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2023 Market Study of the Circular (& Waste) Economy of South Africa

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2023 Market Study of the Circular (& Waste) Economy of South Africa
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by

LINDON
CORPORATION
031 904 1050
info@lindon.co.za
www.lindon.co.za

Authors: Don Govender (Lindon Corporation), Dr. Troy Govender (Lindon Corporation) and Chris Whyte (ACEN)
Reviewer: Katharina Gihring (ACEN)

Executive Summary

Discarded or stockpiled resources (such as solid waste, liquid effluent, gas, slurry, tailings, etc.) are globally being regarded as a resource with significant economic value. The circular economy (CE) deals with channelling these resources back into the economy for sustainable economic growth. This is achieved through designing out, re-using, re-purposing and re-cycling of these resources, with discharge, stockpile, landfill or incineration being the options of last resort.

This report is not an academic study and is a scoping study of the CE opportunities in South Africa (SA) for the purposes of facilitating trade and joint ventures between Dutch and South African firms in CE business opportunities. The report is based on existing knowledge of the South African Consultant, *Lindon Corporation*, the current published literature and data from organisations such as the *Department of Forestry, Fisheries and Environment (DFFE),* the *Council for Scientific and Industrial Research (CSIR)*, and *GreenCape* (see the List of References at the end of the report).

SA is the land of circular economy opportunities that are presenting in sectors such as Mining, Agriculture, Forestry, Timber, Paper and Pulp, Food Systems, Manufacturing, Human Settlements & Built Environment, Mobility/Transportation, Energy, Water, Food Systems, Packaging, Electronics, Fashion & Textile, Waste, inter alia.

This market assessment focuses on specific sub-sectors targeted for the upcoming Dutch Mission, namely sustainable landfill management, solid waste, biomass, biogas, plastics, paper, construction and demolition and waste water, and identifies circular opportunities within these sectors.

In the Forestry, Timber, Paper and Pulp (FTPP) sector, potential circular resources include sawdust, woodchips and black liquor for conversion into solid and liquid fuel.

At slaughterhouse operations, opportunities exist for the conversion of discarded solids and liquids into bio-gas for heat and energy, the processing of blood into petfood and other pharmaceutical products.

The Electronics and Electrical sector, present opportunities for the refurbishment of pre-owned devices, the extraction of components with remaining life and the recycling of e-waste to obtain valuable metals and plastics.

Technology is also emerging to treat and process waste Absorbent Hygienic Products (AHPs), such as diapers, which are having significant impact on landfills and the environment due to the human waste and non-biodegradable materials used in these products.

Construction and Demolition waste (C&DW), almost all of which is currently sent to landfill, has a range of circular opportunities such as in crushed aggregate used in roads, in anti-erosion systems and in making green blocks (using crushed concrete and waste plastic).

Waste leather from tanneries and post-production operations are either dumped in landfill or exported. Several container loads of offcuts of finished (coated) leather from tanneries, car seat and furniture upholsterers are also exported out of South Africa. These could instead be processed locally into footwear, gloves, wallets, placemats, keyrings, handbags, etc. There is also an opportunity to shred and reconstitute leather into bonded or synthetic leather sheets for consumer goods (such as apparel, shoes, etc.), book covers and upholstery.

Other discarded resources with potential circular opportunities include automobile tyres, multilaminate packaging, used oil (plant- and fossil-based), fly ash from coal power stations, waste (water and solids) from waste water treatment plants, grey water from residential and commercial buildings, discarded flat glass, garden refuse and food waste.

Given the current low levels of recycling in South Africa, there appears to be a general need for cost-effective and localised waste technology, technical skills, institutional capacity building, within the public sector waste management departments, at private enterprises, specifically amongst small businesses and informal waste pickers and greater public awareness about the CE.

Specific needs of business include access to funding, technology, technical advice, research and development and access to markets for recyclables.

The reader is cautioned to the fact that this is not an exhaustive academic report but an opportunity scoping report for the purposes of business to business engagement between South African and Dutch enterprises. While care has been taken to provide accurate and current information, there may be errors in the information presented as well as omissions of other CE opportunities in South Africa. Interested parties are encouraged to undertake their own due diligence of the opportunities and information presented.

The Authors

30 August 2023

Contents

1. BACKGROUND 12
2. BACKGROUND TO SOUTH AFRICA'S CIRCULAR ECONOMY 14
3. SOUTH AFRICA'S WASTE REGULATORY FRAMEWORK 17
   - 3.1 INTRODUCTION 17
   - 3.2 SUSTAINABILITY DEVELOPMENT GOALS (SDGS) 17
   - 3.3 THE NATIONAL DEVELOPMENT PLAN 20
   - 3.4 PLANNED CIRCULAR ECONOMY EVENTS IN 2023 AND 2424 21
   - 3.5 POLICY LANDSCAPE FOR WASTE MANAGEMENT 23
   - 3.6 CHALLENGES WITH CURRENT LEGISLATION AND RECOMMENDATIONS 32
4. PROFILE OF SOUTH AFRICA'S WASTE ECONOMY 35
   - 4.1 THE NATIONAL WASTE MANAGEMENT STRATEGY 2020 35
   - 4.2 NWMS 2020 TARGETS AND OUTCOMES 35
   - 4.3 CONTRIBUTION TO GENERAL WASTE BY PROVINCE 36
   - 4.4 POTENTIAL WASTE RESOURCES AVAILABLE FOR CIRCULARITY 36
   - 4.5 MAPPING OF STAKEHOLDERS IN THE CE AND WASTE 39
   - 4.6 INFORMAL WASTE SECTOR 44
   - 4.7 ORGANISATION AND DIVISION OF THE MARKETS AND MARKET CHANNELS 44
5. CE OPPORTUNITIES IN SOUTH AFRICA 45
   - 5.1 CITY CLEANING AND WASTE COLLECTION 45
   - 5.2 BIOMASS 48
   - 5.3 SLAUGHTERHOUSE WASTE 54
   - 5.4 PLASTICS 64
   - 5.5 SUSTAINABLE LANDFILLS 65
   - 5.6 CONSTRUCTION AND DEMOLITION 67
   - 5.7 WASTE OF ELECTRICAL AND ELECTRONIC EQUIPMENT 71
   - 5.8 ABSORBENT HYGIENIC PRODUCTS 76
   - 5.9 GLASS 79
   - 5.10 TYRES 79
   - 5.11 FLY ASH 80
   - 5.12 WASTE WATER AND/OR BIOGAS 82
6. GENERAL RISKS AND MITIGATION MEASURES 86
7. CONCLUSION 88

List of Tables

Table 2.1: Potential job opportunities in the CE 15
Table 3.1: CE Policy Challenges and Recommendations 33
Table 4.1: Make-up of General Waste (GW) 36
Table 4.2: Available Annual Waste Resources (Tons) 37
Table 4.3: Makeup of Hazardous Waste (HW) and availability 38
Table 4.4: Stakeholder roles and Responsibilities 39
Table 5.1: Breakdown of Municipal Waste 45
Table 5.2: Percentage of municipal solid waste generation per province in SA 46
Table 5.3: City cleaning and waste collection partners 47
Table 5.4: List of landfill developers 48
Table 5.5: FTPP biomass resource and potential CE processes 50
Table 5.6: Technology solutions 51
Table 5.7: Potential SA Partners in FTTP sector 53
Table 5.8: Waste resources from animal abattoirs 54
Table 5.9: Waste resources from poultry abattoirs 55
Table 5.10: Waste resources by type of slaughterhouse 55
Table 5.11: Potential uses and advantages of slaughterhouse waste 57
Table 5.12: Formula for the fabrication of cement bonded feather boards 59
Table 5.13: Potential SA Partners in Slaughterhouse waste 63
Table 5.14: Potential SA Partners in Plastic Waste 65
Table 5.15: Potential SA Partners in Landfill Operations 66
Table 5.16: Potential SA Partners in C&D Waste 70
Table 5.17: Top construction firms in South Africa: 70
Table 5.18: Potential SA Partners in WEEE 75
Table 5.19: AHP Raw materials by weight (kg/ton) 76
Table 5.20: AHP Raw Material Types 77
Table 5.21: Potential market outlets for AHP Raw Materials 77
Table 5.22: Potential economic products from AHP 77
Table 5.23: Potential SA Partners in AHP Circularity 78
Table 5.24: Tonnages of Waste Glass by Type 79
Table 5.25: Potential SA Partners in Glass Recycling 79
Table 5.26: Potential SA Partners in Tyre Recycling 80
Table 5.27: Sample oxide analyses of ash and portland cement 81
Table 5.28: Potential SA Partner in Fly Ash Resources 82
Table 5.29: Potential SA Partners in Wastewater 84
Table 6.1: Selected waste streams and economic products 88

List of Figures

Figure 1.1: Integration of CE into manufacturing (from NREL) 12
Figure 2.1: Recycling rates in selected South African provinces. [StatsSA, 2017] 15
Figure 4.1: Provincial contribution to General Waste 36

Abbreviations

Abbreviation	Full Text
AASHTO	American Association of State Highway Transportation Officials
ABS	Acrylonitrile butadiene styrene
ACEN	Africa CE Network
AD	Anaerobic Digester
AHPs	Absorbent hygiene products
AMT	Advanced microwave technology
APTT	Anti-pollution Task Team
ASTM	American Society for Testing and Materials
BIDF	Biorefinery Industry Development Facility
BLGCC	Black Liquor Gasification Combined Cycle
Blm	City of Bloemfontein
BLGMF	Black Liquor Gasification for Motor Fuels
CCBSA	Coca-Cola Beverages SA
CD	Compact Disc
C&D	Construction & Demolition
C&DW	Construction and Demolition Waste
CaO	Calcium Oxide
CD	Compact Disc
CE	CE
CH_4	Methane (Carbon + 4 Hydrogen atoms)
CHP	Combined Heat and Power
CO_2	Carbon dioxide
CPU	Central Processing Unit
CSIR	Council for Scientific and Industrial Research
CT	Cape Town
CV	Calorific Value
CWE	Chemicals and Waste Economy
DALRRD	Department of Agriculture, Land Reform and Rural Development
Dbn	City of Durban
DFFE	The Department of Forestry, Fisheries and the Environment
DHA	Department of Home Affairs
DM	District Municipality
DMRE	Department of Minerals Resources and Energy
DOE	Department of Energy
DOH	Department of Health
DOT	Department of Transport
DPME	Department of Planning, Monitoring and Evaluation
DSI	Department of Science and Innovation
dtic	Department of Trade, Industry and Competition
DWS	Department of Water and Sanitation
ECA	Environmental Conservation Act (Act 73 of 1989)

Abbreviation	Full Text
EED	Electronic & Electrical Devices
EEE	electrical and electronic equipment
EIA	Environmental Impact Assessment
EL	East London
EMI	Environmental Management Inspectors
EoL	End of Life
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
EWASA	e-Waste Association of South Africa
FGE	Fountain Green Energy
FSA	Forestry SA
FTPP	Forestry, Timber, Paper and Pulp
GBCSA	Green Building Council of South Africa
GBP	British pound sterling
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GM	General Manager
GMO	Genetically Modified Organisms
GtE	Gas to Electricity
GtH	Gas to Heat
GW	General Waste
Ha	Hectare (= 10,000 m^2)
HCL	Hydrochloric Acid
HCRW	Health Care Risk Waste
HPCSA	Health Professional Council of South Africa
HQ	Head Quarters/Office
HTTP	Hypertext Transfer Protocol
HW	Hazardous Waste
IC	Internal Combustion
ICTE	Information, Communication, Telecommunications and Electronic
IIWTMP	Integrated Industry Waste Tyre Management Plan
IP	Intellectual Property
IPAP	Industrial Policy Action Plan
IS	Industrial Symbiosis
IWMP	Integrated Waste Management Plan
Jhb	City of Johannesburg
kg	kilogram
KZN	KwaZulu-Natal
LM	Local Municipality
M	Million
MDM	Mechanically Deboned Meat
MEC	Member of the Executive Committee

Abbreviation	Full Text
MFMA	Municipal Finance Management Act
MLD	Minimum Liquid Discharge
MSW	Municipal Solid Waste
Mta	Million tons per annum
MWh	Megawatt-Hour
NaOH	Sodium Hydroxide
NAACAM	National Association of Automotive Component and Allied Manufacturers
NPA	National Prosecuting Authority
NCC	National Consumer Council
NCPC-SA	National Cleaner Production Centre South Africa
NDC	Nationally Determined Contributions
NDP	National Development Plan
NECSA	South African Nuclear Energy Corporation
NEMA	National Environmental Management Act (Act 107 of 1989)
NEMWA	National Environmental Management Waste Act (Act 59 of 2008)
NERSA	National Energy Regulator of South Africa
NGO	Non-Governmental Organisation
NPSWM	National Pricing Strategy for Waste Management
NREL	National Renewable Energy Laboratory
NSI	National System of Innovation
NT	National Treasury
NWMS	National Waste Management Strategy
O-H	Oxygen-Hydrogen molecule
OLX	On-Line eXchange
OPC	Ordinary Portland Cement
ORASA	Organic Waste Association of SA
PAMSA	Paper Manufacturers Association of South Africa
PCB	printed circuit boards
PCBs	Polychlorinated Biphenyl
PCs	Personal Computers
PE	Port Elizabeth
PET	Polyethylene Terephthalate
PETCO	Plastic Engine Technology Corporation
PFMA	Public Finance Management Act, Act 1 of 1999
POLCO	Plastic Packaging Recycling
POP	Persistent Organic Pollutants
PPP	Public Private Partnership
PROs	Producer Responsibility Organizations
PSA	Plastics SA
Pta	City of Pretoria (Tshwane)
PVC	Polyvinyl Chloride.
RBay	Richards Bay
R-CTFL	Retail Clothing, Textiles, Footwear and Leather

Abbreviation	Full Text
RDF	Refuse Derived Fuel
RDI	Research, Development and Innovation
REDISA	Recycling and Economic Development Initiative of South Africa
REEDs	Refurbished Electrical and Electronic Devices
RMAA	Red Meat Abattoir Association
RMI	Retail Motor Industry
RVO	Netherlands Enterprise Agency
SA	South Africa
SABIA	South African Biogas Association
S@S	Separation at Source
SABS	South African Bureau of Standards
SAFCOL	South African Forestry Company Ltd
SAP	Super Absorbent Polymer
SAPS	South African Police Service
SAPRO	South African Plastics Recycling Organisation
SARCHI	South African Research Chairs Initiative
SARS	South African Revenue Services
SATMC	South African Tyre Manufacturers Conference
SAWIC	South African Waste Information Centre
SAWPA	South African Waste Pickers Association
SDG	Sustainable Development Goal
SFD	Superfaiths Corporation Development
SME	Small and Medium-Sized Enterprises
SO_2	Sulphur Dioxide
SOWR	State of Waste Report 2018
STI	Science, Technology & Innovation
SWM	Slaughterhouse Waste Mixed
TEPA	Tyre, Equipment, Parts Association
TIA	Technology Innovation Agency
TIASA	Tyre Importers Association of South Africa
TV	Television
UK	United Kingdom
USB	Universal Serial Bus (removable storage device)
UWC	University of Western Cape
VCD	Video Compact Disc
WC&MR	Waste Classification and Management Regulations
WEEE	Waste Electrical and Electronic Equipment
WML	Waste Management Licence
WtE	Waste-Energy
WWF-SA	World Wildlife Fund South Africa
WWTW	Waste Water Treatment Works
WRRF	Water Resource Recovery Facilities

1. Background

This opportunity scoping of the circular economy (CE) of South Africa is prepared for the Netherlands Enterprise Agency (RVO) as preparation for a business mission to South Africa in October 2023. The mission will focus on specific sectors of the CE of South Africa, namely sustainable landfill management, biomass, biogas, construction and demolition, plastic, paper and waste water. The report also includes opportunities in other problematic waste streams in South Africa for possible consideration by the Dutch mission. This report by the Lindon Corporation was developed in collaboration with the African Circular Economy Network (ACEN).

