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Mpumalanga **Circular Economy** Market Intelligence Report

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Acknowledgements

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INTRODUCTION

1.1.

Background

A circular economy is an economic model designed to minimize resource input, as well as waste and emission production. Circular economy aims to reach the maximum efficiency in the use of finite resources, the gradual transition to renewable resources, and the recovery of materials and products at the end of their useful life.

In a circular economy, products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling, and composting. The circular economy tackles climate change and other global challenges, like biodiversity loss, waste, and pollution, by decoupling economic activity from the consumption of finite resources.

The circular economy is based on three principles, driven by design:

- Eliminate waste and pollution
- Circulating products and materials (at their highest value)
- Regenerate nature

The circular economy is recognised by the South African government as a new source of economic growth for a re-industrialised, modern South African economy. Science, Technology and Innovation (STI) is a fundamental part of evidencing and facilitating South Africa's transition to a low-carbon, circular economy.

The circular economy is acknowledged as being about more than just waste management. The circular economy provides a lens through which to understand South Africa's resource availability and use, and a way to manage associated risks and unlock opportunities in support of national development objectives as outlined in the National Development Plan 2030.

Transitioning to a circular economy is no longer a 'nice-to-have', nor is it only an environmental agenda. The circular economy is an economic imperative for every country facing growing resource insecurity and global environmental, social and economic challenges. The intent of national policy is to transition to a low-carbon, sustainable and resilient economy that supports the needs of all South Africans. This creates opportunities for job creation and enterprise development within various sectors of the South African economy.

Transitioning to a more circular economy provides an opportunity to address many of the planetary crises facing us this century – climate change, biodiversity loss, water stress, and pollution – by decoupling economic activity from the consumption of finite resources.

Over the past decade, the circular economy has found considerable attention and traction, in both developed and developing countries. The transition to more circular economies, globally, has been fuelled by four big drivers: (1) growing resource scarcity in response to increasing resource demand, (2) impending global environmental threats such as climate change, biodiversity loss and water stress; the urgent need for (3) economic recovery, especially post the global pandemic, and (4) socio-economic development and improved quality of life for all.

1.2.

Circular Economy as National Priority

The South African economy is at present predominantly linear, overwhelmingly characterized by export-orientated extraction of minerals and supported by an energy system dominated by fossil fuels.[2] In 2017, 19% of extracted materials were exported, 38% were used for energy, 35% became waste and only 15% were used to build local stock, which is considered low in comparison to other countries.[2] The evidence shows that continuing down a highly linear development path creates risks for the South African economy:

- **Risk of over-exploiting and depleting critical, finite resources:** For example, it is estimated that five of South Africa's 18 critical or strategic minerals have less than 50 years of economically viable mining remaining, assuming no new deposits are found.[3]
- **Risk in service provisioning and ensuring well-being for all:** South Africa's allocation of resources into domestic, societal stocks such as buildings, infrastructure, and machinery, necessary for the provisioning of services to society, is insufficient. The rate of local stock building is three times lower than the EU average, for example.
- **Risk to agriculture and food security:** Growing water insecurity, with national demand expected to exceed supply by 17% by 2030.
- **Risk to business and industry:** The ongoing crisis in the country's energy sector, which is 80% dependent on coal, characterized by regular power outages, significantly impacts all sectors and industries and reduces domestic productivity and exports.

South Africa's economy is highly carbon intensive. The CSIR has shown that adopting circular economy practices can assist in decarbonizing economic activities and improving energy security. Conservative, high-level modelling for South Africa shows that circular economy measures can reduce greenhouse gas (GHG) emissions in 2050 by 34%.

The South African government has recognized the potential of the circular economy in addressing growing resource challenges; achieving national climate and sustainability commitments; and creating new socio-economic opportunities through greening existing sectors and unlocking new circular businesses and business models.

The principles of a circular economy align with the intentions of the National Development Plan (NDP) and several national industrial, developmental, and environmental policies, including Government's Science, Technology, and Innovation (STI) White Paper and STI Decadal Plan (2022-2032), which recognize the catalytic role of STI in a circular economy transition.

As an initiative of the Department of Science, Technology and Innovation (DSTI), this Circular Economy STI Strategy aims to support South Africa's transition to a more circular economy through science, technology, and innovation.

While there is not yet an overarching national circular economy policy or strategy, South African policy and practice has been increasingly referencing circular economy as a development paradigm; recognizing that the policy landscape remains largely siloed by sector and line department.

This strategy aims to guide government in its strategic direction and investment in circular economy STI activities, and to encourage coordination and collaboration between the public and private sectors and the National System of Innovation (NSI) over the period 2024 to 2034. Furthermore, the strategy proposes tangible routes for ensuring that a circular economy transition is well evidenced and de-risked.

1.3. Priority Economic Sectors

Circular economy practices have been taken up within and across various sectors of the South African economy, and at varying scales of implementation. The DSTI, in consultation with relevant stakeholders, has identified three priority economic sectors – mining, agriculture and manufacturing – in need of an innovation-led response to their modernisation. Alignment with the principles of a circular economy, identified as a cross-cutting issue in Government's STI Decadal Plan, provides an opportunity to modernise these sectors through low carbon, sustainable and circular practices that will boost sector productivity and ultimately economic development of the country. Engagement with the sectors confirmed that considerable opportunity exists for strengthening sector-based circular economy related STI.

1.4. Mining

South Africa is richly endowed with mineral resources. The Minerals-Energy-Complex is an important feature of the South African economy – not only in the provision of minerals and metals into the domestic market, but also the global economy. However, it is a resource intensive sector, both in the extraction of resources, and as a major consumer of resources such as energy, water and chemicals. The contribution of the mining sector to the development of the country is gradually diminishing due to declining productivity; increasing operating costs; fluctuating exchange rates and commodity prices; declining ore grades; increasing mining depth; and health, safety, social and environmental challenges.

The Circular Economy STI Strategy's objective with regards to modernising mining is to evidence South Africa's minerals and metals resource base in support of national resource security, with a special emphasis on critical raw materials; reduce the demand for resources in mining; reduce the generation of mining waste; and strengthen alternative, local sources of minerals and metals through, for example, urban mining.

1.5. Agriculture

The South African agriculture sector relies heavily on resources and natural cycles as its primary inputs.

Resources such as water, energy, soil, and nutrients underpin the functioning of the ecosystem in which the sector operates. However, these resources are finite and are already facing constraints in South Africa. Growing food demand and environmental challenges such as climate change, land degradation, biodiversity loss, and resource scarcity are increasingly pressurizing the agricultural system, impacting food security. The sector currently faces numerous challenges. Climate change is directly affecting agricultural productivity in South Africa through changes in precipitation and temperature patterns; surface water runoff; crop and animal breeds; new pests and diseases; and fertilization programs.

The Circular Economy STI Strategy's objective with regards to modernising agriculture is to enable improved food security by supporting greater resource efficiency through decoupling food and feed production from resource consumption; mainstreaming regenerative agricultural practices; ensuring sustainable practices in agro-processing; and unlocking high-value product recovery through bio refinery approaches to residual organic waste.

1.6. Manufacturing

The South African manufacturing sector has suffered from deindustrialization over the past two decades, mimicking global trends. However, the local manufacturing sector continues to operate on the linear 'take-make-dispose' economic model, plagued by excessive resource demand, unsustainable production and consumption patterns, and high levels of wastage. There is a need for systemic shifts in production and consumption patterns to enable effective resource utilization to achieve sustainable economic growth, preserving natural capital and improving socio-economic wellbeing.

The Circular Economy STI Strategy's objective with regards to modernising manufacturing is to support a more efficient and globally competitive manufacturing sector through the mainstreaming of cleaner production and resource efficiency; circular product design; advanced manufacturing; and remanufacturing.

1.7. Potential for Circular Economy

The South African government recognises the potential of the circular economy to address growing resource challenges; achieve national climate and sustainability commitments; and create new socio-economic opportunities through greening existing sectors and unlocking new circular businesses and business models.

The principles of a circular economy align with the goals of South Africa's National Development Plan (NDP) and a number of national industrial, developmental and environmental policies, including Government's STI Decadal Plan (2022-2032), which recognises the catalytic role of STI in the transition to a more circular economy. As outlined in the STI Decadal Plan:

"[the] circular economy approach offers numerous opportunities for socio-economic growth and environmental protection. Several scientific, foresight and policy reports have indicated that the circular economy can contribute to GDP, provide a new source of employment, increase profit margins at firm level and maximise resource utilisation efficiency. For developing countries, the circular economy can reduce reliance on increasingly scarce raw materials, increase disposable income for individuals, enhance utility and convenience, and improve living conditions and health. Consequently, intensifying the circularity of the economy provides a new model for sustained and resilient economic growth and job creation."[25]

The South African economy was estimated to be only 6% circular in 2017, significantly lower than the 9.1% circularity of the global economy.

The South African economy is predominantly linear, overwhelmingly characterised by export-orientated extraction of minerals (mainly coal, iron ore and other ores needed for steelmaking), and supported by an energy system dominated by fossil fuels. According to a national (economy-wide) material flow analysis aimed at mapping the level of circularity of the South African economy, 19% of extracted materials were exported, 38% were used for energy (technical energy, feed and food), 35% became solid and liquid waste which was returned to nature, and only 15% were used to build local societal stocks (e.g., infrastructure, buildings and machinery) (2017 figures). The net addition to stocks (NAS) of 2.0 tonnes per capita in South Africa is very low, above that of sub- Saharan Africa, but significantly below international levels, making it difficult to provide services for the economy and its inhabitants, to create well-being for all. These data reflect several key challenges currently facing the South African economy.

The percentage of extracted materials going towards domestic societal stocks such as buildings, infrastructure and machinery necessary for the provisioning of services to society, is insufficient. The rate of local stock building is three times lower than the European Union (EU) average, for example.

For further comparison, while the EU material consumption rate per capita is 10% higher than that of South Africa, the building and maintenance of domestic stocks is 300% higher.

In addition, the country faces significant water insecurity, with national demand expected to exceed supply by 17% by 2030. Significant water shortages have already been experienced, such as the 2017-2018 Cape Town water crisis, the 2015-2020 drought in the Eastern Cape and more recent crises in the cities of Johannesburg, eThekwini and Tshwane.

The main sources of water consumption are agriculture (61%), cities (30%) and manufacturing (3%). It is crucial that these sectors become more efficient and circular in their water use and decouple economic development from water consumption to ensure that water does not become a constraint to national food security and future economic development.

The ongoing crisis in the country's energy sector, which is 80% dependent on coal, characterized by regular power outages, significantly impacts all sectors and industries, and reduces domestic productivity and exports. Combined with this, the transportation sector's 98% reliance on increasingly finite and costly imported fossil fuels, and widespread pollution from manufacturing, serve as increasingly urgent indicators for a need to rapidly shift from a linear, carbon-intensive economy to a more circular South African economy.

Although the current economy is vastly carbon-intensive, opportunities exist for decarbonisation and improved energy security through circular interventions to improve energy infrastructure and diversify sources. If implemented in a just and inclusive way, the circular economy can help address many of the country's resource-related development challenges. The CSIR has shown that given the carbon intensity of our energy and resource use in South Africa (e.g., in transportation, manufacturing, and agriculture), adopting circular interventions.

in a few strategic economic sectors can lead to significant decarbonisation. Conservative, high-level modelling for South Africa shows that circular economy measures can reduce GHG emissions in 2050 by 34%, keeping levels to below 2019 values. Sizable contributions to mitigation are achieved through ambitious changes to the use of energy resources in the manufacturing, mining, construction, mobility and agriculture sectors.

International and national research confirms that resource scarcity, climate mitigation, economic recovery, and socioeconomic development are as important in driving South Africa's transition to a more circular economy, as they are to other countries.

Realising the circular economy in South Africa requires a fundamental shift that reshapes how the country's economy operates; specifically, how it (i) derives value from resources, assets and labour, (ii) provides value and opportunity to citizens, and (iii) situates itself in a broader global trade system. This is a shift that our institutions are not yet fully designed nor equipped to lead, and a shift which must engage social and cultural norms related to resource access and use.

1.8. International Context

The circular economy is gaining significant traction worldwide as an alternative to the traditional linear economy, which follows a "take-make-dispose" model. In Asia, countries like China and Japan have made notable strides in advancing circular economy principles. China has embraced circular economy strategies as part of its broader environmental reform agenda. In 2020, China introduced a national "Circular Economy Development Strategy and Action Plan," aiming to reduce resource consumption per unit of GDP and increase the recycling rate of key materials. Japan has long been recognized for its waste management and resource efficiency practices, such as its "Sound Material-Cycle Society" policy (2014). This policy prioritizes waste reduction, recycling, and the efficient use of resources, alongside an emphasis on product longevity and reparability. Both countries demonstrate a growing recognition of the need for systemic change in production and consumption, alongside the growing role of digital technology in optimizing resource flows and supply chains.

The European Union (EU) has also been at the forefront of this movement, with its Circular Economy Action Plan (2020) aiming to promote sustainability across various sectors. This includes initiatives like the EU's Waste Framework Directive (2008) and the Eco-design for Sustainable Products Regulation (ESPR) (2024), which encourage product design that facilitates reuse and recycling, as well as strategies for reducing waste and carbon emissions.

