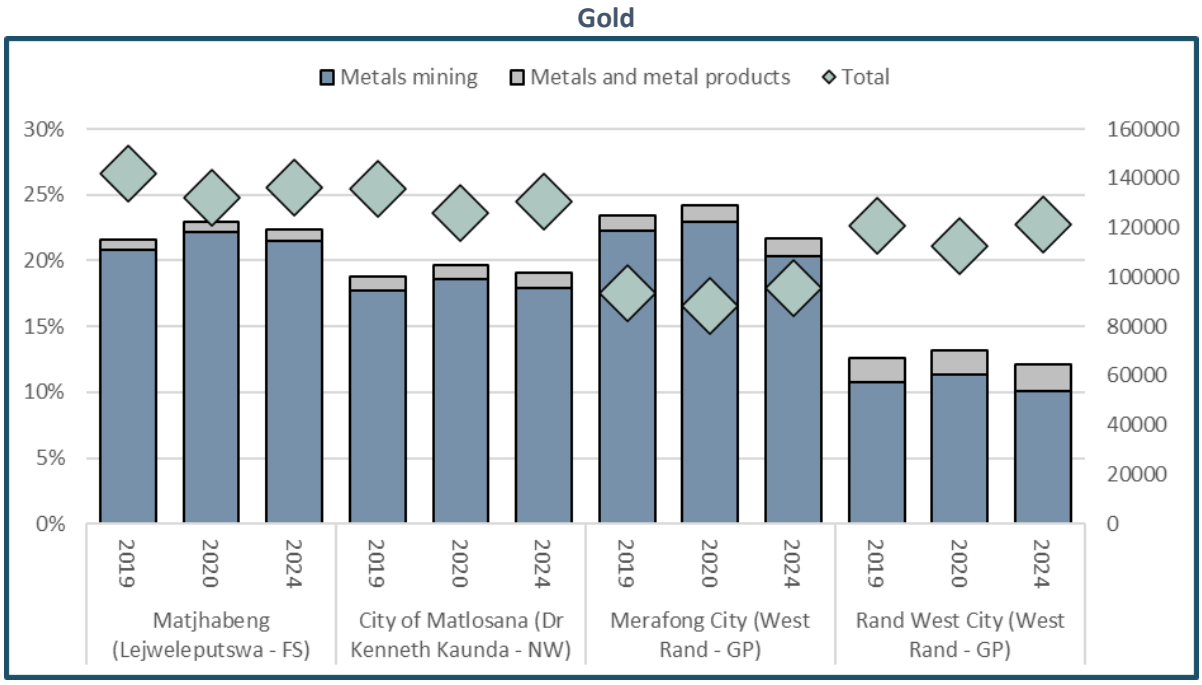
Graph 28. Municipalities with high shares of employment in metals mining, metals as a share of total employment (left axis) and total employment (right axis), selected years, 2019-2024

PGMs/Chrome



Iron ore/Manganese ore





Note: The title for each graph does not necessarily imply the exclusive mining of the associated metal(s).
Source: Calculated from Quantec. EasyData. Employment and compensation by skill level, industry and 2016 local municipal/ward-based metro region level. Downloaded from www.easydata.co.za in July 2025.

6. CONCLUSION

This report sought to assess the vulnerability of workers and communities reliant on the South African metals value chain. These vulnerabilities arise due to climate transition policies focused on energy and emissions, which exposes the metals value chain's dependence on coal-based energy, petroleum fuels, and carbon-intensive production. In the short-to-medium term, risks include SETs, carbon budgets, the carbon tax, potential transition-led electricity price increases, and the EU CBAM. While some of these are already materialising, their impact will intensify in the coming decades. Longer-term risks include the transition to EVs.

The assessment shows that, in the short term, the manufacturing segment and its workers will be harder hit than the mining segment, due to a higher energy and emissions intensity and because workers in the segment have relatively lower financial, human and social resources. Mine workers are relatively safer in the short term due to lower electricity and emissions intensity and due to having generally stronger financial, human, and social resources. However, communities in mining-dependent regions are far more exposed, with limited alternative economic opportunities and high concentrations of employment and value added tied to metals. Without intervention, transition-driven downsizing could have devastating consequences for local economies. This is particularly true in the PGM-dependent towns in the North West province.

In light of these risks, three policy priorities emerge for the SJRP. First, a deliberate shift to renewable energy is essential. Second, targeted interventions are required to strengthen the resilience of vulnerable communities. Economic diversification and proactive planning for mine and smelter closures will be critical to prevent widespread local economic collapse. Finally, existing protections for workers should be strengthened.

REFERENCES

Ackermann, A. and Young, A. 2025. *Draft Carbon Budget and Mitigation Plan Regulations published as South Africa takes important steps to advance national climate change polic*y. Cliffe Dekker Hofmeyr. Available at: https://www.cliffedekkerhofmeyr.com/export/sites/cdh/news/publications/2025/Practice/Environmental-Law/Downloads/Environmental-Law-Alert-14-August-2025.pdf (Accessed 12 November 2025).