The current and predominant economic model for resource utilisation is linear, in that resources are extracted, transformed into products, used, and finally discarded. This so called 'take-make-dispose' or 'take-make-waste' economic model is not sustainable both economically and environmentally. A CE (also referred to as circularity) is "a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible".

Previously discarded or stockpiled resources (such as solid waste, liquid effluent, waste/landfill gas, slurry, tailings, etc.) have potential economic value if value-adding solutions and markets could be found for them. The CE (Figure 1.1) deals with channelling these resources back into the economy for further economic growth. The three key principles of the CE are designing out waste and pollution, keeping products and materials in use, and regenerating natural systems. This is achieved through designing out, re-using, re-purposing and re-cycling of these resources, with discharge, stockpile, landfill or incineration being the options of last resort.

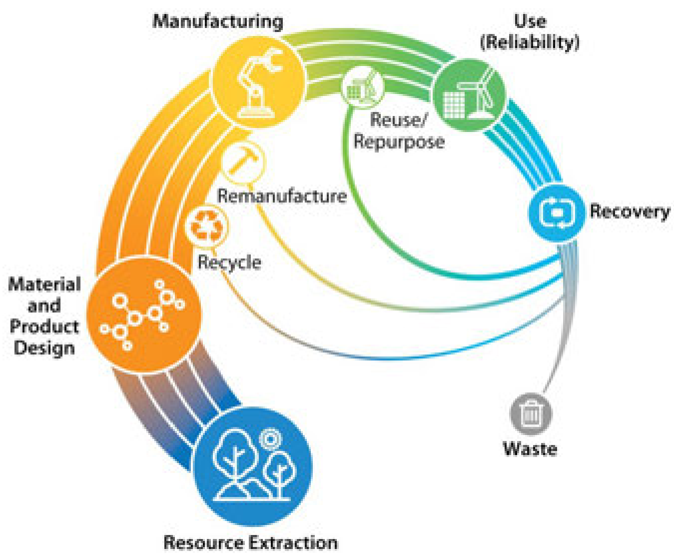

Figure 1.1: Integration of CE into manufacturing [NREL, 2021].

The CE and the potential environmental, financial and economic benefits that it represents cannot be ignored in any organisation's financial, sustainability, social or economic model, especially in the current operating environment, which is characterised by the high cost of extraction of virgin non-renewable raw materials, diminishing profit margins, gross unemployment and local and global environmental challenges.

Natural resources are finite, and the CE aims to keep post-consumer and post-production materials in circulation for as long as possible through reusing, repairing, remanufacturing, sharing, repurposing and recycling. While the concept of the CE is largely focused on developing new technologies and businesses to enable keeping materials in circulation, it also includes the notions of 'designing out' waste, better separation at source (S@S), efficient collection, landfilling, substituting renewable materials for non-renewable ones, and restoring natural systems.

The goal of the CE is therefore to transition from a linear take-make-waste pattern of production and consumption to a circular system in which the societal value of products, materials, and resources is maximized over time.

By prioritizing the implementation of the CE - in line with the United Nations' *2030 Agenda for Sustainable Development*, the South African and Dutch Governments will be contributing significantly to unlocking value that can be found in previously unwanted products. Focusing on the development of the CE, will inevitably create value, generate wealth and provide additional jobs in both countries.

This report aims to provide a comprehensive, reliable and up-to-date overview of the CE opportunities and a list of potential South African businesses who may be interested in doing business with Dutch enterprises. The report specifically focuses on opportunities in solid waste, biomass residue, plastics, water and building and construction waste in South Africa. The results of the study will guide RVO in its matchmaking efforts for the October mission and for a longer term co-operation programme.

2. Background to South Africa's circular economy

Currently, South Africa is approximately 7 percent circular [von Blottnitz et al., 2021], which is slightly lower than the global average of 7.2 percent in 2023 [Circle Economy, 2023]. The South African economy is largely extractive with little domestic stock building. Extracted resources are exported and further processed abroad, while the required infrastructure development is not taking place. Fossil fuels like coal and imported oil are the main energy sources of the country. Circularity takes place around post-consumer packaging by the informal sector which recovers packaging for recycling, while some construction and demolition waste is also reused in informal settlements. Ecological cycling takes place, but industrialised agricultural and forestry practices that do not regenerate the ecosystems are of concern. These practices are reliant on e.g., heavy use of synthetic fertilizers, pesticides and heavy machinery. [von Blottnitz et al., 2021]

Of the approximately 107 million tonnes of general waste produced in SA [SoWR, 2018], approximately 90% (84 million tonnes) ends up in landfill or stockpiles. SA is fast running out of landfill space due to the rapid growth in solid waste generation coupled with very limited S@S and CE initiatives.

Apart from the need to minimise the negative environmental impacts of landfill, slime dams, mine dumps and dumping of waste, a number of waste related laws and strategies are compelling firms and government administrations to reduce waste. The National Waste Management Strategy [NWMS 2020, DFFE] which is a response to NEMA set a number of goals to divert recyclables from landfill sites for re-use, recycling or recovery. The following outcomes, targeted through the implementation of the NWMS 2020, fit well with the proposed Dutch-South Africa CE initiative:

- Prevent waste, and where waste cannot be prevented ensure –
  - 40% of waste from diverted from landfill within 5 years;
  - 55% within 10 years; and
  - At least 70% within 15 years leading to Zero-Waste going to landfill;
- All South Africans live in clean communities with waste services that are well managed and financially sustainable; and
- Mainstreaming of waste awareness and a culture of compliance resulting in zero tolerance of pollution, litter and illegal dumping.

Despite legislation that promote circular economic initiatives and targets, waste recycling has been relatively low across the country. The majority of the waste recycling occurs in provinces with the largest urban populations in the Western Cape and Gauteng and lower levels of recycling in the most rural provinces such as KZN, Eastern Cape, North-West, Limpopo, Northern Cape and Mpumalanga) (Figure 2.1).

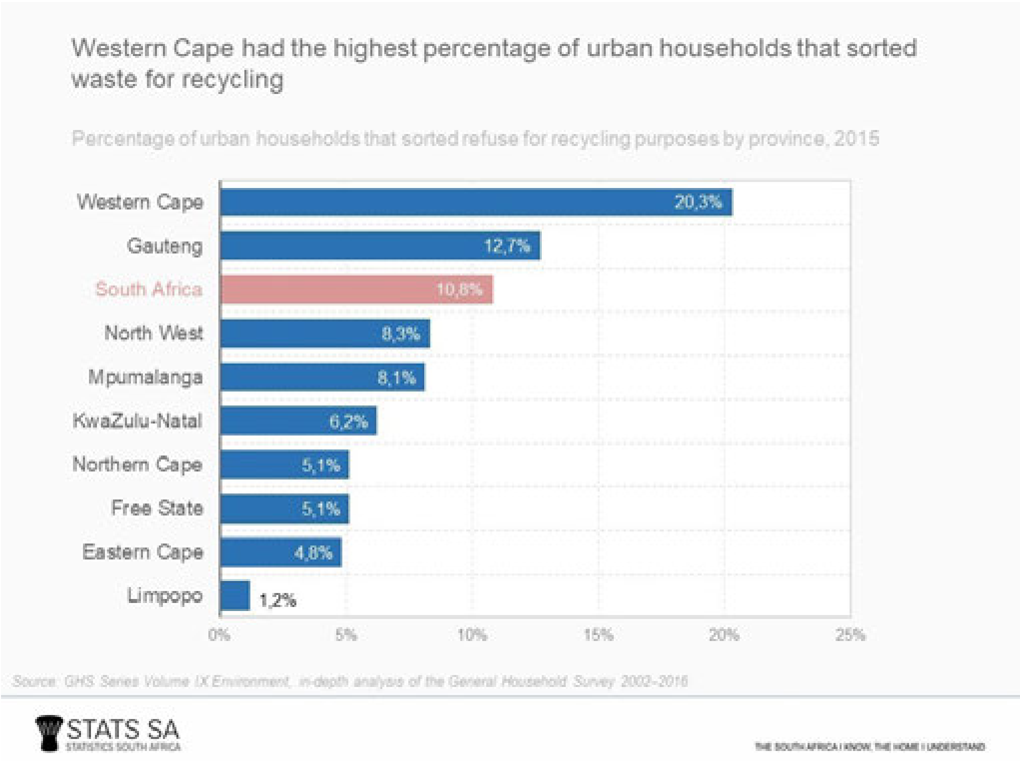

Figure 2.1: Recycling rates in selected South African provinces [StatsSA, 2017].

At the local level, point sources of circular resources include business (paper, plastic, grey water, e-waste), industrial parks (chemicals, inorganic effluent), agricultural zones (biomass), sugar and paper mills (biomass, bio-chemicals), power stations (fly ash), mines (mine tailings, waste water), WWTW (waste water, biomass) and health-care facilities (medical waste), inter alia.

With a scarcity of employment opportunities in South Africa, the country hopes to create massive employment opportunities through waste and the CE as per Table 2.1:

Table 2.1: Potential job opportunities in the CE [SoWR, 2018].

Employment Source	**Employment opportunities**
Bulk industrial waste	28,000
Municipal waste	24,500
Product design and waste minimisation	3,056
Chemicals	3,000
Total	**58,556**

Key aspects of the waste management environment in SA that should be kept in mind during the planning for the trade and co-operation CE initiative mission to SA, include:

(a) The still evolving CE in South Africa, even though there are aspects of the CE that are very mature, such as paper and plastic recycling.
(b) The rapid urbanisation of SA is one of the biggest drivers of waste management;

(c) With the dawn of its democracy, SA is experiencing increased consumption, resulting in significantly increased waste generation.

(d) SA's growing population and economy that are generating increasing volumes of discarded resources but with little growth in all aspects of the waste management hierarchy.

(e) Most landfill sites are approaching their full capacity, with few if any new ones being planned or implemented.

(f) SA has many best practice laws and regulations concerning the environment, however implementation and enforcement remain significant challenges.

(g) Waste collection and disposal is inconsistent across the country with urban areas having better systems in place, while informal and rural settlements have no formal waste management systems.

(h) There is a dearth of accurate data on waste and CE resources. Accurate volumes by type of resource and location are not easily available. The lack of accurate data poses a challenge to full scale development of the CE in SA.

(i) There are significant problems at several landfills such as non-compliance with legislations and poor onsite management practices.

(j) It is estimated that over 82% of all the waste recycled in SA is collected by informal waste pickers [Godfrey and Oelofse, 2017].

(k) SA has implemented Extended Producer Responsibility (EPR) packaging and carbon tax regulations.

(l) SA has proposed banning organic and other recyclable waste streams to landfill by 2028;

(m) SA has not fully exploited the 4th Industrial Revolution relating to waste management, such as emerging waste treatment technologies, digitisation of waste collection, efficient transport and disposal and access to big data.

(n) There's a major focus in bringing women, youth and people with disabilities into the waste sector.

3. South Africa's waste regulatory framework

3.1 Introduction

South African legislation on waste management is one of the most progressive legislations in the world, however, some sectors of the waste economy argue that over-regulation, on the one hand and indecisiveness on the other, may be stifling potential CE projects.

According to current SA legislation [NEMWA, 2008], waste includes any substance, whether or not that substance can be reduced, re-used, recycled and recovered. This includes waste:

(a) that is surplus, unwanted, rejected, discarded, abandoned or disposed of.
(b) which the generator has no further use of for the purposes of production.
(c) that must be treated or disposed of, or
(d) that is identified as a waste by the Minister of the Department of Forestry, Fisheries and Environment (DFFE), and includes waste generated by the mining, medical or other sectors

However, a waste stream for which a solution can be found for its re-use, recycling or recovery, ceases to be waste and becomes an economic resource.

There are a host of regulations, multi-lateral agreements and policies that provide the framework for the CE and waste management in South Africa. The following sections highlight some of the more relevant ones.

3.2 Sustainability Development Goals (SDGs)

In 2015 global leaders developed the Sustainability Development Goals (SDGs) as part of the 2023 Agenda for Sustainability. The 17 SDGs are ambitious goals to move the world to zero poverty and hunger and protect humans from climate change by 2030. Many of these SDGs have linkages to the CE, waste and its management.

Waste circularity with the focus on solid waste for this report is regarded as one of the practical measures that could be adopted to achieve a number of local socio-economic and global SDGs namely:

SDG 3: Good health and well-being
SDG 6: Clean water and sanitation
SDG 7: Affordable and clean energy
SDG 5: Decent Work and Economic Growth
SDG 9: Industry, Innovation and Infrastructure
SDG 11: Sustainable Cities and Communities

SDG 12: Responsible Consumption and Production
SDG 13: Climate Action
SDG 14: Life Below Water
SDG 15: Life on Land

(a) SDG 3: *Good health and well-being*

People's health is compromised by poor waste management especially for marginalised communities and vulnerable groups.

Non-degradable waste enters the food chain, potentially causing illness, disease or death. Organic waste, meanwhile, is implicated in disease, pest outbreaks and contamination of water and soils. Toxic waste is as harmful to humans and wildlife.

Health and well-being is closely linked to a good clean environment.

(b) SDG 6: *Clean water and sanitation*

Poor waste management compromises the quality of water and can affect sewage systems through blockages. The water crisis in South Africa is compounded by contamination of the limited freshwater resources and the pollution of waterbodies.

The diversion of contaminant-containing waste which have a high potential for circularity, such as e-waste, edible oils and fats, chemicals and AHPs, inter alia, into the CE, will have a dramatic positive impact on natural water quality.