In North America, while the circular economy is still in its developmental phase compared to Europe and Asia, the momentum is growing, particularly in Canada and the United States. Canada, through its federal government and provincial efforts, has pushed forward with initiatives aimed at reducing waste and improving resource efficiency, such as the Canada-wide Action Plan on Zero Plastic Waste.

In the US, a mix of private sector innovation and state-level initiatives is driving circular economy practices.

Several large companies have embraced circular principles, focusing on product longevity, remanufacturing, repair and recycling. While there are still challenges in scaling up circular practices across all sectors, North America is making significant inroads, especially in technology and consumer goods industries, setting the stage for Countries around the world are increasingly investing in, and integrating science, technology, and innovation into their strategies to accelerate the transition to a circular economy.

One key approach is the investment in research and development (R&D) of sustainable materials and circular product design; resource efficient manufacturing; remanufacturing; urban mining; circular bio economy solutions; waste management, and the development and scaling of circular business models. In Europe, for example, the EU has committed substantial funding through programs like Horizon Europe, which supports innovation in circular economy practices.

Governments are also fostering innovation through policy frameworks that incentivize businesses to adopt circular practices.

Governments are also fostering innovation through policy frameworks that incentivize businesses to adopt circular practices. More and more countries are implementing Extended Producer Responsibility (EPR) laws requiring manufacturers to take responsibility for the full lifecycle of their products, which includes ensuring products are recyclable or reusable. These policies are often backed by technological advancements in product design, where digital tools such as 3D modelling and simulation are used to design products that are easier to disassemble, remanufacture, repair and recycle; and informed by tools such as life cycle assessment (LCA).

Emerging economies, including India, Brazil, Chile are increasingly adopting circular economy principles, using technology to tackle issues like resource efficiency, the circular bio economy, and waste management. These nations are also utilizing digital platforms and mobile technology to unlock circular economy opportunities at the local level, while also exploring new business models like product-as-a-service, where products are leased rather than sold, encouraging product return and reuse, thereby reducing waste.

Finally, countries around the world are increasingly recognizing the strategic importance of securing critical raw materials (CRMs) to support their economic growth, technological advancements, and energy transition goals. To prepare for future demand, nations are developing comprehensive strategies that include diversifying supply chains, strengthening recycling capabilities, and investing in alternative materials and technologies.

1.9. South African Context

The South African government has recognised the declining contribution of the productive economic sectors to South Africa's GDP, with a shift towards services, as experienced globally.

However, it remains necessary over the short- to medium-term for South Africa to modernise and strengthen productive sectors such as mining, agriculture and manufacturing to absorb larger numbers of low-skilled workers.

This is even more relevant following the global pandemic, which had a significant negative impact on the South African economy and on employment, including job security.

Innovation has the potential to modernise these sectors, and to unlock new business opportunities that can absorb significant labour, contribute to exports, and support economic development.

There is also the potential to increase the productivity of the South African economy through skills development, innovation, investment in infrastructure, regulatory reform, and information and communications technology. Greening the economy will be an important adjunct to such efforts.

The circular and digital economies have been identified by the South African government as new sources of economic growth for the country. Since many circular economy initiatives are not new to South Africa, there is a strong foundation from which to launch STI for a circular economy.

For example, in response to high levels of unemployment, poverty and inequality, end-of-life products are often repaired and reused in South Africa. As a result of water scarcity, grey water has been recycled and reused for decades, with returns making up more than 10% of South Africa's available water.

Additionally, amidst worsening energy insecurity since 2007, the installation of renewable energy technologies has grown significantly over the past decade.

Circular economy practices have been taken up within and across various sectors of the economy, and at varying scales of implementation.

Common goals across such initiatives have included greater financial security and improved quality of life; resource security; increased resource efficiency and productivity; and retaining resources within the South African economy at their maximum value.

The DSTI has identified three economic sectors – mining, agriculture and manufacturing – as growth economic sectors that can serve as useful platforms for implementing circular economy initiatives.

2.

SECTORAL OPPORTUNITIES IN RSA CIRCULAR ECONOMY

The circular economy is an evolving concept that has gained traction over the past four to five years with business and government leaders. It has also appeared in a number of new South African policies, including the White Paper on Science Technology and Innovation (DSI, 2019), the 3rd National Waste Management Strategy (DEFF, 2021) and in the new Department of Science and Innovation Decadal Plan (2021-2031). In this section sectoral opportunities in the RSA circular economy are:

2.1.

Agriculture Sector

Agriculture plays an important role in the South African economy, being deeply interconnected and central to many other industries and their operations. South Africa is a major producer and exporter of agricultural products, with the country consistently remaining a net exporter over the last decade. Agricultural exports amounted to USD10.2 billion in 2020 and a record USD12.4-billion in 2021, creating 829,000 jobs. However, the agricultural sector is resource intensive with a heavy reliance on water, energy, soil, nutrients and natural cycles, as primary inputs.

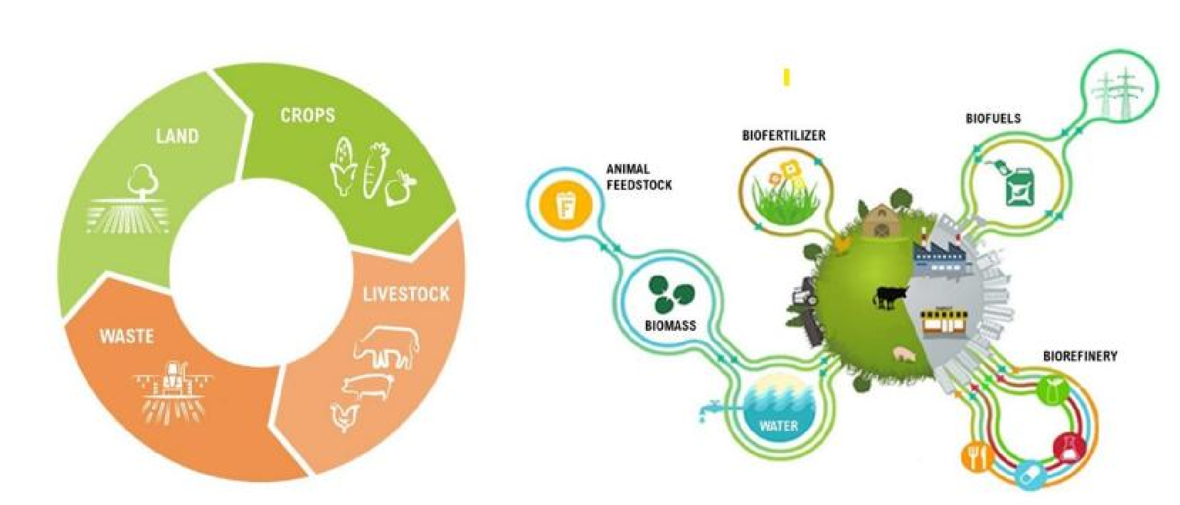
To feed a growing South African population will require embracing new farming methods that can help increase productivity, while reducing associated environmental impacts. While previous evolutions in farming have largely been driven by mechanical improvements (namely, bigger, better machinery), genetic advances (improved seeds), or green revolution (more effective fertilizers, etc.), the next big transformation is being driven by digital tools and lifestyle changes. A number of new, disruptive, technology trends are emerging in the agricultural sector and are regarded as key market opportunities, including the circular economy. The circular economy is based on the principals of designing waste and pollution out of the system, keeping products and materials in use, and regenerating natural systems. Implementation of these transformative technologies requires a collective approach from all stakeholders.

Business opportunities in this sector ranges from food waste interventions, regenerative agriculture, to precision agriculture, agro-processing, sustainable packaging to extend product life, and urban farming.

Agriculture also has major impacts on the environment, being a leading contributor to GHG emissions, water consumption, nitrate and ammonia pollution. Mitigations available are geared generally towards regenerative agriculture interventions (crop rotation, minimum tillage, green manure, integrated pest management) that can reduce GHGs.

Circular agriculture as depicted in Figure 1 below centres on a regenerative system, with the production of agricultural commodities using a minimal amount of external inputs; decoupling production and processing from resource utilization; closing nutrient loops; restoring soil fertility; and reducing discharges to the environment.

Figure 1: Circular agriculture and the valorisation of unavoidable waste from the agri-food sector



Scholten, 2021 and AgrocCycle, 2021).

Circular agriculture means that we keep residuals of agricultural biomass and food processing within the food system as renewable resources.

If done properly, circular agriculture therefore, has the potential to make businesses more economically viable, competitive, and sustainable in the long-term, reducing risks linked to external inputs and commodity prices; reducing the pressure on natural resources; and opening new revenue streams through innovation, new technologies and collaboration between sectors and industry.

Secondly, when scaled, circular agriculture can reduce resource requirements, GHG emissions, land use, water and energy, chemical fertilizers, synthetic pesticides and ultimately the ecological footprint of agriculture thus reducing production cost. A transition to a circular economy, requires a strong evidence base to understand the opportunities that this transition will yield for increased industrialisation.

The following business opportunities are available to implement within the agriculture sector circular economy.

- Organic waste beneficiation: Food losses and waste is a growing reality, estimated to be in the order of 10.3 million tons in 2021 (Oelofse et al., 2021). Not only is food wasted, but all the energy and inputs required to grow, package and transport the wasted food are also lost. Organic waste from farming has long been used as a source of fertiliser for agriculture.
- Biochar, can be produced as a by-product of pyrolysis / gasification of waste biomass. Biochar shows great potential to reduce the environmental impact, address climate change, and establish a circular economy model.
- Agro-processing technologies for value add
- Biorefinery and high-value product recovery from agro-industrial waste streams
- Equipment sharing and chemical leasing
- Urban farming – vertical farming, aquaponics, aquaculture, greenhouse farming, etc.
- Regenerative agriculture is a system of farming practices and principles that increases ecosystem health while improving yields.
- Precision agriculture which uses remote sensing and data collection to ensure the right amount of resources (water, fertilizers, pesticides) are used at the right time in exactly the right place. The technology can also be used to predict yield.

2.2. Mining Sector

This section relates to the circular economy in the context of the South African mining sector. The purpose of this section was to investigate the remaining years of economically viable minerals in South Africa. The investigation will provide an indication of the country's status regarding the availability of mineral reserves while assisting in determining whether mineral scarcity is a driver to transition to a more circular South African economy.

An economically viable mineral is referred to as a reserve and is defined according to the South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves (SAMREC).

According to SAMREC, a reserve is that part of an in situ demonstrated resource that can be economically extracted or produced at the time of estimation. The amount of reserves may increase as the mineral resource and reserve modifying factors change. Furthermore, the demand and supply of minerals is affected by several factors such as commodity prices and emerging technologies.

Three minerals (iron ore, lead and manganese) showed that they would potentially be depleted in less than 20 years of mining, two minerals (gold and cobalt) in 20-50 years, one mineral (zinc) in 50-100 years, four minerals (coal, copper, PGM and vanadium) in 100-500 years, and nine minerals (chromium, fluorspar, nickel, phosphate, titanium, uranium, vermiculite, zirconium and diamonds) would potentially be depleted after 500 years. Despite having sizeable reserves of graphite and REE, there is currently no production – despite positive growth in demand for these minerals globally. Both have an expected compound annual growth rate (CAGR) greater than 4%.

All minerals extracted in South African mines are either sold locally or exported. Mineral exports play a vital role in the economic development of the country, and they account for approximately 66% of exports (Stats SA, 2021). In 2019, South Africa's mining industry's total income was R552.1 billion (Stats SA, 2021).

The most implementable circular economy opportunities in the mining sector are those aligned with the "keep materials in use" principle. These include reducing, reusing and recycling of materials. Although some of the opportunities mentioned within this category are not new concepts, challenges still remain when it comes to implementation of these initiatives.

The challenges are mainly operational and financial, suggesting that RDI are key focus areas to addressing these issues.

In terms of financial constraints to implementation, the cost versus long-term benefit of these interventions needs to be better understood and realised. Even though some mining companies adopt circular economy principles, the interventions need to be scaled up to make a meaningful impact on business, society, environment, and the economy at large.

Although adopting circularity within the mineral value chain may be a potential solution for sustainable resource use, these minerals are mostly exported, thereby imposing limitations on the country's ability to put circular interventions in place that benefit the local economy. It is therefore recommended that local beneficiation, use and value add be implemented.

Eighteen minerals were identified as critical / strategic in South Africa due to their economic importance and supply risk. The critical minerals in South Africa include: aggregate, bauxite, chromite, cobalt, copper, gold, graphite, iron, limestone, lithium, manganese, nickel, PGMs, phosphorous, REEs, silver, titanium, and vanadium. Table 1 presents a list of South Africa's potentially critical / strategic minerals.