Anglo American. 2022. Audited Annual Financial Statements. Available at: https://www.valterra platinum.com/ (Accessed 8 August 2025).

Anglo American. 2023. Audited Annual Financial Statements. Available at: https://www.valterra platinum.com/ (Accessed: 8 August 2025).

Anglo American. 2024a. Audited Annual Financial Statements. Available at: https://www.valterra platinum.com/ (Accessed: 8 August 2025).

Anglo American. 2024b. Sustainability Report. Available at: https://www.valterraplatinum.com/ Accessed 10 August 2025).

AMSA. 2022. Annual Financial Statements. ArcelorMittal South Africa Available at: https://www.arcelormittalsa.com/ (Accessed 10 August 2025).

AMSA. 2023a. Annual Financial Statements. ArcelorMittal South Africa. Available at: https://www.arcelormittalsa.com/ (Accessed 10 August 2025).

AMSA. 2023b. Environmental, Social and Governance Report. ArcelorMittal South Africa Available at: https://arcelormittalsa.com/ (Accessed 10 August 2025).

AMSA. 2024. Audited Consolidated and Separate Annual Financial Statements. ArcelorMittal South Africa Available at: https://www.arcelormittalsa.com/ (Accessed 10 August 2025).

Bleiwas, D.I. 2011. E*stimates of Electricity Requirements for the Recovery of Mineral Commodities, with Examples Applied to Sub-Saharan Africa.* Open-File Report 2011-1253. US Geological Survey. Available at: https://pubs.usgs.gov/of/2011/1253/ (Accessed: 12 August 2025).

Brundtland. no date. Carbon Tax Policy Updates. Available at: https://www.brundtland.co.za/carbon_tax/carbon-tax-policy-updates/ (Accessed: 27 August 2025).

Conradie, A. 2022. *Manufacture and wholesale of basic iron and steel in South Africa*. Who Owns Whom. Available at: https://www.whoownswhom.co.za/ (Accessed 8 August 2025).

Conradie, A. 2023a. *Mining of iron ore and chrome in South Africa*. Who Owns Whom. Available at: https://www.whoownswhom.co.za/ (Accessed 8 August 2025).

Conradie, A. 2023b. *The mining of Manganese in South Afric*a. Who Owns Whom. Available at: https://www.whoownswhom.co.za/ (Accessed 8 August 2025).

Conradie, A. 2024. *Manufacture of basic precious and non-ferrous metals in South Africa*. Who Owns Whom. Available at: https://www.whoownswhom.co.za/ (Accessed 8 August 2025).

Conradie, A. 2025. *The mining of precious metals and minerals: Gold, uranium, platinum and diamonds in South Africa*. Who Owns Whom. Available at: https://www.whoownswhom.co.za/ Accessed 8 August 2025).

DFFE. 2024a. *Draft Sectoral Emissions Targets Report for Public Comment*. Department of Forestry, Fisheries and the Environment. Available at: https://www.dffe.gov.za/sites/default/files/legislations/draft_sectoralemissionstargets2024_g50571gon4763.pdf (Accessed 12 November 2025).

DFFE. 2024b. *National GHG Inventory Repor*t. Available at: https://www.dffe.gov.za/sites/default/files/legislations/unfccc_greenhousegasinventoryreport9_g50607gon4772.pdf (Accessed 28 August 2025).

DMRE. 2024. B1-2024 Mineral Statistics Tables 2001-2023. Mineral Economics. Department of Mineral Resources and Energy. Available at: https://www.dmre.gov.za/mining-minerals-energy-policy-development/operating-mines/mineral-economics (Accessed: 26 May 2025).

Eskom .2025. *Historical average price increase*. Available at: https://www.eskom.co.za/distribution/tariffs-and-charges/tariff-history/ (Accessed 12 August 2025).

Felton, M. 2024. *The motor vehicle industry in South Africa*. Who Owns Whom. Available at: https://www.whoownswhom.co.za/.

Glencore. 2024. *Glencore adds solar power supply for ferroalloys operations in South Africa*. 3 December. Available at: https://www.glencore.com/media-and-insights/insights/2024-12-glencore-adds-solar-power-supply-for-ferroalloys-operations-in-south-africa (Accessed 10 August 2025).

Global Carbon Budget. 2024; Bolt and van Zanden – Maddison Project Database 2023 – with major processing by Our World in Data. 2024. *Carbon intensity: CO_2 emissions per dollar of GDP*. Available at: https://archive.ourworldindata.org/20250716-155402/grapher/co2-intensity.html (Accessed 11 July 2025).

Hakeenah, N. 2025. *South Africa's Largest Private Solar Project to Power Chinese Chrome Smelting Factory*. China Global South Project. 18 February. Available at: https://chinaglobalsouth.com/2025/02/18/south-africas-largest-private-solar-project-to-power-chinese-chrome-smelting-factory/ (Accessed 10 August 2025).