(c) SDG 7: *Affordable and clean energy*

Suitable waste such as biowaste, landfill gas, AHPs could be a good source of cleaner energy as a source of a refuse derived fuel source while diverting this waste from landfill and the environment.

The value of biowaste has risen sharply as the world seeks better ways to manage the large-scale waste generation by high consumption countries and the need for alternative energy. Biowaste is defined as biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises, and comparable waste from food processing plants. Bio-organic waste has immense potential for green energy recovery. Heat and electrical energy can be generated through the fermentation of this waste. Additionally, biowaste is considered a source of sustainable energy and a good alternative to fossil fuels. There are a few biowaste energy initiatives in South Africa currently, for example Fountain Green Energy (FGE) is a landfill gas contractor in Southern Africa, specialising in anaerobic digestion, biogas to electricity and biogas upgrading for the production of biomethane and carbon dioxide.

(d) SDG 5: *Decent Work and Economic Growth*

A CE has the potential to create new income streams for generators of waste, new jobs, and new industries. In Australia, it has been estimated that the value of income streams from waste is approximately $4.5 trillion. Jobs are created in sorting, transportation, recycling into raw materials, repurposing of raw materials into goods, sales, etc.

(e) SDG 9: *Industry, Innovation and Infrastructure*

Innovation in designing-out waste, more efficient use of resources, waste management, waste treatment and promoting sustainable industries underpins sustainable development for which innovations and infrastructure is required as well as public-private partnerships.

(f) SDG 11: *Sustainable Cities and Communities*

It is estimated that the urban population increases by approximately 1.5 million people every week. This rapid urbanisation puts preassure on cities' infrastructure, environment and social fabric and well as generates large volumes of waste which severely compromises the long term sustainability of cities.

(g) SDG 12: *Responsible Consumption and Production*

Reducing and recycling of waste is integral to responsible consumption and production. This is strongly linked to how products are designed and distributed in the first place.

(h) SDG 13: *Climate Action*

Decomposing waste is a source of methane (CH_4) which is one of the chief greenhouse gases (GHG), and 25 times more efficient in trapping heat than CO_2. Reducing the volumes of biowaste disposed to landfill, will significantly reduce the methane emissions in South Africa thereby slowing down climate change.

(i) SDG 14: *Life Below Water*

At least 14 million tons of plastic end up in the ocean every year, and plastic makes up 80% of all marine debris found from surface waters to deep-sea sediments. Marine species ingest or are entangled by plastic debris, which causes severe injuries and death. Food from the ocean consumed by humans also carry risks of plastic entering the human body, which might lead to health impacts. Plastics reaching the South African marine environment are estimated to have an economic impact ranging between 0.05 to 0.5% of South Africa's annual GDP (R3.5 billion and R34.9 billion per year) [Nahman et al., 2022]. Waste recovery and recycling especially of single use plastics will have a significant positive impact on this SDG.

(j) SDG 15: *Life on Land*

There are many causes of the loss of biodiversity including pollution from the increasing volumes of waste generated and disposed by modern society. Poor waste management can harm biodiversity both directly (e.g. the consumption of plastic microbeads by marine wildlife, or death and injury caused by entanglement) and indirectly (e.g. landfill sites, which provide ideal conditions for bacteria that produce methane).

The support and creation of an ubiquitous CE with a network of enterprises involved in aspects of CE such as designing out waste, efficient use of resources, minimising waste, recycling and repurposing of waste eventually help divert waste from the environment (land, air and water) and so will directly support the SDGs.

3.3 The National Development Plan

South Africa is committed to better management of its waste, as articulated in the National Development Plan 2030 (SA Government, 2012). Aspects of the NDP relevant to the CE include:

(a) A global drive for compliance on environmental standards will drive innovation, reduce waste, improve energy efficiency and promote new investment;
(b) Consumer awareness initiatives and sufficient recycling infrastructure should result in South Africa becoming a zero-waste society;
(c) Investment in consumer awareness, green product design, recycling infrastructure and waste-to-energy projects results in significant strides to becoming a zero-waste society.
(d) Rapid expansion of recycling infrastructure, and encouraging the composting of organic domestic waste to bolster economic activity in poor urban communities. (As per the National Waste Management Strategy)
(e) Waste makes up 2 percent of emissions, and South Africa will cut down on solid-waste disposal, promote composting and recycling of organic waste, and run a countrywide programme to capture land-fill methane gas.
(f) Introduce measures such as stepped tariffs and targeted penalties that would reduce the demand for electricity and water, cut water leakages, eliminate waste going to landfill, and generally discourage high-consumption lifestyles.

The NDP also sets an objective for South Africa to move towards absolute reductions in the total volume of waste disposed to landfill each year. (Chapter 5: Environmental Sustainability and Resilience).

3.4 Planned circular economy events in 2023 and 2424

The following are some of the known events that will be taking place in South Africa over the 2023/24 period. These would be useful to attend in order to get a better understanding of the CE opportunities in South Africa as well as to network with some of the key stakeholders.

Additionally, Circular South Africa is currently being developed. CSA's mission is to facilitate cooperation, coordination and networking between businesses, government, knowledge institutions and civil society organisations involved in the CE to accelerate the just CE transition in South Africa. CSA is the first CE platform for South Africa and is hosting events, sharing knowledge, building partnership to break silos in the country and accelerate the transition. A website is currently being developed, however events and news around the CE for South Africa is shared through LinkedIn. CSA is implemented by the African CE Network (CAN) and funded by Netherlands Enterprise Agency.

CIRCULAR SOUTH AFRICA
Accelerating the Transition

Events Overview

National Eco Industrial Park Day
Date: 10 October 2023
Venue: CSIR ICC, Tshwane (Pretoria)

Science, Technology & Innovation for a CE under which Circular Innovation South Africa falls - CE Demonstration Fund
Host: CSIR and funded by the Department of Science and Innovation

Africa's Conscious Brands & CE Summit
Date: 14 to 15 November 2023
Time: 09h00
Venue: CSIR ICC, Tshwane (Pretoria)

Addressing the skills Deficit in the SA Energy Sector
Date: 24 November 2023
Time: 09h00
Venue: The Ridge, 6 Marina Road Portswood District, V&A Waterfront, Cape Town

SADC Private Sector Trade Facilitation & AfCFTA Virtual Workshop on Trade Remedies
20 September 2023
Time: 10h00
Venue: Virtual

International Association of Hydrogeologists (IAH) Congress 2023
Date: 24 Sep 2023
Vene: CTICC, Cape Town, South Africa

The Annual Oppenheimer Research Conference 2023
Date: 06 Oct 2023
Venue:Nicky Oppenheimer Cricket Ground, Midrand, Jhb, South Africa

Shaping the Future Global Conference 2023
Date: 06 Oct 2023
Venue: George, Western Cape, South Africa

The IWA Non-Sewered Sanitation 2023
Date: 18 Oct 2023
Venue: Emperors Palace, Kempton Park, Jhb, South Africa

International Conference on Civil and Environmental Engineering 2023
Date: 26 Oct 2023
Venue: Emperors Palace, The Palace Of Dreams, Kempton Park, Jhb, South Africa

Green Building Convention
Date: 17 November 2023
Venue: Century City Conference Centre, Cape Town, South Africa

International Conference on Chemical, Biological and Environmental Engineering
Date: 17 Nov 2023
Venue: Johannesburg, South Africa

International Water Association Specialist Conference on Natural Organic Matter and the IWA Particle Separation Conference 2023
Date: 3 – 8 December 2023
Venue: Boksburg, Jhb, South Africa

Regional Workshop to Promote the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
Date: 15 December 2023
Venue: Pretoria, South Africa

Ocean Innovation Africa
Date: 22 Feb 2024
Venue: Avenue Conference and Event Venue, Cape Town, South Africa

South Africa CE Hotspot 2024
Date: June 2024
Host: The African CE Network (ACEN)
Venue: TBC, Cape Town

SOUTH AFRICA
CIRCULAR ECONOMY
HOTSPOT 2024

Waste to Wealth Solutions for a Sustainable Future
Date: 15-18 September 2024
Host: ISWA

3.5 Policy landscape for waste management

All legislation, policies and government documents related to the environment for South Africa can be retrieved from the database of the Centre for Environmental Rights. The management of waste in South Africa falls within the mandate of the Department of Forestry, Fisheries and Environment (DFFE). This mandate is derived from Section 24 (Environment) of the Constitution of the Republic of South Africa (Act 108 of 1996) which states that:

"Everyone has the right –

(a) to an environment that is not harmful to their health or well-being; and

(b) to have the environment protected, for the benefit of present and future generations,

through reasonable legislative and other measures that –

(i) prevent pollution and other degradation;

(ii) promote conservation; and

(iii) secure ecologically sustainable development and use of natural resources while,

(iv) promoting justifiable economic and social development."

To give effect to this mandate, the DFFE has developed and promulgated policies, legislation, strategies and programmes. The guiding overarching legislation is the National Environmental Management Key (Act 107 of 1989) under which the National Environmental Management: Waste Act 59, 2008 ("the Waste Act") and the National Waste Management Strategy (NWMS) falls. The NWMS, which is reviewed every 5 years, is a statutory requirement of the Waste Act. The current NWMS was developed in 2020 and its implementation will run until 2025.

The NWMS 2020 provides a coherent framework and strategy for the implementation of the Waste Act and outlines government's policy and strategic approach to waste management within the South African government's context and agenda of socio-economic development that is "equitable, inclusive, sustainable and environmentally sound"[1].

The following clauses extracted from the relevant Acts have a bearing on the CE in SA:

(i) *Principle 4 (a) (iv) of the National Environmental Management Act* (Act 107 of 1989), states: "that waste is avoided, or where it cannot be altogether avoided, minimised and re-used or recycled where possible and otherwise disposed of in a responsible manner".

(ii) *National Environmental Management: Waste Act, Act No. 59 of 2008*
Government Gazette No 278, 10 March 2009

The DFFE manages hazardous waste in South Africa through the National Environmental Management Waste Act. The Act provides protection for public health and the environment by providing measures for:

(a) Minimising the consumption of natural resources
(b) Avoiding and minimising the generation of waste
(c) Reducing, reusing, recycling, and recovering waste
(d) Treating and safely disposing of waste as a last resort

[1] DEFF Budget Policy Statement 2019/20, Minister Barbara Creecy, July 2019.

(e) Preventing pollution and ecological degradation
(f) Remediating land where contamination exits
(g) Securing ecologically sustainable development while promoting justifiable economic and social development.

S16. (1) A holder of waste must, within the holder's power, take all reasonable measures to:

(a) avoid the generation of waste and where such generation cannot be avoided, to minimise the toxicity and amounts of waste that are generated.
(b) reduce, re-use, recycle and recover waste.
(c) where waste must be disposed of, ensure that the waste is treated and disposed of in an environmentally sound manner.
(d) manage the waste in such a manner that it does not endanger health or the environment or cause a nuisance through noise, odour, or visual impacts.
(e) prevent any employee or any person under his or her supervision from contravening this Act; and
(f) prevent the waste from being used for an unauthorised purpose.

S21: General requirements for storage of waste

Any person who stores waste must at least take steps, unless otherwise provided by this Act, to ensure that:

(a) the containers in which any waste is stored, are intact and not corroded or in any other way rendered unfit for the safe storage of waste.
(b) adequate measures are taken to prevent accidental spillage or leaking.
(c) the waste cannot be blown away.
(d) nuisances such as odour, visual impacts and breeding of vectors do not arise.
(e) pollution of the environment and harm to health are prevented.
(c) International Conventions, such as the 1989 Basel Convention on the control of Trans boundary movements of hazardous wastes and other disposal, 1987 Montreal Protocol on substances that deplete the ozone layer and the 2004 Stockholm Convention on Persistent Organic Pollutants.

iii. *Waste Classification and Management Regulations,* Government Notice No. R. 634, 23 August 2013

The WC&MR aim to regulate the classification and management of waste in a manner which supports the implementation of the provisions of the Act. The Regulations:

(a) Prescribe the general duties of waste generators, transporters, and managers
(b) Prescribe the requirements for disposal of waste to landfill

(c) Provide a mechanism for the listing of waste management activities that do not require a waste management licence
(d) Prescribe timeframes for the management of certain wastes

iv. *Environment Conservation Act (Act 73 Of 1989) (ECA)*

Section 19: Prohibition of littering

(1) No person shall discard, dump, or leave any litter on any land or water surface, street, road, or site in or on any place to which the public has access, except in a container or at a place which has been specially indicated, provided, or set apart for such purpose.

(2) Every person or authority in control of or responsible for the maintenance of any place to which the public has access shall always ensure that containers or places are provided which will normally be adequate and suitable for the discarding of litter by the public.

Section 20: Waste management

(1) No person shall establish, provide, or operate any disposal site without a permit issued by the DFFE.

v. *List of Waste Management Activities that have or are likely to have a detrimental effect on the Environment.* Government Notice No. 921, 29 November 2013

In terms of Part 4, section 19 of the Act the Minister may publish a list of waste management activities that indicates whether a Waste Management Licence (WML) is required to conduct the activity or, if a WML is not required, the requirements or standards that must be adhered to when conducting the activity. The list prescribes those activities that require a basic assessment process (Category A), those that require a scoping and environmental impact process (Category B) and those that must comply with the established Norms and Standards relevant to the undertaking of such activities (Category C).

vi. *National Norms and Standards for Assessment of Waste for Landfill Disposal*, Government Notice No. R. 635, 23 August 2013

The Norms and Standards prescribe:

(a) the standard assessment methodology.
(b) total and leachable concentration analysis and limits; and
(c) waste types for landfill disposal.

vii. *National Norms and Standards for Disposal of Waste to Landfill*, Government Notice No. R. 636, 23 August 2013

The Norms and Standards prescribe:

(a) the landfill classification and containment barrier design.
(b) waste acceptance criteria for disposal to landfill; and
(c) waste disposal restrictions.

viii. *National Norms and Standards for Storage of Waste*, Government Notice No. 926, 29 November 2013

The Norms and Standards provide:

(a) a uniform approach to the management of waste storage facilities; and
(b) a minimum standard for the design and operation of new and existing waste storage facilities.

ix. *National Norms and Standards for the Remediation of Contaminated Land and Soil Quality*, Government Notice No. 331, 2 May 2014

The Norms and Standards provide:

(a) a national approach to determine the contamination status of an investigation area; and minimum standards for assessing necessary environmental protection measures for remediation activities.

x. *National Standards for Scrapping or Recovery of Motor Vehicles*, Government Notice No. 925, 29 November 2013

The National Standards provide:
(a) the minimum requirements for the design, construction or upgrading of a vehicle scrapping or recovery facility.

xi. *National Waste Management Strategy (2020) (NWMS)*

The National Waste Management Strategy, 2020 (NWMS) was published in terms of section 6 of the National Environmental Management: Waste Act 59 of 2008 ("NEMWA") which is a revision and update of the 2011 NWMS. The strategy aims to provide a framework for government policy and strategic interventions for the waste sector. The NWMS is designed to respond to SDGs and the NDP.