Table 1: South Africa's critical / strategic minerals

Critical / strategic minerals in SA	**Justification for criticality status**
Aggregates	Essential in the construction sector
Bauxite	Essential in aluminium production, metallurgy, chemical industry, and use as a catalyst. SA does not have bauxite reserves
Chromite	Essential in robotics, UAVs, steel production in SA accounts for about 70% of the world's chrome reserves
Cobalt (Co)	Essential in energy storage technology, EV economy, however, SA was ranked 10th in world production in 2020
Copper (Cu)	Essential in the solar photovoltaic (PV) cell production, electric mobility (e-mobility) industry, in drones and unmanned aerial vehicles (UAVs), remote computing and energy storage
Gold (Au)	Gold is important to the SA economy for its vital contribution to the GD, employment, and for attracting foreign capital. Scarcity of gold resources and difficulty in mining. SA was ranked 7th in production with 100 tonnes in 2021
Graphite	Essential in the e-mobility industry, however, SA has no graphite operations
Iron (Fe)	Essential in steel-making, steel is highly recyclable, reusable, and can be used for renewable energy infrastructure and transportation networks *(ArcelorMittal, 2019)*
Limestone	Essential in steel manufacturing, mining, paper production, water treatment and purification, and plastic production
Lithium (Li)	Essential in the green energy technologies, electric vehicles (EVs), and electronics. SA has no lithium extraction or processing, however, can play a role in the refining and processing stage (Stage 3) as a key supply chain stage. SA does not have significant lithium reserves
Manganese (Mn)	Essential in the steel industry, hydrogen fuel cells, e-mobility, and UAVs. SA contains the largest manganese reserves at 5.5 million tons and is the leading producer. However, production has decreased in 2020
Nickel (Ni)	Essential in e-mobility, drones and UAVs, energy storage
PGMs (individual elements listed below):	Often used as catalysts. SA hosts 88% of the world's PGM reserves
Iridium (Ir)	Essential in use as a hardening agent for platinum, also used in spin electronic devices
Osmium (Os)	Essential in producing very hard alloys for fountain tips, instrument pivots, needles and electrical contacts. Also used in chemical industry as a catalyst
Palladium (Pd)	Essential in catalytic convertors, cans also be used jewellery, medicine and recently started being used in fuel cells to power cars
Platinum (Pt)	Essential in motor industry with use as a catalytic convertor, also used in laboratory equipment, electrical contact and electrodes
Rhodium (Rh)	Essential in use as a catalytic convertor for cars, jewellery chemical and electrical trades
Ruthenium (Ru)	Essential in the chemical industry for coating anodes of electrochemical cells for chlorine production, can also be used in solar cells
Phosphorous	Essential in the agriculture sector for fertilizing purposes

The just-transition to renewable energy necessitates investigations into alternative uses for coal so that the economic benefit that South Africa currently gains from coal sales is not completely lost. Additionally, to avoid locking South Africa into an export model, local beneficiation and manufacturing of PGM (amongst other minerals) becomes increasingly important as the demand for critical minerals increases.

Based on the findings, it was concluded that resource scarcity may in fact be a driver for South Africa to transition to a circular economy. However, other drivers also need to be considered such as job creation, socioeconomic development, climate commitments, and business objectives, amongst others.

It can therefore be argued that all mineral commodities are scarce and should be used sparingly and in a sustainable and responsible manner, for the benefit of present and future generations.

Urgent priority should be directed to those commodities that may potentially be depleted within the next 50 years of extraction – cobalt, gold, iron-ore, lead and manganese – by identifying and investing in circular economy interventions for these commodities.

Table 1: South Africa's critical / strategic minerals (Continued from Page 17)

Critical / strategic minerals in SA	Justification for criticality status
REEs (individual elements listed below):	Essential in clean energy, defence technologies, high-tech devices, LED lighting. SA only contains about 0.7% of the world's REE reserves
Cerium (Ce)	Used in electronics like lights, TVs and ovens
Dysprosium (Dy)	Used in wind turbines, EVs and nuclear reactors when mixed within alloys
Erbium (Er)	Used in lasers and fibre optics cables
Europium (Eu)	Used in light bulbs, nuclear reactors and lasers
Gadolinium (Gd)	Used in magnets, nuclear reactors and magnetic resonance
Holmium (Ho)	Used in magnets and nuclear reactors
Lanthanum (La)	Mixed within alloys that are used in batteries and hydrogen vehicles
Lutetium (Lu)	Used as a catalyst in refineries
Neodymium (Nd)	Used in magnets and lasers
Praseodymium (Pr)	Used in aircrafts engines, fiber optic cables and magnets
Promethium (Pm)	Used in pacemakers and guided missiles
Samarium (Sm)	Used in microwave devices and devices
Scandium (Sc)	Used for fuel cells and alloys used in jet planes
Terbium (Tb)	Used in light bulbs, memory devices and X-rays
Thulium (Tm)	Used in lasers
Ytterbium (Yb)	Used in displays, x-ray machines and fiber-optic cables
Yttrium (Y)	Used in radars and as an additive within allows used in high-tech devices
Silver	Essential in alloys, batteries, light emitting diode (LED) chips, PV energy, electronics, and jewellery
Titanium	Essential in rechargeable batteries, electronics, medicine industry and EVs

The most implementable short-term circular economy opportunities in the mining sector are those within the "keep materials in use" principle. These include reducing, reusing and recycling of materials. Although some of the opportunities mentioned within this category are not new concepts, challenges still remain when it comes to implementation of these initiatives. The challenges are mainly operational and financial, suggesting that research, development and innovation are key focus areas to addressing these issues. In terms of financial constraints to implementation, the cost versus long-term benefit of these interventions needs to be better understood and realised. Even though some mining companies adopt circular economy principles, the interventions need to be scaled up to make a meaningful impact on business, society, environment, and the economy. A considerable number of circular interventions have been identified for the mining sector, some of these may require time to implement, making them more suitable for medium- to longer-term implementation.

2.3. Manufacturing Sector

The South African manufacturing sector (SAMS) has suffered from de-industrialisation over the past two decades, mimicking global trends. The local manufacturing sector continues to operate predominantly on the linear 'takemake-dispose' economic model, plagued by excessive resource demand, unsustainable production and consumption patterns, and high levels of wastage *(Nahman et al., 2021).*

The manufacturing sector, despite its decline, remains a sizeable contributor to national greenhouse gas (GHG) emissions, largely through the sector's fossil-based energy use, and liquid fuel demand *(DFFE, 2021)*. The heavy economic dependence on resource extraction in favour of exports is well recognised *(Khan et al., 2022)*. Despite massive inputs of natural resources, productivity within the manufacturing sector remains low, while significant volumes of waste and pollution are generated *(Von Blottnitz et al., 2021).*

The sector ranks fourth in GDP contribution, embodying a diverse list of sub-sectors, each demanding a broad range of resources, processed materials and finished products. **The main sub-sectors by contribution (%) are as follows:**

- Food and beverages (26%)
- Petroleum and chemical products (including plastics and plastic products) (24%)
- Basic iron and steel (19%)
- Wood products, paper and printing (11%)
- Motor vehicles, parts and accessories (7%)
- Glass and non-metallic mineral products (4%)
- Textiles and clothing (3%)
- Furniture and other manufactured products (3%)
- Electrical machinery (2%)

The manufacturing sector has high resource demands, relying strongly on primary and secondary processing of extracted resources (e.g. base metals) and other feedstocks. These finite resources face increasing risk from over-exploitation *(Khan et al., 2022)*. Moreover, the country mostly exports un-beneficiated ores and unwrought base metals, apart from motor vehicles, and associated spares and accessories. The lack of local beneficiation is exacerbated by high levels of manufactured imports (>80% in 2020), comprising *(IDC, 2021)*:

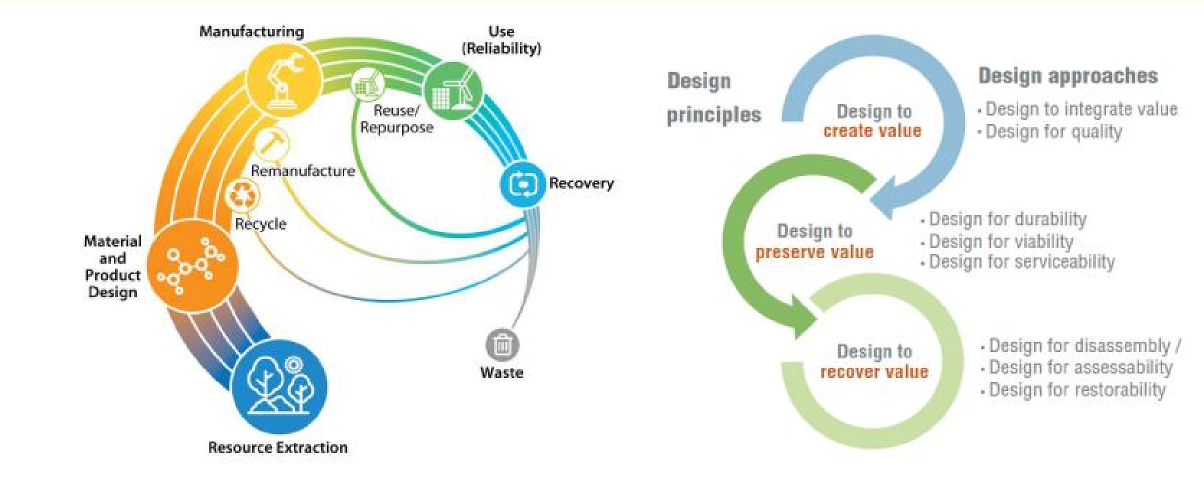


Figure 2: **Integration of circular economy into manufacturing *(NREL)***

The following are three disruptive global trends in the manufacturing sector:

- Remanufacturing
- Renewable energy technologies
- 4IR technologies

Business opportunities to implement in the manufacturing circular economy.

- The re-manufacture of industrial equipment by Value Retention Processes (VRPs) can reduce virgin material usage by 80-98% and cost by 15-80% over Original Equipment Manufacturer (OEM) products (IRP 2018). Globally, remanufacturing is dominated by the automotive and aerospace sectors, as well as construction, electrical equipment, heavy machinery and medical devices.
- Optimising resource yields by constantly circulating products, components, and materials at highest utility.
- The manufacturing sector adopting more renewable energy solutions, the emerging green energy market (estimated at R30Bn) offers new circular manufacturing opportunities for South Africa.
- Scaling circular manufacturing will require disruptive technologies, including digital technologies such as Internet-of-Things (IoT), big data, and blockchain, which allow for advanced tracking and monitoring of resource utilisation and waste capacity.

The obstacles and challenges in the manufacturing sector very similar to those observed in other economic sectors, e.g., agriculture. Major obstacles to transitioning he South African manufacturing sector to a more circular economy, and unlocking associated benefits, included lack of awareness of circular economy interventions and the associated business case; the cost of implementing and the lack of sustainable financing mechanisms; lack of appropriate skills; lack of local case studies or demonstration projects; lack of available markets for circular products and services. In principle, an increased awareness and understanding, upgrading of skills and knowledge base, creation of support platforms and organizations, and collaboration across all sectors of the economy appear to be universal challenges to effective circular economy implementation.

2.4. Energy Sector

The energy sector is the backbone of the South African economy; however, it is one based on an antiquated "extract-make-use-dispose" linear economy model. South Africa's indigenous energy resource base is dominated by coal.

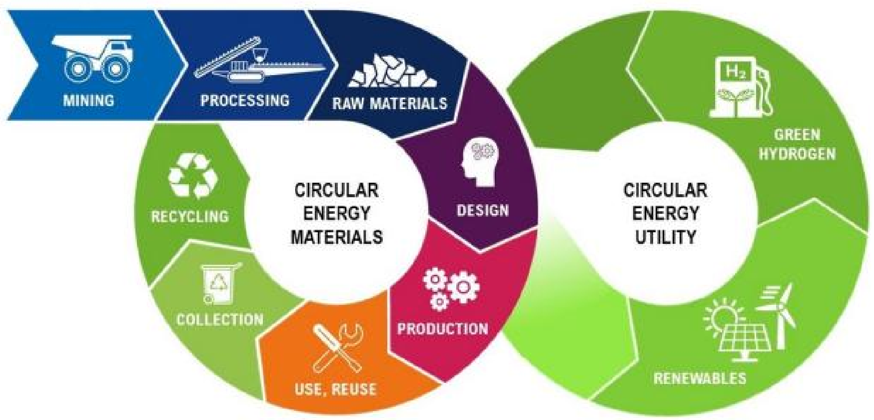
This dependence on coal has multiple negative externalities, such as high resource intensity, inefficiency, carbon intensity with resultant greenhouse gases (GHG), and hazardous waste generation. These externalities exhibit the unsustainable nature of the sector and, more importantly, emphasise the need for transformation to reduce resource and carbon intensity and subsequently increase efficiency.

Introducing the principles of the circular economy into the design, use, and selection of energy pathways and technologies can support this much needed transformation of the sector.

The circular economy presents an opportunity to decarbonise the South African energy sector; reduce the sector's dependence on the extraction of non-renewable resources; reduce the generation of hazardous waste streams; grow energy generation and improve energy security for the country; and decouple economic development from resource intensity in the linked sectors.

