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Supporting the development of a globally competitive *manufacturing sector* through a more circular economy

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The intention of this short think piece on the circular economy in manufacturing, is to initiate discussion on the sector opportunities for South Africa. These opportunities are framed within the context of the current challenges facing the South African manufacturing sector.

"*The lesson for South Africa is to build greater economic resilience – at firm and economy level – and pursue 'strategic autonomy' goals, which in the South African context demands greater levels of innovation and industrialisation".* Minister of Trade and Industry

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CSIR Opinion Pieces and Briefing Notes provide perspectives on current science, technology and innovation developments, and related policy topics.

Introduction

The South African manufacturing sector has suffered from de-industrialization 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.

Various policy and economic drivers have resulted in a declining demand from South Africa's main export markets, which has seen the sector's GDP contribution fall from over 20% in 1993 to 13% in 2020[1]. The South African 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[2]. The heavy economic dependence on resource extraction in favour of exports is well recognized (*See CSIR Mining Briefing Note*). Despite massive inputs of natural resources, productivity within the manufacturing sector remains low, while significant volumes of waste and pollution are generated[3].

The application of circular economy principles of designing out waste, closing resource loops; and regenerating natural systems offers a systemic approach to addressing these challenges and achieving resilience of the local manufacturing economy[4] as outlined below:

- **Design out waste**: redesign manufacturing processes and products to enhance resource efficiency, coupled with sharing economy business models.
- **Keep materials in use:** remanufacture, refurbish, repair and recycle materials and products across value chains.
- **Regenerate natural systems:** transition to green energy (solar, wind, hydrogen) and decouple resource utilization.

The implementation of circular economy thinking can enhance sectoral innovation and competitiveness[5]. This is evident from global trends. The newly adopted EU Circular Economy Action plan forms one of the main anchors for the region's sustainable growth agenda - the European Green Deal[6]. The plan focuses on *design* and *production* for a circular economy ensuring that resources are continuously recirculated within the economy.

Circular solutions can similarly be leveraged locally to fulfil national development objectives, climate obligations and Sustainable Development Goals, with emphasis on economic growth, poverty alleviation, infrastructure development and job creation[7]. The CSIR recognises the pivotal role of the manufacturing sector in driving re-industrialization and the transition to a circular economy. Indeed, the manufacturing sector, in close collaboration with other economic sectors, is centrally placed to design and implement the circularity of resources, with positive impacts on the economy, society and the environment. Manufactured products, chemicals, plastics and industrial machinery play a key role in the productivity and growth of both upstream and downstream economic sectors, such as agriculture, mining, energy, and water. Applying circular principles in the design of products, manufacturing companies can influence the production process, and indeed the entire product life cycle, including usage and end-of-life scenarios (Fig. 1)[7].

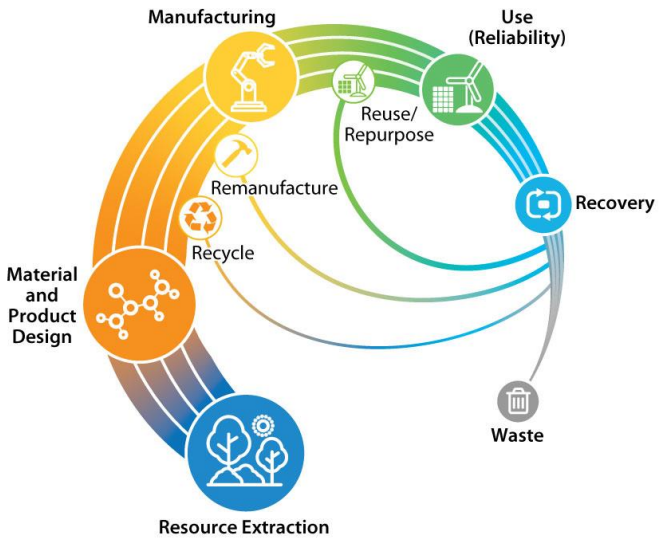

Figure 1. Integration of circular economy into manufacturing[8].