The key issue in the 2020 NWMS is a focus on the “CE” aiming to reduce environmental impacts by re-use and recycling of processed materials. This strategy is based on three strategic pillars, viz:

(a) waste minimisation
(b) effective and sustainable waste services
(c) compliance, enforcement, and awareness.

In addition, the strategy includes key interventions such as institutional arrangements, norms and standards, specific measures for problem areas, licensing, remediation, the national waste information system, compliance, enforcement, and stakeholder engagement.

xii. *The South African Economic Reconstruction and Recovery Plan*

This plan aims to build a new economy and unleash South Africa’s true potential. The overarching goal of the plan is to create sustainable, resilient, and inclusive economy. It will focus on the following priority areas:

(a) Energy security
(b) Industrial base to create jobs
(c) Mass public employment programme
(d) Infrastructure development
(e) Macro-economic interventions
(f) Green economy
(g) Food security
(h) Reviving the tourism sector.

The following sections are applicable to the CE and waste:

Section 3.6 Green Economy interventions identifies the following high impact priority areas, inter alia:

(a) Waste picker integration and revitalisation of buy-back centres
(b) Section 18 Industry Waste Management Plans

Section 3.7 Mass Public Employment Interventions calls for a campaign, “War on Waste” to build the CE.

xiii. *Industrial Policy Action Plan IPAP 2018/19-2020/21*

The Industrial Policy Action Plan (IPAP2) is a radical shift to grow a developmental economy by taking a deliberate decision to ensure that investment targets production sectors of the economy to arrest the decline in manufacturing and accelerate employment creation.

Aspects of this Plan that is relevant to waste circularity include:

(a) Radical economic transformation calls for less waste intensive growth path across all sectors of the economy

(b) the translational programmes and associated infrastructure will focus on establishing a nexus initiative as a national strategic decision-support capability designed to address issues relating to the interaction between the natural environment and industrial development activities. (Addressing competing demands for natural resources such as water, waste and energy)

xiv. *Operation Phakisa - Chemicals and Waste Economy*

The Chemicals and Waste Economy (CWE) Phakisa[2] focuses on four waste streams namely, municipal waste, bulk industrial waste, product design and waste minimisation and chemicals with the following key aspirations:

(a) Reduce the negative environmental and health impact of waste and risks posed by chemicals;

(b) Increase commercialization of the CE and create value from resources currently discarded as waste;

(c) Foster inclusive growth through positioning of South Africa as a globally competitive producer of sustainable products.

The key objectives are

(a) Grow the secondary resources economy by increasing local utilization and beneficiation of waste resources by 50%-75% through creation of an enabling regulatory environment

(b) Generation of opportunities from chemical and waste resources for the creation of jobs/opportunities in new / existing markets specifically through enabling SMMEs

(c) Invest in Research, Development and Innovation (RDI) (including Intellectual Property (IP)) and infrastructure to enhance the utilization of local waste resources for new products, substances and services that will create jobs, and enhance the production of environmentally friendly chemicals

[2] "Phakisa" means "hurry up" in Sesotho and the application of this methodology highlights government's urgency to deliver. It plays a crucial role in accelerating the delivery of some of the development priorities, such as the CE and waste management.

(d) Reduce waste to landfill by 75% of industrial waste and 50% of municipal waste through education and awareness, compliant society, application of cleaner production

xv. *National Pricing Strategy for Waste Management (NPSWM), Section 13A read with Sections 72 and 73 of the National Environmental Management: Waste Act, 2008 as amended*

Economic instruments to specific waste streams to serve as incentives or disincentives to encourage a change in behaviour towards the generation of waste and waste management by all sectors of society are contained in NEMWA. The NPSWM is a legislative requirement and gives effect to the NWMS 2020.

The NPSWM provides details of waste management charges, and the review of these waste management charges from time to time. Section 13B(c) includes procedures for collection of charges through the national fiscal system. Additionally, this strategy contains guiding methodologies for the setting of waste management charges, aimed at funding the re-use, recycling or recovery of waste and for the implementation of industry waste management plans for those activities that generate specific waste streams.

xvi. *White Paper on Science, Technology, and Innovation (STI)*

The core vision of the White Paper on Science, Technology, and Innovation is the conceptualisation of a National System of Innovation (NSI) which seeks to harness the diverse aspects of science and technology through the various institutions where they are developed, practised, or utilised.

Chapter 2: *Looking To The Future*,
2.2 *Implications of the drivers of change for science, technology and innovation in South Africa*,
Section 2.2.12 *Adopting a circular-economy approach*,

States that the idea of a CE is "linked to the SDGs, as a source of new growth across the globe. The concept implies systemic change and a shift to a low- or zero-waste, resource-efficient society, and entails major changes to methods of production and consumption. Beyond the potential to reduce the use of materials and leave a smaller footprint on the environment, a CE would create economic opportunities as new services and business models emerge, transforming the relationship between producer and consumer, and products and their users. Support for the CE would further imply that the environmental impacts of technological developments are understood and taken into consideration in decisions around support for these developments.

The environmental footprint of Science, Technology & Innovation (STI)-based products and services is also increasingly a factor in consumers' spending decisions. Support for the transition to a CE in addition to addressing the SDGs will place the country on a development pathway that avoids getting locked-in to resource-intensive industries and practices. This is especially important to balance increased mining efforts with a transition to a more CE in the next 20 years. A stronger evidence base is required to understand the opportunities that this transition will yield for increased industrialisation."

xvii. *Industry Waste Tyre Management Plan*

In 2012, South Africa introduced the Recycling and Economic Development Initiative of South Africa (REDISA) and the Integrated Industry Waste Tyre Management Plan (IIWTMP). The Plan seeks to manage and reprocess waste tyres, bringing about environmental sustainability and economic prosperity, simultaneously creating jobs.

xviii *Plastic Industry 2020 Master Plan for Growth*

In 2019, the plastics sector developed the *Plastic Industry 2020 Master Plan for Growth* with the following key objectives:

(a) Reduce the trade deficit to less than 10% of the total value of the industry by 2035.
(b) Maintain or improve the tons per employee which equates to 30 tons per formal job in 2018.
(c) Reduce the visible amount of plastics litter in the environment and to increase recycling rates to 60%.

xix Extended Producer Responsibility

Mandatory Extended Producer Responsibility (EPR) came into effect in South Africa on 5 May 2021 under Section 18 of the National Environmental Management Waste Act (NEMWA). Currently, however, the EPR is only applicable product packaging including plastic, metal and paper board.

Producers of packaged goods are now responsible not only for health and safety issues associated with their products, but also for the management of their post-consumer packaging waste, including collection, sorting, take-back and/or recycling.

Essentially, this means that the Producer must ensure that the products they place on the market do not negatively affect the environment after consumers are done with them and must ensure that appropriate post-use treatment is available. This includes taking physical or financial accountability for the products. These policy objectives include changes for both upstream (e.g. Design for Recycling) and downstream (e.g. plans for increased collection and higher overall rates of recycling).

xx. Other documents/initiatives that have relevance to waste circularity

Other initiatives or documents that are of relevance in CE, depending on waste of interest, include:

(a) South African Retail Clothing, Textiles, Footwear and Leather (R-CTFL) Value Chain Master Plan to 2030;
(b) The South African Sugarcane Value Chain Master Plan to 2030;
(c) South African Automotive Masterplan 2035;
(d) Municipal Integrated Waste Management Plans (IWMP);
(e) SA Nationally Determined Contributions (NDCs);
(f) State of Waste Report (SoWR); and
(f) South African Plastics Pact.

3.6 Challenges with current legislation and recommendations

South Africa arguably has some of the best environmental (and waste) regulations in the world, which rival the regulations of even some first world countries. The regulations also support and promote waste circularity as an integral aspect of waste management.

However, implementation of the regulations, policing of possible transgressions and convictions are lacking due to lack of prioritisation of waste, limited resources on the ground and poor co-ordination between the relevant authorities.

Furthermore, there are sectors of the economy, such as private business, that view South Africa has been over regulated. For example, the low thresholds and onerous requirements of an environmental impact assessment (EIA) relating to waste storage and treatment, or the operations of a waste to energy (WtE) plant, is regarded as a stumbling block to fast-track CE projects. On the other hand, certain categories of potentially hazardous waste, such as AHPs, C&DW (especially packaging with residue paints and solvents), inter alia, are disposed as general waste instead of re-categorising these waste streams to force separation at source which increases the chances of these waste streams being recycled.

Private operators in the waste sector, often cite that South Africa does not need more regulation over waste but that the current legislation should be implemented and stream-lined to encourage and fast-track better waste management and circularity. With regards to some of the problematic waste streams identified above inclusion of these waste streams in existing S@S programmes, EPR policies, RDI programmes (e.g. in the Waste RDI Roadmap), Industrial Symbiosis (IS) and business support programmes, would support the CE.

The following policy challenges are highlighted, and recommendations are proposed by the Consultant for waste streams with a high potential for circularity:

Table 3.1: CE policy challenges and recommendations.

Waste Stream	Policy challenges/requirements	Recommendations
Organic waste (abattoir, FTPP, WtE)	Lack of national strategy for organic waste. Waste crosscuts across several legislations: NEMA, NEMWA, Electricity, Energy, Provincial Financial Management Act (PFMA), Municipal Financial Management Act (MFMA), Forestry. National waste collection standards need amendment. Lack of competitive tariffs for green energy (NERSA, DOE, Eskom) Power wheeling regulations	Economic incentives for CE projects such as WtE, bio-refineries, value-adding businesses, RDI. Develop norms and standards for anaerobic digesters (AD), blood collection and processing. Decrease policy hurdles to encourage wheeling of power to meet electricity demands
C&DW	Lack of norms and standards to ensure consistent quality of C&DW-derived raw materials. Lack of co-ordination between DFFE, Human Settlements, Roads Depts. to co-ordinate effective "green procurement". Waste classification of C&DW - made up of many different waste streams, some hazardous.	Develop EPR policy for C&DW. Introduce tax rebates for green infrastructure projects. Develop Building and Road Construction Policy that incorporates C&DW. Include the use of C&DW in public infrastructure projects such as low-cost housing, roads, stormwater management, dollosse, erosion protection systems, etc. Incentivise recovery of re-usable building components.
E-Waste	No coordinated national plan that guides the e-waste sector. No provision in the Industry Waste Management Plan (IWMA) to approve an e-waste plan. Slow EIA turnaround Differing/no legislated standards and codes of practice.	Amend the IWMA to include e-waste as a Priority Waste Stream while not over-regulating the collection and processing. Include e-waste in EPR policy. National e-waste management plan. Fast track EIAs for e-waste circular projects. Define standards and norms for e-waste recyclers.

Waste Stream	Policy challenges/requirements	Recommendations
	Bureaucracy involved in certification of e-waste as hazardous waste	
AHP	Not classified as hazardous waste even though they carry potential pathogens and diseases. Not included in the EPR policy. No policy for S@S, collection, and treatment.	Classify AHP as hazardous waste, requiring S@S, separate collection and treatment or disposal. Include AHP in EPR policy for plastics. Incentives for RDI into bio-degradable AHP.
Leather waste	Not classified as hazardous waste even though they contain dangerous chemicals. Not included in the EPR policy. No policy for S@S, collection, and treatment.	Develop EPR policy for leather. Classify leather as hazardous or as waste that requires separate collection and disposal. Incentives for RDI in green leather (DSI). Incentives that support SMME enterprises that use leather waste (dtic)
Tyres	Slow turnaround of EIAs. Waste licence applications very bureaucratic. Lack of enforcement i.t.o disposal. Conflicting legislation. Lack of communication and co-ordination in the regions.	Legislate and enforce plans for waste tyre collection and processing. Encourage private sector participation in collection, processing and using waste tyres. Support (via the dtic) businesses that add value to tyre waste. Support RDI in waste tyre repurposing.
Fly ash	Lack of norms and standards. Existing policy on fly ash disposal not relevant to processing of fly ash. Red tape w.r.t licence application.	Develop norms and standards for use of fly ash in construction. Review legislation to be more applicable and effective to processing of fly ash. Ease access to fly ash. Introduce incentives for use of fly ash in construction projects. Set national goals and targets.

4. Profile of South Africa's waste economy

4.1 The National Waste Management Strategy 2020

The concept of the CE is at the core of the National Waste Management Strategy of 2020 (NWMS 2020). The CE is seen as a strategic approach to minimising the environmental impact of economic activity by reusing and recycling processed materials to minimise:

(a) the need to extract raw materials from the environment; and
(b) the need to dispose of waste.

The CE is built on innovation and the adoption of new approaches and techniques in product design, production, packaging and use. Industrial symbiosis, for instance, is a way of preventing waste in industrial production by redirecting waste from one production process to serve as raw materials for another production process.

The NWMS 2020 strategy has three (3) pillars, namely:

Pillar 1 : Waste minimisation
Pillar 2 : Effective and sustainable waste services
Pillar 3 : Compliance, enforcement and awareness

with the following predicted outcomes:

- Zero waste in landfills;
- Cleaner communities,
- Well managed and financially stable waste services, and
- A culture of zero tolerance of pollution, litter and illegal dumping.

4.2 NWMS 2020 Targets and Outcomes

The proposed Dutch-South Africa CE initiative will support the following targeted outcomes of the NWMS 2020:

- Prevent waste, and where waste cannot be prevented ensure that,
    - 40% of waste is diverted from landfill within 5 years;
    - 55% within 10 years; and
    - At least 70% within 15 years leading to Zero-Waste going to landfill;
- All South Africans live in clean communities with waste services that are well managed and financially sustainable; and
- Mainstreaming of waste awareness and a culture of compliance resulting in zero tolerance of pollution, litter and illegal dumping.

4.3 Contribution to general waste by province

South Africa is made up of nine provinces, with Gauteng (where Johannesburg and Pretoria are located) being the financial and economic centre of the country, followed by the Western Cape (where Cape Town is located) and KwaZulu-Natal, based on Gross Domestic Product generated.

The Figure below presents a breakdown of the contribution of each of the nine provinces to generation of municipal solid waste in South Africa. It can be seen that Gauteng is responsible for the largest contribution (26.3%), followed by KwaZulu-Natal (17.9%), Western Cape (14.7%), Eastern Cape (10.5%), Free State (10.5%), Limpopo (8.4%), North West (6.3%), Mpumalanga (4.2%), and Northern Cape (1.1%).