As depicted in Figure 3, the circular economy has relevance to the South African energy sector in terms of:

Figure 3: Circular economy paradigm for the energy sector



Source : (Msimanga et al., 2021)

- Circular energy utility, i.e., the process of generating energy. Circularity in energy utility refers to the promotion and adoption of renewable and regenerative energy technologies to replace carbon-intensive. fossil-fuel-based energy generation.
- Circular energy materials, i.e., the process of designing and manufacturing energy technologies such as photovoltaic (PV) panels or wind turbines. It is based on the premise of improved product design for circularity; increased longevity and utilisation rates; production processes that are non-destructive (e.g., additive manufacturing); and recovery of energy technologies at end-of-life supported by greater reuse, repair, refurbishment and recycling, keeping products and materials circulating within the economy

For circular energy materials, increasing energy technology lifespans and technology repair and recycling had the highest levels of readiness and implementation. South Africa has a few manufacturers of energy technologies, and since most of the materials used in manufacturing are imported, there may be opportunity to offset some (or all) of these imports with greater local recycling and resource recovery.

The South African economy is highly energy intensive. The energy sector can be broadly divided into the electricity and liquid fuels sub-sectors. The high resource intensity of the sector is the result of the use of coal as the primary energy source for most of the sector's activities; with approximately 80% of the nation's electricity generated from coal and thermal generation and about 14% generated from renewable sources *(Pierce & Le Roux, 2023).* Approximately 46% of the country's GHG emissions emanate from the electricity sector.

The government recognizes the need to reduce the country's dependence on coal in order to reduce carbon emissions and meet its climate commitments. By 2030 coal will only account for approximately 40% of the country's electricity mix, and his dependence on coal is expected to decrease through to 2050 in order for the country to achieve its net zero commitments (IPP Office, 2022). The country has abundant renewable energy potential, particularly onshore wind and solar, and although there are plans to increase the use of renewable energy sources, there are challenges associated with integrating renewable energy sources into the grid *(SAWEA, 2023)*.

Another constraint facing South Africa's energy sector is the availability of water.Water is an essential resource for electricity generation, particularly in coal-fired power plants, which require large amounts of water for cooling. However, South Africa is a water-scarce country that receives an annual precipitation of 497mm/year, which is almost 50% less than the global average annual rainfall of 860mm/year *(Joan Igamba, 2022)*, and therefore there are concerns about the impacts of water scarcity on the energy sector. This includes the potential for water shortages to limit the operation of power plants, as well as the impacts of pollution on water quality and availability *(DWS, 2019)*. Furthermore, water scarcity presents a challenge to producing green hydrogen (GH2), which is a disruptive clean power fuel that South Africa hopes to become a major producer and exporter of; however, water scarcity may impede South Africa's production of GH2 and the country's potential to participate meaningfully in the global green hydrogen economy *(Tokollo Matsabu, 2022).*

Renewable energy technologies such as solar PV and onshore wind, are seen as forerunners to advance circularity in the energy sector, adopting the principle of regenerating natural systems. However, there are numerous other interventions being implemented locally and internationally. Possible energy sector CEIs that can be applied to the South African energy sector to promote circularity, as aligned with the circular economy principles outlined in Section 1, are briefly highlighted below. Since the circular economy applies to the energy sector both in terms of the manufacturing of energy technologies, as well as the actual generation, storage, distribution and consumption of energy, the CEIs are categorised here into circular energy utility and circular energy materials

The interventions considered for adoption in this segment of the circular economy can be clustered into Clean energy technologies and related interventions, e.g.

- Renewable energy
- Energy storage
- Agrivoltaics
- Electric vehicles
- Green hydrogen
- Freshwater substitution (desalination of sea and wastewater for green hydrogen)
- Waste-to-energy

Abatement of transitioning coal, gas and petroleum use, e.g.,

- Carbon Capture Utilisation and Storage (CCUS)
- Freshwater substitution (Dry cooling)
- Emissions prevention (clean coal technologies)
- Emissions prevention (clean coal technologies)
- Energy efficiency
- Fly ash valorisation

Business opportunities to implement in the energy circular economy,

- Companies in the South African economy depend on electricity supply from Eskom for their daily operations, however due to the utility's current generation constraints and rolling blackouts, many companies are struggling to stay afloat. This requires them to look for alternative means of powering their operations; and currently, renewable energy technologies, especially solar PV coupled with battery energy storage, are the best option. Investing in solar PV will reduce their dependence on Eskom, reduce energy bill costs, and increase their sustainability, among others. Due to the current energy crisis, government is significantly enabling this solution with the recent announcement from National Treasury on a 125% tax deduction for businesses who invest in renewable energy systems of sizes above 1MW *(SARS, 2023).*
- There is also an opportunity to enter the renewable energy market as independent power producers, either within REIPPPP or as embedded generation projects. This is also enabled by government with the removal of licensing requirements for embedded generation systems, thus developers can apply to install solar PV embedded generation systems of any size under the new guidelines as long as they have an offtake agreement (e.g., power purchase agreement [PPA]) *(Botha, 2023).*
- There are further opportunities in construction processes and operations and maintenance of such technologies.
- Battery energy storage, particularly large-scale storage, also presents a great opportunity for companies to invest in. There are multiple business models and revenue streams associated with battery energy storage, such as the provision of ancillary services, transmission and distribution infrastructure services, and bulk energy services *(IRENA, 2020).*
- Hydrogen, especially green hydrogen, is emerging for the decarbonisation of multiple hard-to-abate sectors and as an important energy carrier for sector coupling. This technology presents a variety of opportunities for local companies as the country seeks to become a major player in the global GH2 market as outlined in the South African Hydrogen Society Roadmap *(DSI, 2021).* Production of GH2 is still expensive due to electrolyser manufacturing costs; however, access to raw materials and competitive renewable energy resources will improve the business case for the localisation of the hydrogen value chain. South Africa is a major producer of platinum group metals (PGMs), critical materials in electrolyser manufacturing, such as platinum, iridium, and palladium ; which presents an opportunity for the localisation of electrolyser manufacturing.
- Recycling of end-of-life energy technologies is becoming critical, not only due to the increasing installation of new energy technologies, but also due to growing resource scarcity and access to critical raw materials that support manufacturing. In South Africa, recycling of electronic waste has been limited, with the State of Waste Report *(DEA, 2018)* reporting only a 9.7% WEEE recycling rate.
- Recycling of batteries can recover nickel, manganese, lead, cobalt and lithium *(Mishra et al., 2022).* Current Liion battery waste generation rates in the country are currently insufficient to support a commercially viable recycling plan *(Gericke et al., 2021).* Residues from burning of coal are recycled by using fly ash in the manufacture of cement. Companies such as Cemblocks have produced bricks using ash since 1981 *(Cemblocks, 2023).* Recycling can also provide much needed additional jobs through its value chain. Although South Africa has recycling skills, critical requirements for more viable recycling businesses include improvements in technology, costs, and access to waste streams, and a supportive regulatory environment that recognises 'waste' as a secondary resource.
- The increasing demand for energy technologies, government support through policies, SEZs, and threshold requirements, provide opportunities to promote material efficiency in manufacturing energy technologies. Importation of components is already being done locally, with South Africa also exporting some of the manufactured and imported RE components for solar PV, batteries, and wind.

2.5.

Water Sector

Economic development and population growth are giving rise to increasing demands on South Africa's water resources. A number of studies confirm that South Africa is already over-exploiting its renewable water resources, and without additional interventions, will continue to do so in future. A large portion of South Africa's gross domestic product (GDP) and jobs are directly dependent on water. Primary agriculture (including forestry) is the largest user of water, at 61% of the country's water resources, contributing ~3% to national (GDP) and 7% of formal employment; followed by municipal/domestic use *(DWS, 2018).*

According to the 2 nd National Water Resources Strategy, proposed interventions to increase water supply and reduce demand are not enough to bring the South African water sector into balance. New approaches will have to be adopted to reconcile future national water withdrawals with supply. Therefore, there is a need for improving water systems by considering the whole water-use value chain and by identifying solutions that enhance both the economic and environmental performance of the system.

A more sustainable, efficient, and sufficient approach to our limited water resources is needed to counteract water depletion and ecosystem pressures. A circular economy approach can help to address these challenges by decoupling development from water consumption, thereby addressing national resource security in support of socio-economic development through sustainable water resource use.

Water affects every aspect of societal development, it drives economic growth, supports healthy ecosystems, and is vital for life itself. Water and its related services are required across the whole economy, including critical areas of national economic activity such as cooling water for electricity generation and irrigation water for agriculture and food production *(CIWEM, 2019).*

Climate change has a measurable effect on the water cycle and is expected to reduce freshwater quality and availability. The IPCC (2022) projections indicate that changes in the water cycle will impact on agriculture, energy production, urban water uses and other ecosystem services, with water-related risks expected to increase with every increment in warming level. Population growth and urbanisation are also expected to increase the competition for water resources. These pressures have affected the sustainability of water resources, driving the need for increasingly efficient water use.

Research indicates that the global demand for freshwater will exceed viable resources by 40% by 2030 if business-as-usual water management approaches continue (i.e., if we do not change the way water is used, managed and shared) *(WRG, 2012, Tahir et al., 2019).* A large portion of South Africa's GDP and jobs are directly dependent on water. Primary agriculture (including forestry) contributes about 3% to South Africa's gross domestic product (GDP) and is responsible for 7% of formal employment. The energy sector contributes 15% towards GDP and is responsible for 250,000 jobs.

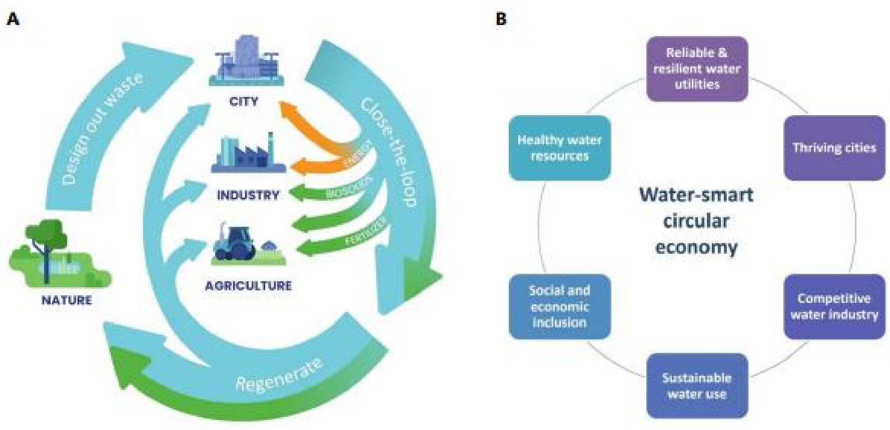
The manufacturing sector contributes 15.5% towards GDP and is responsible for 13.3 % of total employment, while the mining sector contribute 8.8% directly and 10% indirectly towards GDP and is responsible for 1 million direct and indirect jobs *(DWS, 2018).*

A more sustainable, efficient, and sufficient approach to our limited water resources is needed to counteract water depletion and ecosystem pressures as a result of urbanisation, industrialisation and changing climate.

The manufacturing sector contributes 15.5% towards GDP and is responsible for 13.3 % of total employment, while the mining sector contribute 8.8% directly and 10% indirectly towards GDP and is responsible for 1 million direct and indirect jobs *(DWS, 2018).*

A more sustainable, efficient, and sufficient approach to our limited water resources is needed to counteract water depletion and ecosystem pressures as a result of urbanisation, industrialisation and changing climate. A circular economy approach can help to address these challenges facing the country's water system. A circular economy transition provides South Africa with the opportunity to decouple development from water consumption, thereby addressing national resource security in support of socio-economic development through sustainable water resource use. When applied to water resources, the circular economy principles of eliminating waste and pollution; closing resource loops; and regenerating natural systems, provide a framework for South Africa to address water security *(Godfrey, 2020; WRG, 2012) (Figure 4).*

Figure 4: Circular water systems



Source : Delgado et al., 2021 and Zvimba, 2019)

Business Opportunities to Implement in the Circular Water Sector

- Design out waste and pollution. The NWRS 2 recognises that the development of additional conventional surface water resources is limited and that other reconciliation options such as water conservation and demand management need to be implemented. As part of design-out-waste, addressing water conservation through minimising water losses and wastage (transmission losses and improved infrastructure maintenance) and improving water use efficiencies (technologies and water pinch interventions) are key interventions *(Seetal et al., 2021b).*
- Keep products and material in use. he purification of wastewater and its subsequent reuse are fundamental to the circular economy and leads to more environmentally sustainable cities *(MolinaGimenez, 2018).* Apart from reusing the wastewater, resources and energy can be extracted from the wastewater sludge, easing the stress of sludge treatment and disposal *(Liu et al., 2021).* By-products such as compost or biogas generated from wastewater treatment plants, can be recovered and developed into new markets, with value. The anaerobic processes in wastewater treatment plants generate biogas and a solid residual. Biogas is a source of energy which can be sold to a third party or can be utilized on-site to cogenerate electricity and heat for the wastewater treatment plant, improving the plant's energy efficiency, lowering costs, and enhancing the plant's reliability *(Rodriguez et al., 2020).* The compost or solid residual can be applied to land as a soil conditioner or fertilizer *(EMF, 2013).*
- Regenerate natural systems. A nature-based solution such as a constructed wetland offers a variety of benefits, including reduced downstream pollution, improved water quality (sediment trapping, nutrient removal and chemical detoxification) and flood and drought regulation *(UN Environment-DHI, UN Environment and IUCN, 2018).* Dini & Bahadur (2018) reported on a case study in Krom River in the Eastern Cape where a rehabilitated wetland played an important role in reducing potential impacts of floods downstream of the wetland during 2006 floods. The rehabilitated wetland managed to slow the velocity and destructive potential of the floodwaters and trap the sediment.