Overview of the South African manufacturing sector

The manufacturing 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%), and electrical machinery (2%)[9]. The three largest sub-sectors account for over two thirds of manufacturing activity[1]. Despite the sectoral GDP doubling since 1994, its contribution to national GDP has declined, forcing labour migration towards the services industry[10].

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. Moreover, the country mostly exports un-beneficiated ores and unwrought base metals, apart from motor vehicles, and associated spares and accessories. Lack of local beneficiation is exacerbated by high levels of manufactured imports (>80% in 2020), comprising: motor vehicles, parts and accessories (13.6%); machinery and equipment (11.9%); chemical products (8.9%); and basic chemicals (5%)[1]. In addition, the sector draws 52% of national energy demand (*See CSIR Energy Briefing Note*) and 3% of the national water allocation (*See CSIR Water Briefing Note*). Electricity costs have outpaced inflation for over a decade, exceeding R9Bn by Q3 2019 for the iron and steel subsector alone[11]. Blackouts lead to production losses, rising costs, reduced competitiveness and investment. Over 80% of sectoral energy is sourced from coal-fired utilities, a major GHG source[12].

Currently, industrialization driven by localization, import substitution, beneficiation, and embracing of both green and hydrogen economies are key thematic areas of the policy landscape, which if leveraged could pave the way for socio-economic recovery based on circular economy models. The 10th Industrial Policy Action Plan tackles the decline in manufacturing, having to date boosted the automotive and textiles industries, designating specific products for preferential procurement (rail stock, transformers, etc)[13]. Special Economic Zones designated by the SEZ Act, 2014 also present opportunities for promoting circularity in local manufacturing[14]. The OR Tambo SEZ recently launched for fuel cell manufacture, Platinum Valley SEZ for auto-catalyst production and PGM recycling, and Tshwane Automotive SEZ exemplify policy driven revival of the sector.

The **dtic** industry Master Plans afford further opportunities for growth and transition toward a more circular South African economy. Localization driven by preferential procurement and the secure supply of raw materials, chemicals and equipment are key underlying strategies. The Steel Industry Master Plan mandates the use of locally manufactured steel for key infrastructure programs, and value-chain development for capital and transport equipment. Export of steel scrap is restricted via ITAC controls and export taxes, given its economic value[15]. Cross-border carbon taxes will penalize local manufacturers, hence the 2050 Master Plan targets on carbon neutrality for local industry. Power-intensive steel mills, foundries, and smelters reliant on fossil-fuels are highlighted as opportunity areas for renewable energy and gas, water conservation and waste reduction.

The waste sector is recognised by Government as an important industry in which technology and innovation have a crucial role to play in creating a secondary resources economy and driving greater circularity as envisaged in the 2020 National Waste Management Strategy (NWMS)[16]. Despite policy-driven changes aimed at overcoming sector challenges, a detailed stock-take and gap analysis are needed to frame a more coherent approach to circularity.

Circular economy opportunities in the manufacturing sector

Potential opportunities in the manufacturing sector, as aligned to these circular economy principles, are highlighted here:

Design out waste and pollution

Circular business models have come to the fore in recent years, e.g. product-as-service, product sharing, remanufacturing and circular supplies. Changing usage patterns via the sharing economy and product-as-service models can realize significant economic and environmental gains. Tata Steel and the Indian Steel Authority set up *mjunction*, an e-market for steel waste, allowing traders transparent access. *mjunction* has evolved into the world's largest e-market for steel, with trade volumes increasing from $13.8m in 2002 to $9.45Bn in 2016[17].

By selling product functionality or services rather than products *per se*, companies can manage an entire product life cycle, and associated costs, by developing closed material flow loops[4]. Renault, for example extends and optimizes the EV battery lifecycle by selling it as a service. Since starting, battery leasing is now preferred by over 90% of customers. Renault further

extended its EV battery lifecycle by cascading to energy storage applications[17]. In the EU, the circular chemical leasing model shifts focus from increasing sales volumes to value-addition, where the client pays per functional unit, ensuring that both supplier and end-user achieve reductions in chemical use[18].