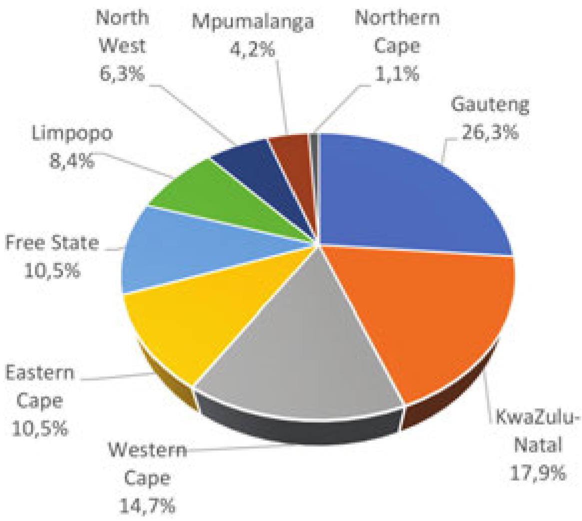

Figure 4.1: Provincial contribution to General Waste [SoWR, 2018].

4.4 Potential waste resources available for circularity

In 2017, South Africa generated 55 million tonnes of General Waste (GW), with only 11% being diverted from landfill [SoWR, 2018]. This figure is expected to exceed 75 million tons per annum in 2023, based on an annual escalation of 6%. It was also estimated that on average, 34.5% of general waste was recycled in 2017 [SoWR, 2018].

Table 4.1: Make-up of General Waste (GW) [State of Waste Report, 2018 [SAWIC, 2017].

Ref	Type	Local generation	Imports	% Waste	Export	Total tonnage	Storage/ Stockpile	Recycling/ Recovery	Resource Available
GW20	Organic	19,247,851	4,048	34.6%	298	19,252,197	0.0%	49.2%	**50.8%**
GW15	Bottom ash	6,489,080		11.7%		6,489,080	0.0%	3.1%	**96.9%**
GW16	Slag	4,859,025		8.7%		4,859,025	0.0%	0.0%	**100.0%**
GW01	Municipal	4,821,430		8.7%		4,821,430	0.0%	0.0%	**100.0%**
GW53	Metals	4,035,929	24,168	7.3%	527,037	4,587,134	0.0%	80.0%	20.0%

Ref	Type	Local generation	Imports	% Waste	Export	Total tonnage	Storage/ Stockpile	Recycling/ Recovery	Resource Available
GW30	C&D	4,482,992		8.1%		4,482,992	0.0%	52.0%	**48.0%**
GW14	Flyash+dust	4,346,080		7.8%		4,346,080	0.0%	3.1%	**96.9%**
GW52	Glass	2,752,636	38,378	4.9%	11	2,791,025	0.0%	71.2%	28.8%
GW50	Paper	2,211,225	57,855	4.0%	129,374	2,398,454	0.0%	58.0%	**42.0%**
GW51	Plastic	1,113,362	6,748	2.0%	20,856	1,140,966	0.0%	43.7%	**56.3%**
GW99	Other	729,615		1.3%		729,615	0.0%	9.0%	**91.0%**
GW10	Com & ind	360,884		0.6%		360,884	0.0%	0.0%	**100.0%**
GW54	Tyres	174,640		0.3%	12,473	187,113	76.4%	23.6%	**76.4%**
	Total	**55,624,749**	**131,197**	**100.0%**	**690,049**	**56,445,995**			

Wood waste accounts for the majority of organic waste generated (65%), and a significant proportion of general waste managed (21.1%). Given that the majority of wood waste is already being reused, recycled and recovered, this waste stream, despite the large amount of waste generated, cannot be considered to be a problematic waste stream. There are currently a number of research projects looking at potential uses of this waste stream, however based on our understanding of this waste stream, these opportunities may be limited as much of the waste stream is already being used or committed.

There is however still an opportunity to divert approximately 6.5 million tonnes of garden and food waste from disposal to landfill, which accounts for approximately 11.1% of general waste or 5.9% of total waste managed. There are a number of potential uses for this waste, including composting and vermiculture, waste to energy (e.g. biogas), livestock feed, and pharmaceuticals. In addition to prolonging the lifespan of waste disposal facilities, the diversion of garden and food waste also reduces the production of leachate and landfill gas [SoWR, 2018].

Following from the above table, the following annual tonnage of available resources could be estimated:

Table 4.2: Available Annual Waste Resources (Tons) [SAWIC, 2017].

Ref	Type	Tons/annum
GW20	Organic	6,500,000
GW15	Bottom ash	6,287,919
GW16	Slag	4,859,025
GW01	Municipal	4,821,430
GW53	Metals	807,186
GW30	Constr & Demol	2,151,836
GW14	Flyash and dust	4,211,352
GW52	Glass	792,759
GW50	Paper	928,715

Ref	Type	Tons/annum
GW51	Plastic	626,823
GW99	Other	663,950
GW10	Commerce & industrial	360,884
GW54	Tyres	133,425

While most of the above resources are available across South Africa and specifically in the large metropolitan areas, industrial waste such as fly ash, is mostly located in the Mpumalanga Province, where the national power utility operates coal-fired power stations. Furthermore, this resource has been stockpiling for over 50 years.

Slaughterhouse waste is also mostly disposed on site and circular initiatives for this waste should target the large slaughterhouse operators.

Table 4.3: Makeup of Hazardous Waste (HW) and availability; POP - persistent organic pollutants; WEEE – Waste of Electrical and Electronic Equipment; HCRW – health care risk waste [SAWIC, 2017].

Ref	Type	Local production	% Waste	Imports	Export	Total tonnage generated	Recycling /Recovery	Resource Available
HW 01	Gaseous waste	6	0.00%	0	0	6	0.00%	100.00%
HW 02	Mercury containing waste	1,392	0.00%	0	0	1,392	4.00%	96.00%
HW 03	Batteries	39,867	0.08%	30750	36223	34,394	90.00%	0.00%
HW 04	POP waste	570	0.00%	0	0	570	0.00%	100.00%
HW 05	Inorganic waste	786,083	1.51%	0	13333	772,750	0.00%	99.40%
HW 06	Asbestos containing waste	6,721	0.01%	5280	0	12,001	0.00%	100.00%
HW 07	Waste oils	116,250	0.22%	76450	0	192,700	80.00%	0.00%
HW 08	Organic halogenated and/or sulphur containing solvents	663	0.00%	0	0	663	19.90%	73.90%
HW 09	Organic halogenated and/or sulphur containing waste	8,812	0.02%	0	0	8,812	0.00%	95.60%
HW 10	Organic waste without halogens or sulphur	4,562	0.01%	0	0	4,562	42.10%	52.40%
HW 11	Other organic waste without	812,963	1.56%	47367	0	860,330	26.00%	74.00%

Ref	Type	Local production	% Waste	Imports	Export	Total tonnage generated	Recycling /Recovery	Resource Available
	halogens or sulphur							
HW 12	Tarry & bituminous waste	249,080	0.48%	0	0	249,080	0.00%	100.00%
HW 13	Brine	5,793,645	11.13%	0	0	5,793,645	0.00%	100.00%
HW 14	Fly ash and dust	33,290,115	63.93%	0	5000	33,285,115	7.00%	93.00%
HW 15	Bottom ash	5,874,726	11.28%	50	0	5,874,776	7.00%	93.00%
HW 16	Slag	2,923,640	5.61%	1750	0	2,925,390	7.00%	93.00%
HW 17	Mineral waste	832,059	1.60%	0	0	832,059	0.10%	99.50%
HW 18	WEEE	360,000	0.69%	2124	598	361,526	9.70%	90.30%
HW 19	HCRW	48,749	0.09%	0	0	48,749	0.00%	0.00%
HW 20	Sewage sludge	632,749	1.22%	0	0	632,749	15.00%	85.00%
HW 99	Miscellaneous	294,064	0.56%	4821	3423	295,462	0.90%	97.60%
	TOTAL	**52,076,716**	**100.00%**			**52,186,731**		

4.5 Mapping of stakeholders in the CE and waste

A number of stakeholders are actively involved and influence policy and operations of the CE and waste industry. The table below lists some of the key stakeholders and their role and responsibilities in the CE and waste industry. Depending on the business need, one or more of these stakeholders would need to be consulted when planning any business venture in South Africa.

Table 4.4: Stakeholder roles and responsibilities.

Stakeholder	Role & Responsibility
Department of Forestry, Fisheries and Environment (DFFE)	DFFE has the overall responsibility for ensuring compliance of the National Environmental Management Act, the implementation of the Waste Act and the NWMS
Department of Trade, Industry and Competition (dtic) and the National Cleaner Production Centre of South Africa (NCPC – SA)	The dtic and the NCPC-SA promote waste minimisation and the CE through cleaner production and industrial symbiosis. They also have an interest in industries associated with a secondary economy around waste, such as the recycling industry./
dtic, South African Bureau of Standards (SABS) and the National Consumer Commission (NCC)	The dtic, SABS and the NCC sets standards, provide guidance on labelling and conduct consumer awareness of products.
Department of Science and Innovation (DSI) Council for Scientific and Industrial Research (CSIR)	The DSI, the CSIR and Technology and Innovation Agency (TIA) develop and implement the Waste Research, Development and Innovation Roadmap (Waste RDI Roadmap). The Waste RDI Roadmap (overseen by the

Stakeholder	Role & Responsibility
Technology Innovation Agency (TIA)	CSIR) has a critical role to play in building technical capacity within the waste sector and undertaking research to support development and innovation in the Waste Sector.
The Department of Minerals Resources and Energy (DMRE),	The DMRE is responsible for the regulation of Waste to Energy (WtE) projects as they pertain to energy generation.
Department of Agriculture, Land Reform and Rural Development (DALRRD)	The DALRRD is responsible for regulation of agriculture and partners with the DFFE in the development and implementation of a strategy to reduce food losses and manage agricultural waste.
Department of Health (DOH)	The DoH is responsible for regulations around the food safety that potentially affect handling of food as a waste prevention measure, as well as regulations around Health Care Risk Waste and Absorbent Hygiene Products (e.g. diapers). DOH also oversees Environmental Health Practitioners, together with the HPCSA (Health Professional Council of South Africa), many of whom are also designated EMIs (Environmental Management Inspectors) at local authority level.
Department of Water and Sanitation (DWS)	The DWS, has regulatory responsibilities and an interest in domestic wastes, contaminated lands, and landfills to the extent that they potentially impact on water quality
Department of Basic Education (DBE)	The DBE plays raises awareness around waste and recycling in schools through the school curriculum, and is responsible for standards around school buildings and the National School Nutrition Programme with which there are important synergies in relation to projects involving the use of biogas digesters in schools to process organic waste and generate biogas and fertiliser, which can be used to cook school meals and as fertiliser in school food gardens
Department of Transport (DOT)	The DoT is responsible for regulating the transportation of goods and services and tracking and tracing transboundary waste including maritime waste (waste from airborne cargo and maritime cargo and dumping at sea).
Department of Home Affairs (DHA) South African Revenue Services (SARS)	The DHA and SARS Customs Unit monitor ports of entry and movement of waste into and out of South Africa
South African Police Service (SAPS) and National Prosecuting Authority (NPA)	The SAPS and NPA have responsibilities in relation to supporting the investigation and prosecution of the Waste Act and they work closely with the compliance monitoring and enforcement arm of the DFFE
Academic research programmes [including South African Research	Research, development and innovation will be conducted by academia and research institutions

Stakeholder	Role & Responsibility
Chairs [SARChi] in CE and waste at the University of KwaZulu-Natal (UKZN), CSIR Bio Refinery Development Unit and the University of Western Cape (UWC)	Courses offered in Waste Management: Masters in Environmental Management: Specialization Waste Management (University of the North West) MSc. Eng. Waste Management (University of KwaZulu-Natal)
Department of Planning, Monitoring and Evaluation (DPME)	The DPME is responsible for government wide monitoring and evaluation of national outcomes in line with the National Development Plan 2030. DFFE works with DPME to mainstream the NWMS 2020 targets and monitor and evaluate on a regular basis.
	DPME also oversees the implementation of the Operation Phakisa, which includes the Chemicals and Waste Economy (CWE) Phakisa (see below). The CWE Phakisa provides detailed plans for both local and national interventions around waste management, particularly in relation to industrial and municipal wastes, that align with the goals of the NWMS
Chemicals and Waste Economy (CWE) Phakisa Unit of the DFFE	The DFFE through CWE Phakisa are constantly seeking new and improved technologies to meet the objectives of the Department's NWMS. Through engagements with private sector, various government departments, waste specialists as well as tertiary institutions the CWE Phakisa is currently focusing on the following, but is not limited to: o Biological Treatment (Anaerobic Digestion / Fluidised Bed Reactors); o Material Recovery Facilities and palletisation; o Composting and re-use of household biomass; o Waste-to-Energy plants; o Pyrolysis; and o Use of ash, sludge and animal matter as a soil ameliorant and input to high agricultural production land.
The Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), Norway Funding Agency [Norfund] & the Swedish Government	The CWE Phakisa collaborates with the GIZ, Norfund and the Swedish Government in specific waste technology focus areas in the different country support programmes.
National Treasury (NT) South African Revenue Services (SARS)	NT and the SARS, which fall under the mandate of the Minister of Finance, have important roles to play in implementation of the NWMS that are inherent to their function. SARS is responsible for collecting revenue from waste management levies such as Plastic Bag Levy and the Waste Tyre Levy, and NT is responsible for allocating this

Stakeholder	Role & Responsibility
	revenue to the Waste Bureau for disbursement to stakeholders and projects as per EPR Schemes, when these exists and are applying for such revenue.
Waste Bureau	The 2014 Amendment to the Waste Act provided for the establishment of the Waste Bureau as an independent juristic entity reporting to the Minister for Environment. It also gave effect to the National Pricing Strategy for Waste Management. The Waste Bureau is responsible for the support of Extended Producer Responsibility (EPR) programmes as well as providing technical support and capacity building to industry and government in relation to waste management plans.
Provincial government	In terms of the Waste Act, Provincial Members of the Executive Committee (MECs) are responsible for developing Provincial Integrated Waste Management Plans (IWMPs). Provinces also have EMIs that regulate certain aspects of the Waste Act, for example, general waste.
Local government: District (DM) and Local Municipalities (LM) South Africa has 257 metropolitan (8), district (44) and local (205) municipalities. They are mandated to provide infrastructure and services, including waste management.	Metropolitan (Metro), district and local municipalities are critical to the implementation of the NWMS as they are responsible for the planning and delivery of waste collection and disposal services and infrastructure. In relation to waste, district municipalities are primarily responsible for providing technical support to local municipalities and assisting with regional planning and coordination. Waste collection and disposal to landfill is typically undertaken by local municipalities and metros, although in some cases – particularly for metros – these services may be accomplished by subcontracting private sector waste services companies. Municipalities are also responsible for the compliance and enforcement on the Bylaws in relation to pollution and waste . They work closely with the compliance monitoring and enforcement arm of the DFFE. Every Municipality is compelled to have an Integrated Waste Management Plan (IWMP), which must be implemented and the outcomes measured.
Private (business) sector	The private sector is involved throughout the waste sector as generators of waste, providers of waste-related services, recyclers of waste and consumers of recycled materials – as well as providing an important interface to consumers.
Non Profit organisations and Industry Associations	A number of non-profit organisations and industry associations operate and or represent businesses with an interest in one or more aspects of the waste value chain, from waste

Stakeholder	Role & Responsibility
	management, recycling, CE to environmental awareness. Some of these include: • Plastics SA (PSA) • South Africa Plastics Recycling Organisation [SAPRO] • PETCO - recycling of post-consumer polyethylene terephthalate (PET). • Plastic packaging recycling [POLCO] • Electronic Waste Association of South Africa [EWASA] • Africa CE Network [ACEN] • GreenCape – Implementation of Western Cape CE initiative • SA Plastics Pact • Polyco • Organic Waste Association [ORASA] • South African Biogas Association [SABIA] • Paper Makers Association of South Africa [PAMSA]
Consumers	Consumers play a significant role in how waste is regarded and managed, including the purchasing decisions they make, reducing waste, separation at source and recycling.
Waste Pickers and associations such as SAWPA	Waste pickers perform the crucial first step in extracting recyclable and reusable materials from the waste stream and initiating their revalorisation. Recyclable Waste is often extracted from municipal waste bags placed on pavements and increasingly out of landfill – a practice which is creating safety and health risks for waste pickers. It is estimated that there are 62,000 informal waste pickers through-out South Africa. The working conditions under which many waste pickers operate do not represent decent livelihoods. While the majority of waste pickers are not organised under a Union, they are forming and joining representative organisations such as the South African Waste Pickers Association (SAWPA). Formal initiatives (business) involving the extraction of recyclates from General Waste or from landfill must take into account the implications on waste pickers and how their livelihoods could be improved.
Management consultants	A number of private consulting firms provide advisory and research services in one or more aspects in the waste value chain.