With expected economic development, most of South Africa's economic sectors are expected to grow, and with it, increasing demand for potable water.

2.6. Mobility Sector

South Africa's mobility sector accounts for 8% of the nation's GDP and is becoming increasingly unsustainable due to the high reliance on road transport.

The decline in rail infrastructure has resulted in 84.3% of all land freight being transported via road networks, leading to increased logistics expenses, congestion and deterioration of road infrastructure.

Public transportation faces challenges due to diminishing train and bus ridership, compelling commuters to depend on minibus taxis, despite safety concerns and high associated costs.

Apartheid-based spatial planning continues to restrict mobility, compelling low-income workers to endure lengthy and expensive commutes.

Transportation accounts for 19% of national energy consumption, resulting in increasing GHG emissions; yet investment in rail, electric vehicles, and climate-resilient infrastructure is insufficient.

Without immediate policy improvements, such as cohesive transport planning, infrastructure investment, and financial incentives for sustainable technologies, South Africa's transport system will remain costly, inefficient, inequitable, and environmentally unsustainable.

South Africa's mobility sector can transition towards a circular economy through sustainable urban planning, cleaner transport options, and efficient use of resources.

Based on local, regional and global trends, key interventions identified in this report include increased use of public transport systems, dedicated non-motorised transport infrastructure, and ride-sharing that all encourage low-carbon mobility, while concepts like 15-minute cities promote walkability and reduce reliance on private vehicles.

Electrification, alternative fuels, and improved vehicle efficiency help cut emissions, while road-to-rail transport shifts can contribute to reducing congestion and logistics costs.

Circular supply chains, alternative road materials, and end-of-life vehicle recycling assist in minimising waste and extend resource life cycles.

Lastly, climate-resilient infrastructure and sustainable drainage systems ensure long-term durability in the face of environmental challenges. Several interventions are considered for enhancing resilience and competitiveness, including the use of alternative road materials, local EV component manufacturing, second-life battery use, and process optimisation for logistics.

While all interventions were deemed somewhat ready for implementation, flexible working arrangements and Mobility-as-a-Service (MaaS) had the highest readiness scores due to their existing adoption. The most widely adopted interventions in South Africa are flexible working arrangements, MaaS, and dedicated bicycle and pedestrian facilities.

South Africa's resource intensive mobility sector provides the perfect impetus for Transitioning South Africa to a more circular mobility system (Figure 5).

Circular mobility requires a primary focus on designing for users and goods, instead of vehicles – such as planning transport networks that provide reduced travel distance and time per journey.

Transitioning towards a circular mobility system creates opportunities for improved productivity, efficiency, and reduced costs, with positive spillover effects for other critical sectors of the South African economy such as agriculture, manufacturing, and human settlements.

Figure 5: Mobility within a circular economy

Source : SIFA 2022.

The transition to a more circular mobility sector and the adoption of circular interventions, will result in disruption, whether intended or unintended.

Shifting commuters from single-occupancy vehicles (whether ICE or EVs) to public transport, will result in reduced demand for light passenger vehicles, which will disrupt local automotive manufacturing, but will create new opportunities in public transport systems and local manufacturing of larger passenger vehicles.

Shifting freight from road to rail, will disrupt long-haul trucking, but will create trucking opportunities for last-mile solutions, and new opportunities in rail systems, including local manufacturing of rolling stock.

With more than 60% of locally manufactured passenger vehicles destined for export markets (Lamprecht, 2023), international commitments to shift to NEVs will disrupt the local automotive industry (See Section 2.5.4) but can create new opportunities in local remanufacturing and refurbishment.

2.7. Human Settlement Sector

A circular approach that integrates urban agriculture within human settlements indicates that substantial fresh produce could be grown. Modelling food gardens within the City of Johannesburg neighbourhoods suggests that 320,000 t of fresh produce per year could be targeted. It is estimated that this option could provide approximately 20% of vegetable requirements for a projected urban population of 10.3 million people (3.4 million households) who will live in Johannesburg in 2042 and make a valuable contribution to improving food security. Instead of directing organic waste to landfill, a circular approach that composts organic waste within human settlements provides fertility for soils and urban agriculture. For the City of Johannesburg, modelling suggests that about 550 kt (about 24% of all domestic solid waste) could be diverted from landfill sites.

At the same time, 5,050 fulltime jobs could be created and carbon emissions between 165 and 330 kt could be avoided. Greywater systems use lightly soiled water from, for instance, showers, for irrigation and flushing toilets in buildings, thereby conserving valuable potable water.

Modelling this option for households in the City of Johannesburg indicates that 307.7 ML per day could be generated, saving large amounts of potable water. Rainwater harvesting systems capture rainfall from collection surfaces such as roofs and use this within buildings.

Modelling the adoption of rainwater systems within human settlements in the City of Johannesburg indicates that 46,531 ML could be harvested per year. This water could be used to flush toilets and for irrigation, substantially reducing requirements for potable water. Thus, greywater and rainwater harvesting could be used to conserve scarce water resources and reduce the pressure on stretched municipal systems.

Reusing materials and products salvaged during the deconstruction of buildings reduces resource consumption and avoids waste. Modelling this circular option for the City of Johannesburg shows that 225,210 t of building materials and components per year could be reused.

This represents a 44.% reduction in construction waste that would normally end up in landfill or be illegally dumped in urban open spaces. The study finds that circular options have the potential to make substantial contributions to the development of more sustainable and liveable human settlements.

It is hoped this document can be drawn on in identifying and developing circular human settlement systems that reduce resource inefficiencies and waste, create new small enterprises and jobs, and improve quality of life for all.

The adoption of circular practices would be beneficial for South African human settlements.

The three most beneficial and appropriate circular interventions to South African human settlements included: greywater reuse; localising supply chains; and urban agriculture.

The three least beneficial circular interventions were seen to be biobased construction materials, composting, and reuse of materials and products.

2.8. Climate and Circular Economy

South Africa is reliant on the combustion of fossil fuels to meet its energy needs and recognises the need to shift to a low carbon economy. The country has made commitments towards reducing its GHG emissions through updates to its NDC which seeks to attain a low GHG emissions pathway that is aligned to its national circumstances and development challenges.

There is little understanding at present on the potential to enhance the country's mitigation efforts through a circular economy approach.

The energy sector has the largest emission reduction potential of -75.85 MtCO2e. Sizable contributions to mitigation are achieved through ambitious changes to the use of energy resources in the manufacturing, mining and construction sectors (-44.51 MtCO2e); mobility sector (- 34.58 MtCO2e) and in the agriculture sector (-13.47 MtCO2e). Included in the total emission reductions are 8.60 MtCO2e already aimed at reducing GHG emissions from the BAU 2019 to the BAU 2050.

There is little understanding at present on the potential to enhance South Africa's climate mitigation efforts through the transition to a more circular economy, and the adoption of circular economy interventions across various resource-intensive sectors of the South African economy.

3.

STANDARD FRAMEWORK FOR CALCULATING THE SUPPLY OF WASTE IN MPUMALANGA

A detailed scientific funnel approach that served as a filtering process was developed and applied to estimate the nature and magnitude of waste and alternative materials in the Mpumalanga Province. Firstly, a detailed list of waste and alternative materials was compiled. **This list is provided in Table 2 below.**

Table 2: Detailed list of waste and alternative materials

Material	
(i) Materials from Agriculture	(iii) Materials from Mining
• Bio-fibres e.g. Sisal fibre	• Feldspar
• Bio-resins	• Quartz
• Citrus peels	• Hematite
• Maize cob ash	• Andalusite
• Bagasse	• Corundum
• Bagasse ash	• Asbestos
• Cow dung	• Transition metals
• Grass/straw	• PGMs
• Chicken feathers	• Industrial mineral fillers
• Cashew nut shells & liquid	
• Rice husks	
(ii) Materials from Forestry	(iv) Materials from Manufacturing
• Tannin	• Blast Furnace Slag
• Paper sludge	• Steel Slag
• Wood/Timber	• Ferrochrome Slag
• Waste wood	• Copper Slag
• Wood chips	• Electric Arc Furnace Slag
• Sew dust	• Furnace Dust
• Waste paper sludge	• Cement Dust
• Eucalyptus poles	• Hydraulic Lime
• Bio-chemicals	• Gypsum/phosphorgypsum
• Timber pulp waste	• Silica fume or Nano-silica
• Timber based laminates	• Galvanizing waste
• Recycled Materials	• Foundry Sand
	• Metakaolin
(iii) Materials from Agriculture	(v) Materials from power stations & boilers
• Rammed earth	• Boiler Slag
• Lateritic soil	• Coal Bottom Ash
• Clays (kaolinitic)	• Coal Fly Ash
• Bentonite (nano-clay)	• Incinerator Residue/Ash (municipal waste)
• Halloysite (nano-clay)	• Building Rubble
• Brick clays	• Gypsum
• Coal	
• Silica Sand	(iv) Plastic Wastes
• Diatomite	• Recycled asphalt
• Magnesium Silicate Rocks (e.g. Dunite)	• Recycled concrete
• Forsterite	• Demolition waste
• Magnesite	• Clay brick waste
• Perlite	• Crushed Ceramics waste
• Vermiculite	• Rubber Tyres
• Mica	• Sewage Sludge
• Quartzite	• Waste paper
• Sandstone	• Water treatment sludge
• Dolomite	• Glass waste/cullet
• Basalt	• Scrap steel
• Dolerite	• Scrap non-ferrous metals (copper, zinc, brass etc)
• Slate	

The list identified the waste and alternative materials according to the main sectors of the economy as classified by the Standard Industrial Classification (SIC) as well as for final consumption expenditure by households and general government. **It is important to note that the list denoted in Table 2 above is a general list and is not at this stage capturing waste and alternative materials that can be used for construction purposes only.**

Further it does not necessarily imply that the waste and alternative materials denoted in *Table 2* (previous page) will in essence occur in Mpumalanga. The reason for this is that this model could be used to identify waste materials that can be identified and be reclaimed for other purposes other than construction in the end and for application in other provinces.

It is important to recognize that the correct way to commence with an analysis of this nature is to use a broad and detailed standard sectoral framework as a point of departure. To this end, a hybrid model / Matrix built from a broad and detailed list of waste materials presented in *Table 2* as well as Table 3 form, the basis and point of departure for the standard framework of calculating the supply of waste in volume terms (tonnage). Waste generated at residences, businesses, and institutions pass through multiple economic sectors, hence a detailed sectoral standard list of commodities according to national accounts is required for this type of analysis.

The economic sectors analysed in this study form the drivers and generators of waste. The standard framework also assists in developing a methodology for estimating waste generation from a detailed sectoral basis by material type and business type.

The Standard list of commodities according to the National Accounts of South Africa and adapted for Mpumalanga Province.