Manufacturing product design must consider optimising materials, durability, and repairability to design out waste. In the *textiles industry*, there is increased focus on design of more durable, re-usable and eco-friendly textiles. Natural fibre development can help avoid use of harmful chemicals in the textiles value chain, a global problem. Improved textile design would reduce the level of hazardous chemicals and micro-fibre waste entering ecosystems[19]. In the *plastics industry*, the South African Plastic Pact calls for zero waste by redesigning problem packaging such that 100% of plastics are reusable, recyclable, or compostable by 2025[20].

Improved resource efficiency in manufacturing is critical to the sectors global competitiveness. The National Cleaner Production Centre (NCPC-SA), tasked by the **dtic**, fulfils a vital role in helping reduce energy, water and materials use across various manufacturing sub-sectors. Over the period 2010-2020 the NCPC's industrial energy efficiency program has worked with 274 large companies and 180 manufacturing SMEs, saving over 6500 GWh in energy and R5.275 Bn in direct costs[21]. The recent NCPC I-GO (Integrated Greening Operations) initiative, facilitated on behalf of UNEP aims to scale-up resource efficiency efforts of SMEs in Africa.

Keep products and materials in use

Circular economies aim to optimize resource yields by constantly circulating products, components, and materials at highest utility. Tight product cycles are a key circularity trait, circumventing a loss of embedded energy, resources and labour from simple recycling and disposal. The remanufacture 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[22].

Globally, remanufacturing is dominated by the automotive and aerospace sectors (*See CSIR Mobility Briefing Note*), as well as construction, electrical equipment, heavy machinery and medical devices. However, global uptake remains low due to lack of infrastructure, supply chains and investment in remanufacturing technologies[23]. Remanufacturing of internal combustion (IC) engines is a well-established industry within the local automotive sector. In contrast to simple reconditioning, local ICE remanufacturers adopt industry standards to guarantee used engines are returned to OEM approved specifications through an extensive and audited process. Remanufactured engines provide levels of performance, reliability and lifespan that equal, and, in many instances exceed the original[24].

Caterpillar, the global heavy machinery OEM has been remanufacturing components since 1973. Caterpillar's dedicated remanufacturing arm (CAT Reman) is now a leader in developing value recovery processes and technologies, profitably growing to nine locations worldwide (>3500 employees) based on its component recovery business model. Durable parts enjoy repeated remanufacturing, e.g. gearboxes, drivetrains and brakes[4]. The circular framework of designing for multiple remanufacturing cycles has been increasingly used by CAT, given that the major costs lie in materials (65%).

Local manufacturing features an established recycling industry across various sub-sectors, despite a need to improve recycling rates. The South African *metals sector* has established a mature scrap metal recycling industry, achieving a recycling rate of 80% in 2018[25]. Continued recycling is necessary to maintain steel scrap in a constant loop, and to supplement primary steel production, given the insufficiency to satisfy rising world demand. Almost half of EU steel originates from secondary process and end-of-life (EoL) scrap[26]. A strategic value chain with opportunity for closing resource loops is the primary processing of local platinum group metals (PGMs). The reliance on exports of unwrought PGM base metals mandates the need for local beneficiation. Dedicated SEZs for fuel cell and auto-catalyst manufacture present opportunities for refurbishment and recycling of components at EoL, enabling beneficiation and retention of extracted precious metals within the local economy.

The *electrotechnical sector* is one of the fastest growing sectors globally, with high resource demands and high levels of waste electrical and electronic equipment (WEEE). Since 2014, e-waste has grown by 9Mt globally. Currently, <10% of locally generated WEEE is recycled, mostly pre-processed with export for metal recovery, resulting in the loss of resources. Increasing the local WEEE recycling rate would provide local job opportunities[25].

The South African *plastics sector*, despite implementing voluntary EPRs two decades ago, has only achieved a 43% collection rate (input), with much lower recycling (output) rates. Plastics recycling is an important local industry with opportunity for businesses to actualise the SA Plastic Pact target: all packaging to contain 30% recycled content with 70% of packaging effectively recycled by 2025[18]. Extended Producer Responsibility (EPR) regulations for paper and packaging, e-waste and lighting are expected to significantly scale up the collection, reuse, repair and recycling of these goods in line with mandated targets[27].