4.6 Informal waste sector

It is estimated that between 70% to 90% of all the waste recycled in SA is collected by informal waste pickers, also referred to as waste reclaimers [Godfrey and Oelofse, 2017]. While there is no official estimate of the number of waste reclaimers in South Africa, estimates range between 60 000 and 90 000 reclaimers [DFFE, 2014] while other studies quote estimates as high as 215 000 reclaimers [Godfrey and Oelofse, 2017]. These stakeholders are an important part of the South African CE. Waste reclaimers are starting to receive acknowledgements for their invaluable work in the waste management value chain, however they are still working under hazardous conditions and are not receiving fair compensation for their work. Waste picker integration guidelines for South Africa have been developed [DFFE & DSI, 2018]. The guideline's aim is to support municipalities and industry to integrate the informal sector into their activities and to improve work conditions, recognition and livelihoods overall [DFFE & DSI, 2018].

Waste reclaimers re-cover recyclable waste, such as paper, plastic, PET, HDPE, LDPE, PP, glass and metal (e.g. cold drink cans) from the municipal bags placed on pavements. Although illegal and very dangerous, there is a growing trend of waste reclaimers entering landfill sites to recover recyclables.

The informal sector is largely a "cherry-picking" system where only high-value products are collected. Pricing of these recyclables goes up and down based on supply and demand, loadshedding restrictions, geographic area, international market pricing, etc.

4.7 Organisation and division of the markets and market channels

While information on the organisation and division of the market and market channels are difficult to come by as no formal studies have been done in this area, observations from the market indicate that collected recyclables go through several routes: either through middlemen (what we call in South Africa, the "bakkie[3] brigade") or sold to a multitude of buyback centres across the country. These centres are mapped and can be viewed online. From here the material goes to primary processors and secondary processors/manufacturers according to the same map of points. While information on recycled material is relatively well established, this is not always highly accurate or verified. Organisations such as Plastics SA have a database of some 800 processors across the country, but each individual application would need to undertake its own research to obtain the relevant data for decision making.

The remainder of recyclables is collected from formal processes either through Source Separation or via formal waste management channels servicing commercial and industrial properties.

[3] Bakkie is a small pick-up truck or light delivery vehicle.

5. CE Opportunities in South Africa

Building on the recent studies by Lindon Consulting, GreenCape, CSIR and ACEN, some of CE sectors which present opportunities for B2B collaboration are listed below. Where available, specific “low-hanging fruit” are highlighted for consideration by Dutch business enterprises.

The following CE sectors, covered in this report, present interesting business opportunities for Dutch business enterprises:

a. City Cleaning and Waste Collection
b. Biomass Treatment
c. Plastic Recycling
d. Sustainable Landfilling
e. Construction And Demolition Waste
f. Water
g. Electronic Waste
h. Absorbent Hygienic Product Waste
i. Glass
j. Tyres

5.1 City cleaning and waste collection

Approximately 67.85% [StatsSA, 2023] of SA’s population lives in urban areas, either in formal dwellings or informal settlements. Of the approximately 122 million tonnes of general waste produced annually, it is estimated that 23.1 million tonnes are concentrated in municipalities or densely populated metropolitan urban areas such as Johannesburg, Tshwane (Pretoria), eThekwini (Durban) and Cape Town. The municipal solid waste is comprised of waste from residential areas, commercial, retail, institutional and industrial premises. It is estimated that paper and board make up over 28.5% (1.37 Mta) of municipal waste and food waste about 13.9% (670 thousand tons per annum) of the municipal solid waste in SA. The table below show the approximate breakdown of municipal waste in all waste categories.

Table 5.1: Breakdown of municipal waste in percent [Rao, 2016]. Tonnage from SAWIC [2018].

MW Type	%	2017 tonnage
Paper & Paperboard	28.50%	1,374,108
Food Scraps	13.90%	670,179
Yard trimmings	13.40%	646,072
Plastics	12.40%	597,857
Metals	9%	433,929
Rubber, Leather & Textiles	8.40%	405,000
Wood	6.40%	308,572
Glass	4.60%	221,786

MW Type	%	2017 tonnage
Other	3.40%	163,929
Total	**100.00%**	**4,821,430**

It should be noted that while general municipal waste has increased, paper, plastic and glass disposal to landfill sites have decreased due to increasing separation at source (S@S) and recycling initiatives in urban centres. S@S include the provision of colour-schemed refuse bags by municipalities – orange for paper and plastic and blue for garden refuse. In addition to this, there are drop-off bins for glass bottles, paper, plastic and e-waste, usually provided by private sector recyclers.

Table 5.2: Percentage of municipal solid waste generation per province in SA [SoWR, 2018].

Province	Percentage of waste produced
Gauteng	26.3%
KZN	17.9%
Western Cape	14.7%
Eastern Cape	10.5%
Free State	10.5%
Limpopo	8.4%
North-West	6.3%
Mpumalanga	4.2%
Northern Cape	1.1%

Opportunities

Apart from the opportunity to extract recyclables from municipal waste bag, opportunities also exist in the following areas:

- Supply of waste information management systems
- Integrating 4th Industrial Revolution solutions into current city cleaning programmes
- Supply of equipment, vehicles and personal protective gear
- Training and capacity development within city waste management units
- Introduction of good waste management practices and sustainability into standard operating procedures.
- Solving the rural and informal waste problem
- Training and development of informal waste pickers

Businesses wishing to participate in city cleaning and waste collection initiatives need to be aware of the following factors influencing city cleaning and waste collection operations:

(a) The need to integrate local waste pickers into their CE solutions.
(b) Compliance with municipal waste management regulations and facilities.
(c) All contracts issued by the public sector is through an open tender process.

(d) Preferential procurement criteria for black, women, youth and disabled South Africans.
(e) The current problematic outsourced waste collection services, which is characterised by inefficiencies, fraud and corruption.
(f) Difficulty in accessing recyclables once sent to landfill sites.
(g) Sporadic implementation of S@S initiatives.
(h) Lack of waste collection services in the growing number of informal settlements and rural areas, which often leads to dumping of waste in the environment.
(i) Lack of enforcement of waste regulations;

Table 5.3 lists some of the city cleaning and waste collection operators in the various provinces of South Africa.

Table 5.3: City cleaning and waste collection operators.

Province/Organisation	City
Gauteng	
Cleanplicity	Pta
Waste Management Division	Pta
DFFE	Pta
Pikitup	Jhb
Waste Wise Services	Jhb
Whole Earth Recycling	Jhb
SA Healthcare Foundation (SAHF)	Jhb
Western Cape	
CR Goodwood City Cleaning Services	CT
Kerby	CT
Waste Management Service	CT
KwaZulu-Natal	
Bargaining Council for Contract Cleaning Services Industry	Dbn
Planet Care Waste	Dbn
Cleansing and Solid Waste	Dbn
Adopt a River Eco Solutions	Dbn
CO2LOW	Dbn
CO2LOW	Dbn
BASADI SOLUTIONS	Dbn
Free State	
Waste Retrievers	Blm
Dump A Skip	Blm
Magic Skips	Blm
Solid Waste Management Services	Blm
DESTEA	Blm
Eastern Cape	

Province/Organisation	City
Waste Management Services	PE/ Nelson Mandela Bay
DNF Waste	EL
Collect-It-All	EL

Table 5.4 lists some of the landfill operators in the various provinces of South Africa

Table 5.4: List of landfill developers.

Organisation	Region	Telephone	Business Email
MACCAFERRI SOUTH AFRICA (PTY) LTD	Jhb, Gauteng	011 010 0651	info.za@maccaferri.com
LEOMAT	RBay, KZN	035 797 4611	info@leomat.net
FGE	Jhb, CT and Dbn	031 764 7914	fge@fountain.co.za
RAALEBBORG	Jhb, Gauteng	0825532833	nfo@raalebborg.co.za
SRK CONSULTING	Cape Town, W. Cape	021 659 3060	capetown@srk.co.za
SRK CONSULTING	Durban, KZN	021 659 3060 011 441 1111	durban@srk.co.za
SRK CONSULTING	SRK Johannesburg	011 441 1111	johannesburg@srk.co.za
AQUATAN	Jhb, Gauteng	011 974 5271	aqua@aquatan.com
AVERDA	Jhb, Gauteng	010 141 5722	supportsa@averda.com
GIBB	Jhb, Gauteng	011 519 4600	info@gibb.co.za
JPCE	CT, W.Cape	021 982 6570	info@jpce.co.za
THE WASTE GROUP	Pta, Gauteng	021 982 6570	marketingmanager@ wastegroup.co.za

5.2 Biomass

Agricultural-related activities such as the growing and processing of crops, result in the generation of large volumes of agricultural residue called biomass, which may be in solid, liquid, resin or slurry forms.

Biomass sources include:

- Wood and wood processing operations such as commercial forestry, wood mills, furniture making, paper and pulp mills. Resultant biomass resources include forest residue (branches, leaves, stumps, rejected poles), bark, leaves, pellets and chips, sawdust, black liquor.
- Edible crop production and processing such as vegetable spoils/rejects, maize stalks and cobs, soybean stalks and leaves, sugar cane bagasse, fibre-grass (hemp, kenaf, etc.) leaves and stalks, discarded woody plants, algae, crop and food processing residues, such as peels, seeds, etc.
- Animal by-products and manure from livestock farming and processing.

- Biogenic materials in municipal solid waste — paper, cotton, and wool products, food waste (households and dining establishments), consumer wood waste (furniture, wood offcuts, paper and packaging), to name a few.
- Human sewage

i. Forestry, timber, paper and pulp waste

One of the significant generators of biomass in SA is the forestry, timber, paper and pulp (FTPP) industry. The FTPP industry consists of commercial forest plantations, timber processing factories (poles, board, particle board, plywood, fibreboard) and the pulp and paper industry.

South Africa has approximately 500,000 hectares (1ha = 10,000 m^2) of commercial forest plantation, which yields approximately 4 million m^3 of soft round logs each year. The majority of timber waste and residues, constituting 50% of the sawlogs and pulpwood received at the mills, currently undergo little value adding and are mostly utilised for process heat or incur additional costs for disposal. [SAFCOL, 2022]

From FTPP waste, a range of raw materials could be identified such as:

- Forest residue – uneconomic log sizes and leaves
- Bark from de-barking operations
- Saw dust and off-cuts from processing
- Stored chemical with energy potential
- Organic polymers
- Fibrous cellulose
- Organic material
- Black liquor

Waste of the FTPP industry equates to approximately 2 million m^3 per annum [CSIR Biorefinery Unit, 2022]

Available resources and potential circular opportunities

Currently most forest residue (small branches, stumps, etc.) is left in the field to compost. Collection of forest residue is not economical due to the high volume - low value of the biomass and the transportation costs. One possible opportunity is in-situ shredding and bagging of wood chips.

Biomass generated at point sources, such as timber processing plants, are currently incinerated to avoid disposal costs. In this case, the biomass is used as fuel to produce heat or electricity to reduce energy costs and dependence on external energy sources. There is an emerging opportunity to produce excess electricity for sale into the power grid.

In other cases, pelleting and briquetting operations, based at the source of the resource, could produce extruded fuel pellets, compressed logs and charcoal for the consumer market.

Although the FTPP industry uses existing wood waste and residues for bioenergy, this typically involves generating internal process heat at a very low efficiency to consume the high volumes of biomass and reduce disposal costs. There is an opportunity to generate better value through the co-production of other chemical and fuel products.

Timber biomass also has a range of stored chemicals with potential for high value uses. A total of 129 chemical, thermochemical, biological, and mechanical processing pathways can be identified to generate 78 different unique products including true commodities, pseudo-commodities, fine chemicals and specialty chemicals [CSIR, 2022]. Some of the CE opportunities in the FTPP industry are shown in the Table 5.5 below.

Table 5.5: FTPP biomass resource and potential CE processes [CSIR, 2022].