Table 3: List of commodities as defined by the National Accounts

No.	List of commodities / Sectors	No.	List of commodities / Sectors	No.	List of commodities / Sectors
01	Barley	24	Other Agriculture	47	Rutile
02	Grain Sorghum	25	Forestry	48	Ilmenite (Titanium ore)
03	Maize Dryland	26	Fishing (incl. seafood)	49	Zinc
04	Maize Irrigation	27	Coal Mining Exports	50	Other Non-Ferrous Metal Mining
05	Sunflower Seed	28	Coal Mining Domestic	51	Alumina
06	Wheat	29	Coal Mining PowerStation	52	Gypsum
07	Soya Beans	30	Coal Mining Sasol	53	Zircon
08	Rice	31	Coal Mining Fly Ash	54	Stone
09	Vegetables	32	Crude Oil	55	Granite
10	Potatoes	33	Natural gas (Moss Gas)	56	Limestone
11	Cassava	34	Iron Ore Exports	57	Rock Phosphate
12	Sugar Cane Dryland	35	Iron Ore Domestic	58	Sulphur
13	Sugar Cane Irrigation	36	Precious metal ore	59	Fluorspar
14	Cotton	37	Silver	60	Salt
15	Grapes	38	Diamonds	61	Other nonmetallic minerals
16	Subtropical fruit	39	Gold	62	Precious and semi-precious stones (excl. diamonds)
17	Citrus	40	Magnetite	63	Other mining
18	Deciduous fruits (excl. table grapes)	41	Chrome	64	Processed food
19	Milk (bulk)	42	Copper	65	Sugar
20	Wool and Mohair	43	PGMs	66	Soya bean products
21	Eggs	44	Manganese Exports	67	Slaughtered animal meat (incl. broilers)
22	Livestock (Red Meat)	45	Manganese Domestic	68	Animal feed
23	Poultry (White Meat excl. Eggs)	46	Titanium slag	69	Beverages (incl. malt)

No.	List of commodities / Sectors	No.	List of commodities / Sectors	No.	List of commodities / Sectors	No.	List of commodities / Sectors
70	Tobacco products	82	Other petroleum products	94	Scrap metals (incl. Recycling)	106	Water Generation
71	Textile products (incl. Leather)	83	Chemicals	95	Non-ferrous metal products	107	Water Distribution
72	Wood timber and products	84	Fertilizer	96	Metal products (excl. machinery)	108	Building construction
73	Wood chips	85	Other chemicals	97	Electrical machinery	109	Civil engineering and other construction
74	Paper and Paper Products	86	Pharmaceutical products	98	Machinery and equipment	110	Wholesale and retail trade
75	Pulp of Wood and Paper	87	Rubber products (excl. car/truck tyres)	99	Motor vehicles and trucks	111	Catering and accommodation services
76	Recycled paper	88	Non-metallic mineral products	100	Motor vehicle parts & accessories (incl. car/truck tyres)	112	Transport and storage
77	Printing	89	Bricks	101	Transport Equipment	113	Communication
78	Petrol	90	Cement	102	Furniture	114	Finance and insurance
79	Diesel	91	Iron & steel	103	Other manufacturing industries	115	Business services
80	LNG and methane rich gas (Piped Gas Transnet)	92	Ferrochrome	104	Electricity Generation	116	Community, social and personal services (incl. Government)
81	Jet fuel	93	Ferromanganese	105	Electricity Distribution		

4.

DEVELOP A FRAMEWORK FOR CALCULATING THE SUPPLY OF WASTE IN MPUMALANGA

In *Table 4* (below) a qualitative method of identifying the nature and magnitude of waste is presented. The process the initial step of the funnel approach that will in the end inform the final selection of waste and alternative materials that will be considered for construction in the Mpumalanga Province. The qualitative Table also serves as a base to determine which commodities will in the end drive or generate the waste and alternative materials.

Table 4: Matrix defining the various potential sources of waste and alternative materials for the applicable commodities present in Mpumalanga

	Alternative Materials																		
	Mpumalanga																		
															Services				
	Production (tons)	1,066,159	512,789	64,655	71	10,194,262	1,503,530	81,801	305,884	485	740,278	66,720	32,163,910	1,318,372	-	-	-	-	-
	Production (Rand Million , 2016 constant)														15,573	13,359	7,920	21,655	7,373
		Agriculture, Forestry and Fishing		Mining and Quarrying				Manufacturing							Construction (Contractors)				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Citrus	Forestry	Copper	PGM's	Limestone	Rock Phosphate	Slaughtered animal meat (incl. broilers)	Wood timber and products	Iron & steel	Ferrochrome	Non-ferrous metal products	Coal-fired PowerStation	Water	Building construction	Civil engineering and other construction	Catering and accommodation services	Transport and storage	Consumption Expenditure
	(i) Materials from Agriculture																		
1	Citrus peels	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Chicken feathers	-	-	-	-	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-
	(ii) Materials from Forestry																		
3	Waste wood	-	1.00	-	-	-	-	-	1.00	-	-	-	-	-	-	-	-	-	-
4	Saw dust	-	-	-	-	-	-	-	1.00	-	-	-	-	-	-	-	-	-	-
	(iii) Materials from Mining																		
5	Waste stone	-	-	1.00	1.00	1.00	1.00	-	-	-	-	-	-	-	-	-	-	-	-
	(iv) Materials from Manufacturing																		
6	Steel and iron slag	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-	-	-	-	-
7	Ferrochrome slag	-	-	-	-	-	-	-	-	-	1.00	1.00	-	-	-	-	-	-	-
8	Copper slag	-	-	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	Furnace dust	-	-	1.00	1.00	-	-	-	-	1.00	-	-	-	-	-	-	-	-	-
10	Silica fume or nano-silica	-	-	-	-	-	-	-	-	-	1.00	1.00	-	-	-	-	-	-	-
11	Galvanizing waste	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-	-	-	-	-
	(v) Recycled Materials																		
12	Plastic waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	1.00
13	Recycled asphalt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	Recycled concrete	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1.00	-	-	-
15	Demolition waste	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-
16	Clay brick waste	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-
17	Crushed ceramics waste	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-

	Alternative Materials																		
	Mpumalanga																		
														Services					
	Production (tons)	1,066,159	512,789	64,655	71	10,194,262	1,503,530	81,801	305,884	485	740,278	66,720	32,163,910	1,318,372	-	-	-	-	-
	Production (Rand Million , 2016 constant)														15,573	13,359	7,920	21,655	7,373
		Agriculture, Forestry and Fishing		Mining and Quarrying				Manufacturing							Construction (Contractors)				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Citrus	Forestry	Copper	PGM's	Limestone	Rock Phosphate	Slaughtered animal meat (incl. broilers)	Wood timber and products	Iron & steel	Ferrochrome	Non-ferrous metal products	Coal-fired PowerStation	Water	Building construction	Civil engineering and other construction	Catering and accommodation services	Transport and storage	Consumption Expenditure
18	Sewerage sludge	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-
19	Paper Waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	1.00
20	Water treatment sludge	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-
21	Glass waste/cullet	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	1.00	-	1.00
22	Scrap steel	-	-	-	-	-	-	-	-	1.00	-	-	-	-	1.00	1.00	-	1.00	-
23	Non-ferrous scrap metal (copper, zinc, brass, etc)	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	1.00	-	1.00	1.00
	(vi) Materials from Power stations and boilers																		
24	Boiler slag (Coal bottom ash)	-	-	-	1.00	-	-	-	-	-	-	-	1.00	-	-	-	-	-	-
25	Coal fly ash	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-	-

Note: Waste generation for commodities produced are expressed i.t.o. the tonnage that they generate per ton of commodity produced. Waste generation for services are expressed i.t.o. tons of waste generation per million-rand services that they rendered.

5.

DEVELOP THE WASTE COEFFICIENTS

Table 5: Calculated coefficients estimating various waste and alternative materials yields for applicable commodities for the Mpumalanga Province per commodity unit

	Alternative Materials																		
	Mpumalanga																		
													32,163,910						
													-		Services				
	Production (tons)	1,066,159	512,789	64,655	71	10,194,262	1,503,530	81,801	305,884	485	740,278	66,720	32,430,122	322,377,893	-	-	-	-	-
	Production (Rand Million , 2016 constant)														15,573	13,359	7,920	21,655	7,373
		Agriculture, Forestry and Fishing		Mining and Quarrying				Manufacturing							Construction (Contractors)				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Citrus	Forestry	Copper	PGM's	Limestone	Rock Phosphate	Slaughtered animal meat (incl. broilers)	Wood timber and products	Iron & steel	Ferrochrome	Non-ferrous metal products	Coal-fired PowerStation	Water	Building construction	Civil engineering and other construction	Catering and accommodation services	Transport and storage	Consumption Expenditure
	(i) Materials from Agriculture																		
1	Citrus peels	0.05																	
2	Chicken feathers							0.05											
	(ii) Materials from Forestry																		
3	Waste wood		0.56						1.09										
4	Saw dust								0.03										
	(iii) Materials from Mining																		
5	Waste stone			50.00	166,667	0.06	1.13												
	(iv) Materials from Manufacturing																		
6	Steel and iron slag									0.15									
7	Ferrochrome slag										1.26	1.26							
8	Copper slag			1.10															
9	Furnace dust			0.01	2.79					0.002									
10	Silica fume or nano-silica										0.14	0.14							
11	Galvanizing waste									0.001									

	Alternative Materials																	
	(v) Recycled Materials																	
12	Plastic waste														0.07		0.065	
13	Recycled asphalt																	
14	Recycled concrete												1.65	3.30				
15	Demolition waste												0.83					
16	Clay brick waste												0.66					
17	Crushed ceramics waste												0.17					
18	Sewerage sludge											0.01						
19	Paper Waste														0.02		0.019	
20	Water treatment sludge											0.02						
21	Glass waste/cullet												0.02		0.03		0.033	
22	Scrap steel								0.02					0.01	0.01		0.02		
23	Non-ferrous scrap metal (copper, zinc, brass, etc)												0.002	0.002	-	0.01	0.008	
	(vi) Materials from Power stations and boilers																	
24	Boiler slag (Coal bottom ash)			277.78							0.018							
25	Coal fly ash										0.116							

In essence the waste coefficient is calculated by dividing the volume of the waste by the total volume of the commodity involved. However, different factors also had to be taken into account not to underestimate nor overestimate the volume of waste.

For purposes of this exercise, a hybrid methodology comprising of Standard Input – Out Analysis (I-O) and detailed projections of the South African economy, on a sectoral and regional basis, formed the basis of estimating the supply of waste. The Mpumalanga province Social Accounting Matrix (SAM) formed the basis of the analysis.

As already mentioned, the IO Table is in monetary values, however for purposes of a study of this nature it is more appropriate to use a system where relationships are denoted physical volume terms (tonnage). An example of this is to estimate metal scrap waste per ton of metal produced where both the output and the base product is in physical volumes rather than to express the volume in scrap metal in tons but to express it in terms of an output in Rand values. The conversion from Rand values to physical volumes (tonnage) was done by making use of a price per ton of a specific commodity.

To calculate the total volume (tonnage) of a specific type of waste, the waste coefficient in physical volumes was multiplied with the production of a specific commodity.

The tables are self – explanatory.

In Table 5 *(above)* the calculated coefficients estimating various waste and alternative materials yields for applicable commodities for the Mpumalanga Province per commodity unit.

A series of tables explaining the algorithm estimating the waste coefficients for various commodities are presented in this section starting from Table 6.

Table 6: Waste & Alternative Materials from Agriculture

CITRUS PEELS WASTE (TONS): CITRUS	
Total Citrus Production(Tons- Fresh Peels)	1,066,159
Citrus that are peeled in the Production Process	0.50
Citrus To Be Peeled (Tons)	533,080
Percentage of Peel relative to Total Orange	0.40
Citrus Peels (Tons - Wet)	213,232
Peels - Dry/ Wet Factor	0.25
Citrus Peels (Tons - Dry)	53,308
Percentage Peels of Intermediate Demand	0.05
CHICKEN FEATHERS (TONS) : SLAUGHTERED ANIMAL MEAT	
Total Animal Slaughter (Tons)	305884
Chicken Component Factor (%)	0.385
Broiler components of chicken	0.8
Chicken (Tons)	94212
Percentage of Feathers relative to Weight of Chicken	0.15
Feathers (Tons)	14132
Feathers as a Percentage of Animal Slaughter	0.0462

Table 7: Waste and Alternative Materials from Forestry

2a.WASTE WOOD (TONS): FORESTRY	
Total Forestry Production (Tons)	512,789
Waste Factor	1.13
Forestry Waste Reclaimed (Tons)	578,252
Eucalyptus Poles (Tons)	-
Sub- Total	578,252
Usable waste wood (%)	0.50
Usable waste wood (Tons)	289,126
Percentage Waste Wood of Production	0.56

Table 8: Waste and Alternative Materials from Mining

8a. COPPER SLAG (TONS): COPPER	
Total Copper Metal Production (Tons)	70.6
Waste Factor (Slag)	2.2
Slag Reclaimed (Tons)	155.3
Furnace Dust (Tons)	0.0
Sub- Total	155.3
Usable Copper Slag (%)	0.5
Usable Copper Slag (Tons)	77.6
Percentage Copper Slag Waste of Production	1.1

8b. FURNACE DUST (TONS): COPPER	
Total Copper Production (Tons)	70.59
Dust Factor (%)	0.01
Furnace Dust Reclaimed (Tons)	0.71
Percentage Furnace Dust of Production	0.01

8c. WASTE STONE(TONS): COPPER	
Total Copper Production (Tons)	71
Waste Stone Copper Content Factor (%)	0
Waste Stone Reclaimed (Tons)	3,529
Waste Stone Percentage	0
Waste Stone (Tons)	-
Percentage Waste Stone of Production	50

8d.FURNACE DUST (TONS): PGM	
Total PGM Production (Tons)	69.88
Total PGM Concentrates (Tons)	19479.74
Factor: Furnace Dust (%)	0.01
Furnace Dust (Tons)	194.80
Percentage PGM FURNACE DUST of Production	2.79

8e. PGM SLAG (TONS): PGM	
Total PGM Production (Tons)	69.9
Factor: Slag to Metal	0.0
Recoverable Slag (Tons)	19409.9
Percentage PGM SLAG of Production	277.8

8f. WASTE STONE (TONS): PGM	
Total PGM Production (Tons)	69.9
Waste Stone (%)	0.0
Waste Stone Reclaimed (Tons)	11645918
Percentage Waste Stone of Production	166667

Table 9: Waste Stone (Tons): Limestone

9. WASTE STONE (TONS): LIMESTONE	
Total Limestone Production (Tons)	**10194262**
Limestone	0.06
Limestone Reclaimed (Tons)	650698
Percentage Limestone Waste of Production	0.06