HSRC. 2025. *Life in the platinum belt: socioeconomic struggles in the village of Luka*. Human Sciences Research Council Available at: https://hsrc.ac.za/news/review/life-in-the-platinum-belt-socio economic-struggles-in-the-village-of-luka/ (Accessed 28 August 2025).

Implats. 2022. Audited Annual Financial Statements. Available at: https://www.implats.co.za/index.php (Accessed 8 August 2025).

Implats. 2023. Audited Annual Financial Statements. Available at: https://www.implats.co.za/index.php (Accessed 8 August 2025).

Implats. 2024a. Audited Annual Financial Statements. Available at: https://www.implats.co.za/index.php (Accessed 8 August 2025).

Implats. 2024b. *Climate Change Report*. Available at: https://www.implats.co.za/index.php (Accessed 10 August 2025).

Implats. 2025. *Implats signs renewable energy wheeling agreement with Discovery Green to supply 90% of its refineries powe*r. Available at: https://www.implats.co.za/pdf/press-releases/2025/media-statement-27012025.pdf (Accessed 10 August 2025).

ITC. no date. Trade Map. Available at: https://www.trademap.org/.

Joe Morolong Local Municipality. 2024. Integrated Development Plan. Available at: http://www.joemorolong.gov.za/2024/Planning/IDP/June/2024-2025%20Final%20IDP.pdf (Accessed 27 August 2025).

Kumba Iron Ore. 2022. Audited Annual Results. Available at: https://www.angloamericankumba.com/ (Accessed 8 August 2025).

Kumba Iron Ore. 2024a. Annual Financial Statements. Available at: https://www.anglo americankumba.com/ (Accessed 8 August 2025).

Kumba Iron Ore. 2024b. *Climate Change Repo*rt. Available at: https://www.anglo americankumba.com/ (Accessed 9 August 2025).

Maimele, S. 2025. *Sustainability in the steel industry*. Industry Study. Trade & Industrial Policy Strategies. Available at: https://www.tips.org.za/manufacturing-data/manufacturing-sectors/item/5001-industry-study-sustainability-in-the-steel-industry (Accessed 13 August 2025).

Makgetla, N., Maseko, N., Montmasson-Clair, G. and Patel, M. 2019. National Employment Vulnerability Assessment: Analysis of potential climate-change related impacts and vulnerable groups. Trade and Industrial Policy Strategies. Available at: https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/3988-sector-jobs-resilience-plan-national-employment-vulnerability-assessment-analysis-of-potential-climate-change-related-impacts-and-vulnerable-groups (Accessed 30 April 2025).

Mthenjane, M. 2025. 'Government assistance must address reliability and affordability of power'. *Mining Review Africa.* 8 October. Available at: https://www.miningreview.com/news/government-assistance-must-address-reliability-and-affordability-of-power/ (Accessed 13 November 2025).

North-West University. 2018. *Before and now: the contrast in miners' living conditions*. Available at: https://news.nwu.ac.za/and-now-contrast-miners%25E2%2580%2599-living-conditions (Accessed 27 August 2025).

Parker, D. 2025. 'MMC signs deal to get 70% of its power from NOA's renewable sources'. *Mining Weekly.* 30 January. Available at: https://www.miningweekly.com/article/mmc-signs-deal-to-get-70-of-its-power-from-noas-renewable-sources-2025-01-30 (Accessed 11 August 2025).

Quantec. 2025. EasyData. Available at: https://www.easydata.co.za/.

Stats SA. 2024. LMD2023. ISIbalo Data Portal. Statistics South Africa. Available at: https://isibaloweb.statssa.gov.za/pages/surveys/pss/qlfs/2025/qlfs2025.php (Accessed 1 June 2025).

Stats SA. 2025a. GDP P0441 – GDP Time 2024Q4. Statistics South Africa. Available at: https://www.statssa.gov.za/?page_id=1854&PPN=P0441&SCH=73854 (Accessed 26 May 2025).

Stats SA. 2025b. QLFS202501. ISIbalo Data Portal. Statistics South Africa. Available at: https://isibaloweb.statssa.gov.za/pages/surveys/pss/qlfs/2025/qlfs2025.php (Accessed 1 June 2025).

Thabazimbi Local Municipality. 2025. Integrated Development Plan 2025/2026. Available at: http://www.thabazimbi.gov.za/documents/Final%20IDP%202025_26%20Adopted%20by%20Council%20Signed.pdf (Accessed 27 August 2025).

TIPS. 2025. The Real Economy Bulletin – First Quarter 2025. Trade & Industrial Policy Strategies. Available at: https://www.tips.org.za/images/The_Real_Economy_Bulletin_-_First_Quarter_2025.pdf (Accessed 4 August 2025).