Resource	Potential market application
Stored chemicals	Gasification of black liquor to obtain syngas for use in boilers or Internal Combustion (IC) engines for power generation. Syngas can also be used to produce bio-fuels for motor-vehicles.
	Useful components can be extracted directly from particular wood species or can be pyrolyzed or gasified to yield bio-char/bio-oil and syngas respectively, which can be used as feed stocks in chemical syntheses.
	Chips, fibres, shavings and sawdust could be used to manufacture engineered wood products like panel boards
	Used in the prevention of soil erosion on slopes.
Organic polymers	Material for biological feed. Soil additives and water retention in agriculture. Bark conversion into mulch and seed bed material.
Fibrous cellulose	Black liquor contains more than half of the energy content of the wood fed into the digester of a kraft pulp mill. It is normally concentrated to 65 - 80% by evaporators and burned in a recovery boiler to produce energy and recover the cooking chemicals. Black liquor is produced as a by-product from the kraft process when digesting pulpwood into paper pulp removing lignin, hemicelluloses and other extractives from the wood to free the cellulose fibres. Pulp mills use black liquor as an energy source. This has helped paper mills reduce costs of effluent discharge and use chemicals through recovery and reuse.
Black liquor	Conversion into fuel

Resource	Potential market application
[7 tonnes of black liquor per ton of pulp].	
Lignin	Used in environmentally friendly pesticides, dyes, carbon black, coal briquettes as a binder to suppress dust on unpaved roads, tanning of leather and as a cement additive
Lignosulphate	Source of bio-fuel
Lignin	Source of bio-oil
Wood waste	Source of tall oil used in paints, varnishes and pigments
Tall oil	Production of alcohol by fermentation Sorbitol used in the food (as a sweetener) and in laxative industry
Hemicellulose	Bio crude oil, ethanol and other products
Biomass	Ethanol
Sugars	Adhesive, energy
Black liquor	Nanofibers

Opportunity for technology transfer

The multitude of processing pathways to generate valuable products from forestry biomass are defined by appropriate technologies and technology combinations for particular processing routes. The CSIR identified 129 different pathways involving chemical, thermochemical, biological and mechanical processing, from 7 types of FTPP wastes and residues [CSIR, 2022]. Current proven technology options are shown in the table below for consideration by Dutch enterprises that may possess such technologies for transfer to SA partners.

Table 5.6: Technology solutions [CSIR, 2022].

Technology	Feedstock
Ligno-boost	Lignin
Lignosulphate recovery plant	Lignosulphate
Renfuel	Lignin
Pyrolysis	Wood waste
Tall oil recovery	Tall oil
Hydro-chloric Acid (HCL) Clean Tech	Sugars
Combined heat and power (CHP)	Hemicellulose
AVAP® [Evaporation process] [see note]	Biomass
API	Sugars
Lignin	Black liquor
Licella fibre fuels	Biomass
Cellulose nanofiber	Cellulose

Bio-mass to ethanol conversion

Of particular interest to Dutch businesses would be the refining of biomass to extract valuable chemicals. A biorefinery is defined as '*the sustainable processing of biomass into a spectrum of marketable bio-based products (chemicals, materials) and bioenergy (fuels, power, and/or heat)*'. A Biorefinery integrates a range of technology and processing routes to produce a spectrum of energy and material bioproducts.

Other established commercial technologies that can add value to wood wastes and residues include HCL Clean technology for the production of bio-fuels; pyrolysis to produce bio-oil as a petroleum oil replacement; and Rayon to replace polyester textiles. Mechanical processing is also used to produce mulch, insulating material, filler and binder in cement and brick-making, and natural dyes; while established commercial technologies that can add value to black liquor include the use as a dust dispersant and asphalt additive.

A bio-refinery at existing sugar or pulp and paper mills, has a number of cost advantages such as:

- Savings of up to 1/3 of infrastructure capital (vs. Greenfield) – as plant for steam and power, water and effluent stations, warehouses, wood yards, storage tanks, etc. already exist.
- Plant already has operating permits.
- Expertise in sales, procurement and logistics.
- Modern mills produce 30% excess energy which could be tapped by the refinery. [CSIR Biorefinery Unit, 2022]
- Paper mills in particular, produce base chemicals on-site ($NaOH$, CaO, etc.), which are key inputs into the refinery process.

Biomass to energy conversion

The use of black liquor gasification has the potential to achieve higher overall energy efficiency than the conventional recovery boiler, while generating an energy-rich syngas from the liquor. The syngas can be burnt in a gas turbine combined cycle to produce electricity (usually called *BLGCC* for Black Liquor Gasification Combined Cycle) or converted through catalytic processes into chemicals or fuels such as methanol, dimethyl ether, or F-T diesel (usually called *BLGMF* for Black Liquor Gasification for Motor Fuels).

The black liquor gasification route used for biofuels production, has very high conversion efficiency and greenhouse gas reduction potential.

Hydrothermal liquefaction

Hydrothermal liquefaction is suitable for converting black liquor to advanced biofuels due to the process's ability to handle high moisture inputs.

Water recovery

Sugar and timber mills use vast quantities of water, and even though some water recovery processes are employed, still dispose of large quantities of water as treated effluent.

Challenges and mitigation measures

Most sugar and timber mill operations in SA use the biomass as a fuel source in boilers to generate heat and electricity. This could make it difficult for third parties to access the biomass unless an equivalent or lower cost alternative could be provided on the one hand or a higher value use of the biomass could be demonstrated on the other hand. However, once a high value solution is demonstrated for the bio-mass, the owners are likely to increase the price of the feedstock substantially.

1. The continuing challenge remains in finding applications or markets that would consume sufficiently large quantities of these materials to enable price reduction and allow biomass to compete economically in the market as a feedstock for chemical and fuel production.

2. Many South African timber board mills have closed down due to demand of round logs by the pulp and paper industry and conversion of forests to logs more suitable to this industry. As a result, raw biomass from timber mills have been drastically curtailed. Processed biomass is therefore mostly available from pulp and paper mills and sugar mills.

Some of these challenges could be overcome if projects are undertaken as joint ventures with the owners of the sugar and timber mills and bio-mass projects are located at or next to the mills to reduce transportation costs.

Table 5.7: Potential SA partners in FTTP sector.

Organisation	Region
Gauteng	
Sappi HQ	Jhb, Gauteng
SAFCOL	Pretoria, Gauteng
PAMSA	National
Forestry SA	National
Chemical & Allied Industries Association	National
KwaZulu-Natal	
Mondi KZN	Richards Bay, KZN
Forestry SA (FSA)	Pmb, KZN

Organisation	Region
SAPPI	Dbn, KZN
CSIR Bio-refinery Unit	Dbn, KZN
SA Sugar Association	Dbn, KZN
Biotech industries	Dbn, KZN
Dube AgriZone	Dbn, KZN
Tiger Brands	Dbn, KZN
Illovo Sugar	Sezela, KZN

5.3 Slaughterhouse waste

Introduction

Slaughterhouses (or abattoirs) generate large volumes of animal by-products. While these by-products are an important source of industrial protein that could potentially be utilized in various value-added applications, in SA this resource is currently under-utilized in high-value applications and are instead being used to make low-value products such as animal feed and pet food. On the other hand, a large volume of this waste is composted on site. Some of the condemned by-products of animal slaughterhouses cannot enter the food and feed chains and thus their disposal poses a serious economic and environmental challenge to operators.

Source and quantification of the waste

Approximately 32,000 large animals (cattle, sheep, pigs) are slaughtered each day at registered abattoirs across South Africa [DFFE, 2022]. The process results in waste such as blood, stomach contents, unborn foetuses, fat, unused parts and condemned parts and carcasses, etc.

Estimates of the volumes of by-products are as follows:

Table 5.8: Waste resources from animal abattoirs [DFFE, 2022].

Type of waste	Kg per week	Tons Per Annum
Infectious and condemned flesh and organs	488,697	25,412
Blood	1,048,487	54,521
Stomach contents	806,462	41,936
Manure from lairages	8920	464
Hooves	n.m.	n.m.
Bones	n.m.	n.m.
Total	**2,352,566**	**122,333**

n.m. = Not Measured

These volumes exclude waste from game abattoirs, where the number of processed units are increasing as the demand for trophy hunting, culling and meat increases.

Approximately 2.4 million poultry are slaughtered each day at registered poultry abattoirs across South Africa [DFFE, 2022].

Table 5.9: Waste resources from poultry abattoirs [DFFE, 2022].

Type of waste	Kg per week	Tons Per Annum
Infectious material	409,695	21,304
Blood	531,630	27,645
Feathers	1,077,058	56,007
Total	**2,018,382**	**104,956**

As a result, at least two million tons of waste are generated each week by commercial poultry processing plants creating a major solid waste problem [DFFE, 2022]. Demand for this by-product is low while traditional disposal, such as burial and incineration, are expensive and time consuming, while posing environmental risks such as greenhouse gases and pollution of land and water. Small volumes are ground and mixed into animal feed due to the protein fibre, keratin, that poultry waste, and particularly, feathers, have. This limited usage of poultry waste is not sustainable in the long term as demand for poultry meat increases.

Potential circular raw materials

Raw materials from abattoirs with potential for value-addition and circulation back into the economy are summarised in Table 5.10 below:

Table 5.10: Summary of waste resources by type of slaughterhouse.

Abattoir type	Raw material type				
	Beef	Sheep	Pig	Poultry	Game
Slaughterhouse waste mixed (SWM) - discarded organs, parts, fats, condemned carcasses, etc	x	x	x	x	x
Blood	x	x	x	x	x
Stomach contents such as undigested food, bile	x	x	x	x	x
Hooves and horns	x	x			x
Body hair	x	x	x		x
Feathers (chicken, ducks, geese, turkey & ostrich)				x	x

Potential uses of the raw materials

Between 40-50 % of a cow is inedible but these parts find applications in various industries, some totally remote to agriculture [agricultureportal.co.za, 2023]. For instance, jet engine lubricants and brake fluid is made from the bovine fatty acids. Heparin, a frequently prescribed anticoagulant drug, is made from the lungs and bovine mucosa. The adrenal gland is used in making steroid drugs. The pancreas and the thymus gland are served to diners as sweetbreads, and the pancreas itself is used to make insulin. Cosmetics and pharmaceuticals are made from the placenta. The dura mater is used as an implant in human brain surgery.

Slaughterhouse waste mixed:

Slaughterhouse waste mixed (SWM) such as discarded parts and condemned animal organs, unborn foetuses and blood are high in methane content, which could be used by in-situ anaerobic bio-digesters to produce methane gas for heating or for the generation of electricity for use by the abattoir or for sale into the local electricity grid.

SWM such as bones, meat and fat offcuts, intestines, chicken heads and feet, inter alia, could be rendered and processed into meat and bone meal, a protein-rich ingredient in animal feed, and collagen for human consumption.

Tallow

Tallow is a rendered form of beef, pig or sheep fat, primarily made up of triglycerides (a compound with an O-H molecule, used in a range of applications). Rendered tallow is made into a number of raw materials such as edible tallows, industrial tallow, glycerine and glycerol and fatty acids, inter alia.

Blood

Blood collected at abattoirs is a potentially valuable by-product used by food additive companies, pet-food companies, black pudding and sausage makers and pharmaceutical companies, inter alia.

Potential economic outputs

Slaughterhouse waste mixed:

Gas to Heat (GtH)

Given the regular flow of the waste, abattoir-based anaerobic bio-digesters are effectively renewable energy generators. Research shows that the yield of methane from abattoir waste is approximately 208.25 m^3/ton SHWM [Anyonga, 2022]. The lower heating value of slaughterhouse methane is around 37 MJ/m^3. Methane could be used to heat water for sanitation purposes as well as for space heating.

Gas to Electricity (GtE)

Assuming the conservative value of 37 MJ/m^3 for the methane from the waste of a 150-unit per day slaughterhouse, a primary energy production unit would generate 16,735 MWh of electrical energy. This electrical generation is higher than the energy consumption of the abattoir, making the facility energy self-sufficient and potentially a net exporter of green electricity into the grid.

Cow offal:

Cow intestines could be used as casings for sausages or could be cleaned, dried, chemically treated to make long-lasting high strength strings for tennis rackets, drums and upholstery.

Blood:

Blood can be used in the formulation of food products, additives (emulsifiers, stabilisers, clarifiers, nutritional additives, egg albumin substitute), pharmaceuticals, fertilisers, animal feeds as well as in numerous industrial applications. The value of blood can be increased by separating the blood into plasma and haemoglobin (corpuscles, serum & red albumin). For example, 10,000 litres of hygienically collected blood equals 6,000 litres of plasma and 4,000 litres of haemoglobin.

Cell culture involves keeping alive pieces of living tissue, such as pieces of lung or kidney, and multiplying this in an artificially created environment. Cells in this situation need nutrients such as proteins, vitamins, and amino acids just as a human body does, and bovine serum is an extremely rich source of these nutrients. Cell culture is a modern biotechnology process which has many uses in the scientific laboratory, such as virus diagnosis, cancer research, vaccine production, toxicity testing of drugs and cosmetics, transplantation research (heart, kidney) and examination of unborn children for genetic defects such as mongolism. In vaccine production, cell culture is used to grow the virus which is then killed or made non-infectious. The vaccine can then be used to protect humans and animals against infection by that virus. Production of polio virus vaccine in cell culture has been responsible for saving many lives. The serum can be derived from either adult or foetal bovine blood or from other mammalian blood.

There are two blood derived products (serum and plasma) used in pharmaceutical industries. Plasma and serum have different characteristics and therefore different applications. Global market data indicates that the world market for cell culture reagents, sera and media is approximately £400 million per annum. Production capacity in biopharmaceutical manufacturing is expected to expand by 48% over the next five years. Much of this will be for mammalian cell culture systems.

Table 5.11: Potential uses and advantages of slaughterhouse waste [Bandaw and Herago, 2017; Khan et al, 2023; Philipp et. al, 2021; Ragasri and Sabumon, 2023].

Resource	Uses	Advantages/Benefits
Whole blood	Black pudding, soup	
	Petfood	Increased water content

Resource	Uses	Advantages/Benefits
Blood plasma	Sausages, black pudding, hotdogs, hamburgers, pâtes, meatballs	Replace other protein additives, increased animal protein content
	Meat stretcher	Improved sensoric values (taste, juice, texture and bite)
	Gelling agent	Better binding of mechanically deboned meat (MDM)
	Soya substitute	Soy-free labelled products Non-allergenic) genetically modified organism (GMO) free additives Spray dried plasma
Haemoglobin	Petfood, Feed for livestock (piglets, fish farms, chicken)	Low cost feed
	Bio-gas	Unsed in heating and electricity generation
	Colouring agent	Natural colouring
Pharmaceuticals		
Serum	Vaccines, antibodies	Mammalian cell culture media
Plasma	Serum albumin, globulins	

Hooves:

Hooves are rendered to extract the protein keratin, which is used for human and pet food, gelatine, glue, buttons, handles, lubricants, cow- heel jelly, bonemeal, soaps, hair treatment formulas, a special fire extinguisher foam used at airports, and fertilizers. In addition rendered hooves are the base raw material for the manufacture of various consumer products such as human and pet food, gelatine, glue, buttons, handles, lubricants, cow-heel jelly, bonemeal, soaps, the foam in fire extinguishers, and fertilizers, inter alia

Poultry feathers:

Feathers are also made of keratin. The crystal structure of feather fibres also makes them naturally stable and durable. As a result of these properties, feathers can be put to good use in the manufacture of consumer goods, replacing wood pulp and other expensive fibres.