Table 10: Waste Stone (Tons): Rock phosphate

10. WASTE STONE (TONS): ROCK PHOSPHATE	
Total Rockphote Production (Tons)	**1503530**
Rock Phosphate (%)	0.2
Rock Phosphate Reclaimed (Tons)	7517650
Percentage Rock Phosphate of Production	5.0

Table 11: Waste and Alternative Materials from Manufacturing

11a. WASTE WOOD:WOOD TIMBER AND PRODUCTS	
Total Wood Products (Tons)	305884.1738
Waste wood Component Factor (%)	1.127659574
Waste wood (Tons)	344933.2173
% Waste wood minus Saw dust %	0.97
Waste wood as a Percentage of Wood Products	1.093829787

11b. SAW DUST:WOOD TIMBER AND PRODUCTS	
Total Wood Products (Tons)	305884.1738
Waste wood Component Factor (%)	1.127659574
Waste wood (Tons)	344933.2173
Saw dust % of Waste Wood	0.03
Saw dust as a Percentage of Wood Products	0.033829787

Table 12: Waste and Alternative Materials from Iron and Steel

12a. STEEL AND IRON SLAG: IRON AND STEEL	
Total Iron and Steel (Tons)	484.86
Steel and Iron slag Component Factor (%)	0.15
Steel and Iron slag (Tons)	72.73
% furnace dust of furnace slag	0.99
Iron and steel slag (Tons)	72.00
Steel and Iron slag as a % of Iron and Steel	0.15

12b.FURNACE DUST: IRON AND STEEL	
Total Iron and Steel (Tons)	484.86
Furnace dust slag Component Factor (%)	0.15
Furnace dust slag (Tons)	72.73
% furnace dust of furnace slag	0.01
Furnace dust (Tons)	0.73
Furnace dust as a Percentage of Iron and Steel	0.00

Table 13: Waste and alternative materials from Ferrochrome

13a. FERROCHROME SLAG: FERROCHROME	
Ferrochrome (Tons)	740278.0
Ferrochrome slag Component Factor (%)	1.4
Ferrochrome slag (Tons)	1036389.2
% ferrochrome slag of ferrochrome	0.9
Ferrochrome slag (Tons)	932750.2
Ferrochrome slag as a Percentage of Ferrochrome	1.3

13b. SILICA FUME AND NANO SILICA: FERROCHROME	
Ferrochrome (Tons)	740278.0
Silica fume and or nano-silica Component Factor (%)	1.4
Silica fume and or nano-silica slag (Tons)	1036389.2
% ferrochrome slag of ferrochrome	0.1
Ferrochrome slag (Tons)	103638.9
Silica fume and or nano-silica as a Percentage of Ferrochrome	0.1

Table 14: Waste and Alternative materials from Non Ferrous metal Products

14a. FERROCHROME SLAG : NON FERROUS METAL PRODUCTS	
Non-ferrous metal products (Tons)	66719.7
Ferrochrome slag Component Factor (%)	1.4
Ferrochrome slag (Tons)	93407.6
% ferrochrome slag of ferrochrome	0.9
Ferrochrome slag (Tons)	84066.8
Ferrochrome slag as a Percentage of Non-ferrous metal products	1.3

14b. SILICA FUME AND NANO SILICA : NON FERROUS METAL PRODUCTS	
Non-ferrous metal products (Tons)	66719.70
Silica fume and or nano-silica Component Factor (%)	1.40
Silica fume and or nano-silica slag (Tons)	93407.58
% ferrochrome slag of ferrochrome	0.10
Ferrochrome slag (Tons)	9340.76
Silica fume and or nano-silica as a Percentage of Non-ferrous metal products	0.14

Table 15: Waste and Alternative Materials from Coal Fired Power Stations

15a. BOILER SLAG (COAL BOTTOM ASH) : COAL FIRED POWER STATION	
Coal-fired power station (Tons)	32163910
% Waste	0.29
Waste	9418298
Boiler slag Component Factor (%)	0.06
Boiler slag (Tons)	565098
Boiler slag as a Percentage of Coal-fired power station	0.02

15b. FLY ASH : COAL FIRED POWER STATION	
Coal-fired power station (Tons)	32163910
% Waste	0
Waste	9418298
Fly ash Component Factor (%)	1
Fly ash (Tons)	8853200
Sailable fly ash (%)	0
Sailable fly ash (tons)	3726094
Fly ash as a Percentage of Coal-fired power station	0.12

Table 16: Waste and Alternative Materials from Water Distribution

16a. SEWAGE WATER SLUDGE : WATER DISTRIBUTION	
Water (l/d/person)	209
Population (Mpumalanga)	4225967
Water Usage (Tons/year)	322377892.6
Urban (%)	0.25
Urban Water (Tons/year)	80594473.15
Slush (%)	0.1
Slush	8059447.315
Reclaimable sludge (%)	0.5
Reclaimable sludge (tons)	4029723.657
Sewage sludge as a Percentage of Water	0.0125

Table 17: Waste and Alternative Materials from Building Construction

17a. RECYCLED CONCRETE : BUILDING CONSTRUCTION	
Building Construction (Mil Rands)	15572.6
Recycled concrete Component Factor (t/Mil Rand)	1.7
Recycled concrete (Tons)	25719.7
Recycled concrete as tons/mil rand of Building construction	1.7

17b. DEMOLITION WASTE : BUILDING CONSTRUCTION	
Building Construction (Mil Rands)	15572.6
Demolition waste Component Factor (t/Mil Rand)	0.8
Demolition waste (Tons)	12859.9
Demolition waste as ratio (tons/Mil rand) of Building construction	0.8

17c.CLAY BRICK WASTE : BUILDING CONSTRUCTION	
Building Construction (Mil Rands)	15572.6
Clay brick waste Component Factor (%)	0.7
Clay brick waste (Tons)	10287.9
Clay brick waste as a Percentage of Building construction	0.7

17d. CRUSHED CERAMIC WASTE: BUILDING CONSTRUCTION	
Building Construction (Mil Rands)	15572.6
Crushed ceramic waste Component Factor (%)	0.2
Crushed Ceramic waste (Tons)	2572.0
Crushed Ceramic waste as a Percentage of Building construction	0.2

17e. GLASS WASTE /CULLET: BUILDING CONSTRUCTION	
Building Construction (Mil Rands)	15572.64
Glass waste / cullet Component Factor (%)	0.02
Glass waste / Cullet (Tons)	311.45
Glass waste /cullet as a Percentage of Building construction	0.02

17f. SCRAP STEEL: BUILDING CONSTRUCTION	
Building Construction (Mil Rands)	15572.6
Scrap steel Component Factor (%)	0.0
Scrap steel waste (Tons)	123.3
Scrap Steel as a Percentage of Building construction	0.0

17g. NON FERROUS SCRAP METALS (COPPER,ZINC,BRASS ETC):BUILDING CONSTRUCTION	
Building Construction (Mil Rands)	15572.6
Non Ferrous Scrap metals Component Factor (%)	0.0024
Non Ferropus Scrap Metals (Tons)	37.7
Non Ferrous Scrap Metals as a Percentage of Building construction	0.0024

Table 18: Waste and Alternative Materials from Civil Engineering and Other Construction

18a.RECYCLED CONCRETE : CIVIL ENGINEERING AND OTHER CONSTRUCTION	
Civil engineering and other construction (Tons)	13358.8
Recycled concrete Component Factor (%)	3.3
Recycled concrete (Tons)	44126.6
Recycled concrete as a percentage of Civil engineering and other construction	3.3

18b.SCRAP STEEL : CIVIL ENGINEERING AND OTHER CONSTRUCTION	
Civil engineering and other construction (Tons)	13358.8
Scrap steel Component Factor (%)	0.0
Scrap steel (Tons)	105.8
Scrap steel as a percentage of Civil engineering and other construction	0.0

18c.NON FERROUS SCRAP METAL : CIVIL ENGINEERING AND OTHER CONSTRUCTION	
Civil engineering and other construction (Tons)	13358.8
Non-ferrous scrap metal Component Factor (%)	0.0024
Non-ferrous scrap metal (Tons)	32.3
Non-ferrous scrap metal as a percentage of Civil engineering and other construction	0.0024

18d.NON FERROUS SCRAP METAL: BUILDING CONSTRUCTION	
Consumption Expenditure (R mil)	7373.07
Non-ferrous scrap metal Component Factor (%)	0.01
Non-ferrous scrap metal (Tons)	59.44
Non-ferrous scrap metal as a percentage of Building construction	0.01

Table 19: Waste and Alternative Materials from Catering and Accommodation Services

19a. PLASTIC WASTE : CATERING AND ACCOMMODATION	
Catering and accommodation services (R mil)	7920.45
Plastic Waste Component Factor (t/Mil Rand)	0.07
Plastic waste as a ratio (t/Mil Rand) of Catering and accommodation services	0.07

19b. PAPER WASTE : CATERING AND ACCOMMODATION	
Catering and accommodation services (R mil)	7920.45
Paper Waste Component Factor (t/Mil Rand)	0.01874
Paper Waste (Tons)	148.4237844
Paperwaste as a ratio (t/Mil Rand) of Catering and accommodation services	0.018739309

19c. GLASS WASTE : CATERING AND ACCOMMODATION	
Catering and accommodation services (R mil)	7920.45
Glass Waste Component Factor (t/Mil Rand)	0.03
Glass Waste (Tons)	260.19
Glasswaste as a ratio (t/Mil Rand) of Catering and accommodation services	0.03

Table 20: Waste and Alternative Materials from Transport and Storage

20a. SCRAP STEEL : TRANSPORT AND STORAGE	
Transport and storage (Tons)	21655.3
Scrap steel Component Factor (%)	0.018
Scrap steel (Tons)	400.2
Scrap steel as a percentage of transport and storage	0.018

20b. NON FERROUS SCRAP METAL : TRANSPORT AND STORAGE	
Transport and storage (Tons)	21655.29
Non-ferrous scrap metal Component Factor (%)	0.01
Non-ferrous scrap metal(Tons)	122.20
Non-ferrous scrap metal as a ratio (ton/mil rand) of transport and storage	0.01

Table 21: Waste and Alternative Materials from Consumption Expenditure

21a. PLASTIC WASTE : CONSUMPTION EXPENDITURE	
Consumption Expenditure (R mil)	7373.07
Plastic Waste Component Factor (t/Mil Rand)	0.07
Plastic Waste (Tons)	480.56
Plastic waste as a ratio (t/Mil Rand) of Consumption Expenditure	0.07

21 b. PAPER WASTE : CONSUMPTION EXPENDITURE	
Consumption Expenditure (R mil)	7373.1
Paper Waste Component Factor (t/Mil Rand)	0.0
Paper Waste/cullet (Tons)	138.2
Paper waste as a ratio (t/Mil Rand) of Consumption Expenditure	0.0

21 c. GLASS WASTE/CULLET : CONSUMPTION EXPENDITURE	
Consumption Expenditure (R mil)	7373.07
Glass waste/cullet Component Factor (t/Mil Rand)	0.03
Glass waste/cullet (Tons)	242.21
Glass waste/cullet as a ratio (t/Mil Rand) of Consumption Expenditure	0.03

21d. NON FERROUS SCRAP METAL : CONSUMPTION EXPENDITURE	
Consumption Expenditure (R mil)	7373.1
Non-ferrous scrap metal Component Factor (%)	0.0
Non-ferrous scrap metal (Tons)	59.4
Non-ferrous scrap metal as a percentage of Building construction	0.0

Table 22: Literature references used to estimate waste materials for commodities and services in Mpumalanga

Category	Source
(I) Materials from Manufacturing	
• Steel and iron slag	
• Ferrochrome slag	IFAPA. Production, characteristics, and use of Ferrochrome Slags. Pekka Niemela and Maurii Kauppi.
• Copper slag	Multilateral Investment Guarantee Agency.2017. Environmental Guidelines for Copper Smelting
• Furnace dust	
• Silica fume or nano-silica	
• Galvanizing waste	
(ii) Materials from Mining	
• Waste stone	SAMI.2015. .Department of Mineral and Resources
(iii) Materials from Power stations and boilers	
• Boiler slag (Coal bottom ash)	South Africa's power producer's revised Coal Ash Strategy and implementation progress. 2017.Kelley Reynolds Clausen and Nico Singh.
• Coal fly ash	South Africa's power producer's revised Coal Ash Strategy and implementation progress. 2017.Kelley Reynolds Clausen and Nico Singh. Field Visits to Matimba & Medupi PowerStation's
(iv) Materials from Agriculture	
• Citrus peels	
• Chicken feathers	Journal of Science: ISSN0031-7683 .2010. Waste Chicken Feather as reinforcement in Cement – Bonded Composites.