The *clothing and textiles sector* requires significant circular interventions given its impacts in terms of resource demand and resultant wastage. Currently, less than 20% of textiles are recycled globally, despite a massive environmental burden. As a developing country, end-of-life clothing in South Africa often finds reuse opportunities driven by high levels of poverty and unemployment. Locally, organisations such as *The Clothing Bank*, and *Rewoven*, have partnered with major local retailers to drive greater textile reuse of excess stock, customer returns, store damages, end-of-season and bulk rejections. The textile sector can phase out hazardous substances, enhance resource utilization, adopt renewable resources and inputs, and radically improve recycling along the value chain via circular interventions. Cascaded recycling allows re-use of textiles in

lower value applications (insulation, cleaning materials, etc)[19]. NCPC-SA has partnered under the UNEP's InTEX project in developing Innovative Business Practices and Economic Models across the textiles value chain[21]. NCPC and GreenCape have championed industrial symbiosis (IS) to close resource loops, with opportunities to scale up and lower material input costs, whilst addressing resource scarcity and waste[28]. Over the period 2015-2020, NCPC assisted 80 companies through IS, diverting 215,000 tonnes of waste resources from landfill and saving R17.7m in landfill diversion[21].

Regenerate natural systems

In addition to the sector adopting more renewable energy solutions, the emerging green energy market (estimated at R30Bn) offers new circular manufacturing opportunities. NERSA's exemption on self-generation (up to 100MW) renders embedded generation via local solar panel, wind tower and turbine manufacture feasible. A 1GW/yr solar PV market is sufficient for five manufacturers to set up local facilities of 200MW each, providing opportunities for circular renewable energy products[11]. Policies call on national R&D organizations to assist in developing a green, circular industry[13]. Bio-based energy and materials, including bio-catalysis, can also help in moving away from fossil-based resources.

Circular impacts can be further achieved by adopting a suite of tools, such as Life Cycle Analysis (LCA), an important part of circular economy modelling and analysis. LCA quantifies resource inputs and outputs to air, water and soil over the product lifecycle, complementing circular economy models by testing model assumptions and exploring alternatives[29]. Mitigating resource use throughout product lifecycles can help restore natural systems and reverse pollution damage, whilst enabling carbon footprint or climate change impact reductions.

It is clear that the application of circular economy principles is not new to the South African manufacturing sector, with activities being driven locally, regionally and internationally to decouple growth from resource consumption and transition to alternative circular economy business models. However, while many of the underlying principles are already being applied in the local manufacturing sector, more needs to be done in achieving the scale required for meaningful impact. Collaboration at all levels is vital, and companies can employ the ReSOLVE framework (regenerate, share, optimize, loop, virtualize, exchange) to navigate the complexities in transitioning to a circular economy[30].

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 utilization and waste capacity. Additive manufacturing for instance, has disrupted traditional manufacturing processes (machining, casting, injection moulding) enabling reductions in development costs, resource utilization, waste and energy consumption. Its on-demand, digitally distributed manufacturing, allows for reduced physical inventories and more resilient supply chains.

Conclusions

South Africa needs to reverse pre-mature de-industrialisation trends of the past two decades in a more sustainable and inclusive manner, moving away from the linear economic 'take-make-dispose' model to a more resilient economic framework. The manufacturing sector is centrally placed to unlock circular opportunities, by designing and producing for circularity of resources, and adopting circular business models that minimise consumption. The benefits of a circular economy include environmental gains, job creation, and improved competitiveness due to greater efficiencies and reduced manufacturing costs. New opportunities exist in designing out waste by enhancing resource efficiency, re-use, and remanufacture. New businesses can be created by closing resource loops using value retention processes, and existing circular initiatives can be scaled to achieve impact. Similarly, new circular manufacturing opportunities exist in the green energy market, and adoption of renewable materials for regeneration of natural capital. Digital transformation driven by 4IR technologies allow for advanced monitoring of resource utilization and waste. Industry Master Plans afford further opportunities for growth and transition toward a more circular South African economy, providing a framework from which to drive circularity as part of re-industrialization. To aid in this transition, impact investment is required, as well as enhanced collaboration within the local manufacturing sector.

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