(v) Materials from Forestry	
• Waste wood	Forest and Forest products research Centre. KZN. CSIR. Dr Bruce Sithole.
• Saw dust	
(vi) Recycled Materials	
• Plastic waste	Mascon Trading. Data from Polokwane Landfill Site and StatsSA, Statistical Release P0145.
• Recycled asphalt	
• Recycled concrete	Mascon Trading. Data from Polokwane Landfill Site.
• Demolition waste	Mascon Trading. Data from Polokwane Landfill Site.
• Clay brick waste	Mascon Trading. Data from Polokwane Landfill Site.
• Crushed ceramics waste	Mascon Trading. Data from Polokwane Landfill Site.
• Sewerage sludge	Sewag Sludge Incineration in South Africa. Ethekwnin Water & Sanitation & Water Research Report No PEP-WP11047-PEP4)
• Paper Waste	Mascon Trading. Data from Polokwane Landfill Site.
• Water treatment sludge	National Waste Information Baseline Report. 2012.Department of Environmental Affairs
• Glass waste/cullet	
• Scrap steel	
• Non-ferrous scrap metal (copper, zinc, brass, etc.)	

In Appendix A, the data gathered from Polokwane landfill site is also presented. This data was also used as a basis for determining waste from recycled materials.

6.

VOLUMES OF WASTE GENERATED

6.1.

Potential Waste for Re-Use in Mpumalanga Province

In Table 23 an estimation of waste materials in the Mpumalanga Province is presented for the base year 2018 and for the projected years 2033 and 2048 respectively as well as a detailed exposition of the commodities that generate the various waste products is provided for the various years, Table 24 for 2018, Table 25 for 2033 and Table 26 for 2048.

The selection of potential waste was based on a validation criterion which in this case was a 100 000 tons threshold.

	Total Waste Material (Tons)			
		2018	2033	2048
	(i) Materials from Agriculture			
1	Citrus peels	53,308	78,895	108,378
2	Chicken feathers	3,779	5,560	8,544
	(ii) Materials from Forestry			
3	Waste wood	623,711	804,599	1,090,467
4	Saw dust	10,348	15,331	23,606
	(iii) Materials from Mining			
5	Waste stone	17,343,230	22,223,866	28,606,960
	(iv) Materials from Manufacturing			
6	Steel and iron slag	72	62	48
7	Ferrochrome slag	1,016,817	1,406,559	1,942,371
8	Copper slag	71,120	90,851	124,386
9	Furnace dust	845	1,075	1,438
10	Silica fume or nano-silica	112,980	156,284	215,819
11	Galvanizing waste	0	0	0
	(v) Recycled Materials			
12	Plastic waste	-	-	-
13	Recycled asphalt	-	-	-
14	Recycled concrete	-	-	-
15	Demolition waste	-	-	-
16	Clay brick waste	-	-	-
17	Crushed ceramics waste	-	-	-

Table 23: Estimation and projection of waste materials

	Total Waste Material (Tons)			
		2018	2033	2048
17	Crushed ceramics waste	-	-	-
18	Sewerage sludge	4,029,724	5, 423 477	7, 156 163
19	Paper Waste	-	-	-
20	Water treatment sludge	-	-	-
21	Glass waste/cullet	-	-	-
22	Scrap steel	10	8	7
23	Non-ferrous scrap metal (copper, zinc, brass, etc.)	-	-	-
	(vi) Materials from Power stations and boilers			
24	Boiler slag (Coal bottom ash)	589,382	792 ,066	1 043 962
25	Coal fly ash	3,756,934	5,059 858	6, 682 527

Table 24: Exposition of waste materials for the Mpumalanga Province for the year 2018 (next page)

	Production (tons)	**1,066,159**	**512,789**	**64,655**	**71**	**10,194,262**	**1,503,530**	**81,801**	**305,884**	**485**	**740,278**	**66,720**	**32,430,122**	**322,377,893**	**-**	**-**	**-**	**-**	**-**	
	Production (Rand Million , 2016 constant)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**15,573**	**13,359**	**7,920**	**21,655**	**7,373**	
		Agriculture, Forestry and Fishing		**Mining and Quarrying**				**Manufacturing**						**Construction (Contractors)**						
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		Citrus	Forestry	Copper	PGM's	Limestone	Rock Phosphate	Slaughtered animal meat (incl. broilers)	Wood timber and products	Iron & steel	Ferrochrome	Non-ferrous metal products	Coal-fired PowerStation	Water	Building construction	Civil engineering and other construction	Catering and accommodation services	Transport and storage	Consumption Expenditure	Total Waste Material (Tons)
	(i) Materials from Agriculture																			-
1	Citrus peels	53,308	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53,308
2	Chicken feathers	-	-	-	-	-	-	3,779	-	-	-	-	-	-	-	-	-	-	-	3,779
	(ii) Materials from Forestry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Waste wood	-	289,126	-	-	-	-	-	334,585	-	-	-	-	-	-	-	-	-	-	623,711
4	Saw dust	-	-	-	-	-	-	-	10,348	-	-	-	-	-	-	-	-	-	-	10,348
	(iii) Materials from Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Waste stone	-	-	3,232,727	11,764,336	650,698	1,695,470	-	-	-	-	-	-	-	-	-	-	-	-	17,343,230
	(iv) Materials from Manufacturing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Steel and iron slag	-	-	-	-	-	-	-	-	72	-	-	-	-	-	-	-	-	-	72
7	Ferrochrome slag	-	-	-	-	-	-	-	-	-	932,750	84,067	-	-	-	-	-	-	-	1,016,817
8	Copper slag	-	-	71,120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	71,120
9	Furnace dust	-	-	647	197	-	-	-	-	1	-	-	-	-	-	-	-	-	-	845
10	Silica fume or nano-silica	-	-	-	-	-	-	-	-	-	103,639	9,341	-	-	-	-	-	-	-	112,980
11	Galvanizing waste	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	0
	(v) Recycled Materials	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	Plastic waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Recycled asphalt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	Recycled concrete	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Demolition waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	Clay brick waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Crushed ceramics waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Sewerage sludge	-	-	-	-	-	-	-	-	-	-	-	-	4,029,724	-	-	-	-	-	4,029,724
19	Paper Waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	Water treatment sludge	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	Glass waste/cullet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	Scrap steel	-	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	-	10
23	Non-ferrous scrap metal (copper, zinc, brass, etc)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(vi) Materials from Power stations and boilers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

24	Boiler slag (Coal bottom ash)	-	-	-	19,607	-	-	-	-	-	-	-	569,775	-	-	-	-	-	-	589,382
25	Coal fly ash	-	-	-	-	-	-	-	-	-	-	-	3,756,934	-	-	-	-	-	-	3,756,934

Table 25: Exposition of waste materials for the Mpumalanga Province for the year 2018 (next page)

	Production (tons)	**1,577,896**	**547,859**	**82,592**	**89**	**14,504,619**	**2,087,705**	**120,348**	**453,179**	**418**	**1,036,212**	**80,105**	**495,938,719**	**4,966,883,146**	**-**	**-**	**-**	**-**	**-**	
	Production (Rand Million , 2016 constant)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**23,838**	**20,523**	**105,178**	**12,090**	**32,153**	
		Agriculture, Forestry and Fishing		Mining and Quarrying				Manufacturing							Construction (Contractors)					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		Citrus	Forestry	Copper	PGM's	Limestone	Rock Phosphate	Slaughtered animal meat (incl. broilers)	Wood timber and products	Iron & steel	Ferrochrome	Non-ferrous metal products	Coal-fired Powerstation	Water	Building construction	Civil engineering and other construction	Catering and accommodation services	Transport and storage	Consumption Expenditure	Total Waste Material (Tons)
	(i) Materials from Agriculture																			-
1	Citrus peels	78,895	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	78,895
2	Chicken feathers	-	-	-	-	-	-	5,560	-	-	-	-	-	-	-	-	-	-	-	5,560
	(ii) Materials from Forestry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Waste wood	-	308,899	-	-	-	-	-	495,700	-	-	-	-	-	-	-	-	-	-	804,599
4	Saw dust	-	-	-	-	-	-	-	15,331	-	-	-	-	-	-	-	-	-	-	15,331
	(iii) Materials from Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Waste stone	-	-	4,129,596	14,814,222	925,827	2,354,220	-	-	-	-	-	-	-	-	-	-	-	-	22,223,866
	(iv) Materials from Manufacturing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Steel and iron slag	-	-	-	-	-	-	-	-	62	-	-	-	-	-	-	-	-	-	62
7	Ferrochrome slag	-	-	-	-	-	-	-	-	-	1,305,627	100,932	-	-	-	-	-	-	-	1,406,559
8	Copper slag	-	-	90,851	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90,851
9	Furnace dust	-	-	827	248	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1,075
10	Silica fume or nano-silica	-	-	-	-	-	-	-	-	-	145,070	11,215	-	-	-	-	-	-	-	156,284
11	Galvanizing waste	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	0
	(v) Recycled Materials	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	Plastic waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Recycled asphalt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	Recycled concrete	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Demolition waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	Clay brick waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Crushed ceramics waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Sewerage sludge	-	-	-	-	-	-	-	-	-	-	-	-	5 423 477	-	-	-	-	-	5 423 477
19	Paper Waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	Water treatment sludge	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	Glass waste/cullet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	Scrap steel	-	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	8
23	Non-ferrous scrap metal (copper, zinc, brass, etc)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	(vi) Materials from Power stations and boilers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	Boiler slag (Coal bottom ash)	-	-	-	24,690	-	-	-	-	-	-	-	767 376	-	-	-	-	-	-	792 066
25	Coal fly ash	-	-	-	-	-	-	-	-	-	-	-	5 059 859	-	-	-	-	-	-	5 059 858

Table 26: Exposition of waste materials for the Mpumalanga Province for the year 2048

	Production (tons)	2,167,564	580,319	113,078	110	21,040,011	2,939,182	184,936	697,792	325	1,437,735	103,829	6,363,024,556	63,770,729,829	-	-	-	-	-	
	Production (Rand Million, 2016 constant)	-	-	-	-	-	-	-	-	-	-	-	-	-	35,847	30,922	149,243	18,104	48,297	
		Agriculture, Forestry and Fishing		Mining and Quarrying				Manufacturing							Construction (Contractors)					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		Citrus	Forestry	Copper	PGM's	Limestone	Rock Phosphate	Slaughtered animal meat (incl. broilers)	Wood timber and products	Iron & steel	Ferrochrome	Non-ferrous metal products	Coal-fired Powerstation	Water	Building construction	Civil engineering and other construction	Catering and accommodation services	Transport and storage	Consumption Expenditure	Total Waste Material (Tons)
	(i) Materials from Agriculture																			-
1	Citrus peels	108,378	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	108,378
2	Chicken feathers	-	-	-	-	-	-	8,544	-	-	-	-	-	-	-	-	-	-	-	8,544
	(ii) Materials from Forestry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Waste wood	-	327,201	-	-	-	-	-	763,266	-	-	-	-	-	-	-	-	-	-	1,090,467
4	Saw dust	-	-	-	-	-	-	-	23,606	-	-	-	-	-	-	-	-	-	-	23,606
	(iii) Materials from Mining	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	Waste stone	-	-	5,653,888	18,295,696	1,342,979	3,314,397	-	-	-	-	-	-	-	-	-	-	-	-	28,606,960
	(iv) Materials from Manufacturing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	Steel and iron slag	-	-	-	-	-	-	-	-	48	-	-	-	-	-	-	-	-	-	48
7	Ferrochrome slag	-	-	-	-	-	-	-	-	-	1,811,546	130,824	-	-	-	-	-	-	-	1,942,371
8	Copper slag	-	-	124,386	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	124,386
9	Furnace dust	-	-	1,132	306	-	-	-	-	0	-	-	-	-	-	-	-	-	-	1,438
10	Silica fume or nano-silica	-	-	-	-	-	-	-	-	-	201,283	14,536	-	-	-	-	-	-	-	215,819
11	Galvanizing waste	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	0
	(v) Recycled Materials	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12	Plastic waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	Recycled asphalt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	Recycled concrete	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	Demolition waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	Clay brick waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Crushed ceramics waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	Sewerage sludge	-	-	-	-	-	-	-	-	-	-	-	-	7 156 163	-	-	-	-	-	7 156 163
19	Paper Waste	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	Water treatment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

	sludge																			
21	Glass waste/cullet	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	Scrap steel	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	7
23	Non-ferrous scrap metal (copper, zinc, brass, etc)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(vi) Materials from Power stations and boilers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	Boiler slag (Coal bottom ash)	-	-	-	30,493	-	-	-	-	-	-	-	1 013469	-	-	-	-	-	-	1 043962
25	Coal fly ash	-	-	-	-	-	-	-	-	-	-	-	6 682 527	-	-	-	-	-	-	6

7.

CONCLUSIONS

More needs to be done to raise awareness of the Circular Economy and the potential benefits they can provide across various sectors in Mpumalanga Province and the RSA economy.

However, a number of obstacles and challenges to scaling circular economy in the various sectors are notable.

These included, amongst others, financial constraints and the lack of incentives; lack of technical and technological capacity; legislation; a lack of political will and leadership; lack of knowledge on the circular economy; a lack of collaboration between government, industry, and academia.

In addition, key and strategic economic sectors should be incentivised to upscale and mainstream circular economy within their sectors.

2026
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