Several commercial applications have been explored to utilize fibres from chicken feathers by the CSIR et al (2016). However, due to the low volume requirements of these products these applications have not significantly reduced the volume of feathers generated each year. An innovative way to utilize poultry feathers into a novel composite material is to bind them with Portland cement. Recent studies showed that cement bonded chicken feather composites (called feather-boards) are suitable for non-structural applications in low cost housing projects in developing countries. Tests showed that stiffness, flexural strength and dimensional stability of feather-boards were slightly lower or comparable to that of commercially available wood-fibre cement board of similar thickness and density. Cement bonded feather-boards had excellent decay and termite resistance which makes them attractive as construction materials in tropical climates such as South Africa. Furthermore, the density and configuration (layered or homogenous) of the board can be varied to suit various applications such as panelling, sidings and insulation boards.

Despite the need for more research on the use of waste chicken feather as reinforcement in cement bonded composite, it offers an environmentally friendly method of disposing a serious waste product and promotes competitiveness of both the poultry and construction industries.

Table 5.12: Formula for the fabrication of cement bonded feather boards [Menandro, 2009].

Component	Percent by Weight
Chicken feather (fibre, ground or whole feather)	10-20%
Portland cement (Type 1)	40-50%
Sand (Fine)	40-50%
Accelerator (e.g. CaCl2, Al2(SO4)3), etc.)	3-5% weight of cement
Superplasticizer (e.g. lignosulfonate based)	3-7% weight of cement
Coupling agent (silane based, etc.)	0-5% weight of cement
Water	60-80% of weight of cement

Considering that chicken feathers are fluffy and very light in weight, the proportion of feathers in feather-board represents a relatively large amount of feather material.

Feathers could also be used as replacements for glass or carbon fibres. According to Sithole (CSIR, 2016), "natural-fibre-reinforced polymer composites have attracted a great deal of attention and interest, as environmentally friendly replacements for glass or carbon fibres in fibre-reinforced composites".

Keratin:

The extraction of keratin protein from feathers create a new high value market opportunity for feathers. The CSIR's bio-refinery unit at the University of KwaZulu-Natal had undertaken research into the extraction of keratin from chicken feathers in 2016.

Chicken feathers contain about 91 per cent keratin, 1 per cent lipids and 8 per cent water: "Keratin is in high demand in a variety of high-value industries, resulting in it selling for more than 2,400 South African rand per kilogram (about 140 GBP per kilogram). By extracting keratin from feathers you might, in effect, be able to make this by-product just as valuable as poultry meat" (Sithole, 2006).

While this research was a first for South Africa, international studies and patents on extraction of keratin and other products from feathers are available. The CSIR study looked into developing new extraction procedures – by using a combination of unique solvents and microwave extraction techniques – to significantly reduce extraction costs – with very positive results.

The chicken feathers are pre-treated to remove debris and decontaminated to remove any bacteria and viruses, before the keratin is extracted. Once extracted the keratin proteins are characterised according to their physical and chemical properties. According to Prof Sithole, the extracted keratin protein could be incorporated into all kinds of hair products, due to its moisturising properties.

The harvested proteins could also be made useful in the form of keratin bio-fibres or keratin protein based products. Electrospinning could, for example, be used to regenerate keratin bio-fibres that could in turn be used to replace synthetic petroleum-based fibres in the textile industry.

Keratin proteins, on the other hand, could be converted into high-value chemicals.

Tallow:

Some of the uses of tallow are as follows:

Edible tallow - Used in shortening for baked goods and in combination with vegetable oils for frying foods and in chewing gum

Industrial tallows - White and yellow grease

Fatty acids (derived from tallows): plastics, tyres, candles, crayons, cosmetics, lubricants, soaps, fabric softeners, asphalt emulsifiers, synthetic rubber, linoleum (metallic stearate), PVC (calcium stearate), jet engine lubricants, carrier for pesticides and herbicides, wetting agents, dispersing agents, defoamers, solubilizers, viscosity modifiers.

Oleic acid (derived from tallows) - synthetic motor oil, antibiotics

Azelaic acid - high-performance coatings for planes and cars, food packaging, fishing line, acne medication, furniture

Stearic acid - cosmetic gels, pharmaceutical additives, grease additives, toner adjuvants, antifoam agents, explosive additives, waterproofing agents

Fatty acid amides - Lubricants in industrial processes, fatty acid amines, rubber, textiles, ore floatation, corrosion inhibitors, metalworking lubricants.

Fatty acid esters - Emulsifiers, coating agents, textile sizers, lubricants, plasticizers, defoaming agents, lithium-based greases, textile lubricants, rolling and cutting oils, metal-machining lubricants

Fatty alcohols - Sodium alkyl sulphates, ultimately made into detergents.

Glycerine (derived from tallows) - A wide range of pharmaceuticals including cough syrups and lozenges, tranquilizers, eyewashes, contraceptive jellies and creams, ear drops, poison ivy solutions, solvent for digitalis and intramuscular injection, sclerosing solutions for treatment of varicose veins and haemorrhoids, suppositories, gel capsules.

Glycerol - Solvent, sweetener, dynamite, cosmetics, liquid soaps, candy, liqueurs, inks, lubricants, antifreeze mixtures, culture nutrients for antibiotics

Glycerine mist - Aftershave preparations, shaving cream, toilet soap, toothpaste, sunscreens and sunblock, dental floss, bath salts, bubble baths, body lotions, cleansing creams, moisturizing creams, external analgesics and counter-irritants, shampoos, hair colouring preparations (bleaches, dyes, rinses, tints), hair dressings (brilliantines, creams, pomades), hair mousse, hair and scalp conditioners, hairspray, topical antibiotic preparations, hemorrhoidal preparations, pharmaceuticals for veterinary use, liquid household hard-surface cleaners, laundry aids (ironing and dry-cleaning spotting solutions), agricultural chemicals, automobile body polish and cleaners

Potential technology transfer opportunities

Anaerobic bio-digester

Anaerobic bio-digesters used to extract the biogas, such as methane, from biological waste such as SWM.

Additional revenue may also be generated from the sale of excess electricity into the regional power grid as well as the sale of fertilizer derived from the AD digestate, which does not need any further treatment, because of the pasteurisation process.

Advanced microwave technology

Advanced microwave technology (AMT) can be used to treat blood without destroying some of its important components. Microwaves heat the blood by delivering energy directly into the total volume of the liquid. This method of "Volumetric Heating" is not only very cost effective but it has many advantages over other conventional thermal heating systems which rely on energy being transferred into the liquid from a hot surface by conduction and convection. For example, the AMT allows for the proteins in the blood to coagulate, while it allows more than 50% of the contained water to freely drain away from the solids, thereby reducing the overall transportation weight. An AMT plant can be located at the slaughterhouse, where it can heat and sterilize the blood as it is produced.

The remaining sterile proteins are of a very high quality and can be used as a fertilizer, a pet food ingredient or, if the blood is hygienically collected as a high-quality protein, for the food industry. This enables abattoirs to convert an expensive waste into a potentially very valuable income stream.

The AMT unit can be custom-sized to cater for blood flows of 150litres per hour to several thousand liters per hour.

Meat Rendering plants

Unused parts, such as heads, feet, bones, intestines etc. could be processed in a rendering plant to make meat and bone meal, a protein rich meal that can be used as an animal feed ingredient.

Rendering plants located adjacent to the slaughterhouse help reduce transport costs while creating an addition value-added product with a consistent revenue stream.

Feather-board manufacturing plant

The process of making of cement bonded feather-board involves collecting feathers from chicken processing plants, washing to remove manure, blood, oil, dirt and residual odour, disinfection against any pathogens and finally drying either under the sun or by using heated dryers with temperatures not exceeding 100ºC. The feathers are separated into fibres and quill using a feather separator or cut to size and then ground to powder form depending on desired board configuration (homogenous or layered). The feather media is then mixed with cement, water and chemical admixtures according to a specific formula and target density. The mixture is then poured uniformly into a mould and then pressed to the desired thickness using a hydraulic press. The board is removed from the press after three hours and allowed to completely dry for two weeks. After curing, the board is trimmed to size and is readily for use for general construction such as in ceilings, dry walling or cupboards. The use of waste chicken feather with a combination of chemical admixtures (accelerator, superplasticizer and coupling agent) results a lightweight, strong and very durable building material.

The technology for fabricating cement bonded feather-boards for non-structural applications such as wall panelling and ceiling materials in low cost housing projects is technically feasible as most of the equipment is available and used in other applications. It requires simple machinery and equipment that could be sourced locally or fabricated. The project is ideal for rural entrepreneurs based adjacent to poultry abattoirs. Opportunities for feather-board manufacturing exist throughout South Africa (and Africa), wherever chicken processing is taking place commercially and where there is a demand for low cost durable board, such as for economic housing projects.

Estimates of the retail price of a feather-board show that it could be 40-50% less than comparable cement bonded panel available in the market to date. Considering that chicken feathers are essentially free and make up 10 – 20% of the volume of a feather-board, that the equipment is relatively cheap and available, and that a ready market exits for cheaper board, the probability is relatively high that the production of feather-board could be an economic proposition and that end users would be open to the idea of using feather-board in construction. There could also be potential for the production of other small cement-fibre products such as hollow blocks, plant pots, packaging boxes and crates, etc. Feathers could potentially create a whole new industry out of the production of feather-boards and other related products.

Key challenges that Dutch businesses need to be aware of when considering slaughterhouse waste:

- Access to the raw materials may not be free or at rate which would make a processing plant an economic proposition.
- Environmental authorisations would be required for the waste processing plant.
- Off-take agreements with customers for the processing outputs would need to be secured.
- Management systems for diseases in the waste stream such as avian flu, foot and mouth disease, inter alia.

It is recommended that Dutch firms undertake a thorough due diligence of any specific opportunities in this waste stream.

Table 5.13: Potential SA partners in slaughterhouse waste.

Organisation	**City**
Gauteng	
The Compost Kitchen	Jhb
Red Meat Abattoir Association	Pta
KwaZulu-Natal	
Biomass Waste	Dbn
Adopt a River Eco Solutions	Dbn
Council for Scientific and Industrial Research (CSIR)	Dbn
Madisin	Dbn
CO2LOW	Dbn
South African Sugar Association (SASA)	Dbn
Tongaat Hullett	Dbn
South African Farmers Development Association (SAFTA)	Dbn
Green Corridors	Dbn

Organisation	City
Free State	
DESTEA	Blm

5.4 Plastics

Plastic waste remains a big challenge in SA, due to the inconsistent S@S, absence of waste management systems in specific areas, incorrect handling and poor disposal practices of plastics in the country. There is also a significant increase in single-use plastics from personal protective equipment and plastic wrapping generated during the Covid-19 pandemic.

Sasol Polymers and Safripol are the primary plastic raw-material producers in SA. There are several importers of plastic raw-material such as Dow Chemicals. In 2018, 1 270 000 tonnes of virgin plastic were locally produced. Of that, 582 000 tonnes were exported and 688 000 tonnes were used locally. In addition, 856 000 tonnes of virgin plastic were imported. [*WWF SA*, 2020]

Approximately 2.4 million tons of plastic waste is generated annually in SA. However, only 14% of this plastic is recycled and hardly any multilayer materials/plastic (MIC) is recycled in South Africa due to economic implications and technical difficulties in separating the layers. Furthermore, both local and imported plastic raw material are cheaper than recycled plastic material in SA. [WWF SA, 2020]

The plastics industry in SA is dominated by the packaging industry which accounts for 52% of the local market. The Building and Construction sector consumes 13% another 8% is consumed by the agricultural sector [PlasticsSA, 2021].

The SA plastic sector has the following characteristics:

(a) Plastic consumption per capita is predicted to increase over the next few years by an average of 3% per year;
(b) In 2010, the total plastic consumption was approximately 1 510 000 tonnes and by 2018, it had grown to 1 876 000 tonnes;
(c) Factors influencing the projected increase includes urbanisation, an increase in middle-income households characterised by a culture of fast moving consumer goods that generate waste;
(d) Approximately 408 000 tonnes of finished and semi-finished plastic products were also imported in 2018;
(e) Rigid and flexible packaging makes up approx. 52% of the plastics market sector in SA; [PlasticsSA, 2021]

Although SA has a well-developed plastic recycling sector, numerous challenges remain in the sector, which Dutch firms need to bear in mind, such as:

- Low levels and sporadic S@S initiatives at the urban domestic level while there is a complete absence of waste collection in informal and rural settlements, resulting in dumping.
- Contamination of waste plastic in the municipal waste bag.
- Small local market for plastic recyclables.

It is recommended that Dutch firms collaborate with the relevant city departments and waste management services and to undertake a thorough due diligence of any specific opportunities in this waste stream.

Table 5.14: Potential SA partners in plastic waste.

Organisation	City
Gauteng	
Plastics SA	Jhb
Plastics SA	Jhb
Extrupet	Jhb
Extrupet	Jhb
Interwaste	Jhb
Interwaste	Jhb
South African Plastics Recycling Organisation	Jhb
Expanded Polystyrene Association of SA	Jhb
Western Cape	
PolyCo	CT
PetCo	CT
Polystyrene Packaging Council	CT
Plastics SA	CT
KwaZulu-Natal	
Green Corridors	Dbn
Planet Care Waste	Dbn
BASADI SOLUTIONS	Dbn
Adopt a River Eco Solutions	Dbn
Use-It	Dbn

5.5 Sustainable landfills

The majority of waste in South Africa is disposed to landfill. Organic waste constitutes the largest portion of general waste in SA at approximately 34.6% [SoWR, 2020]. This is mainly made up of biomass from sugar mills, sawmills, and the paper and pulp industry.

General waste also consists of bottom ash, slag, municipal waste, metals and construction and demolition waste.

The following statistics provide an overview of the waste resources disposed to landfill in SA:

(a) 65.2% of the total of 55.6 million tonnes of general waste.
(b) 93% of the total 338 237 tonnes of the hazardous waste.
(c) 23.7% of imported hazardous waste.
(d) 56.3% of plastic waste.
(e) 24 tons of dry cell batteries.
(f) About 12 001 tonnes of asbestos containing waste.
(g) Spent foundry sand.
(h) 90% of Waste from Electrical and Electronic Equipment (WEEE). There is currently little separation and collection of WEEE. While some WEEE is recovered or recycled, the non-functional parts are disposed of at landfills.
(i) Several thousand waste pickers extracting recyclable material from landfill.
(j) Treated Health Care Risk Waste is sent to landfill.
(k) Accurate data on waste volumes entering landfills is problematic due to a lack of weigh bridges, low capacity at many municipal landfill sites, *inter alia*.
(l) Most cities are running out of landfill airspace rapidly, e.g. Cape Town and Johannesburg (and others) have less than 4 years of landfill airspace remaining.
(m) SA is working on a proposed Landfill Tax to support gate fees and discourage the disposal of waste to landfill.
(n) There are number of initiatives to reduce waste going to landfills, such as the rollout of S@S programmes at some metropolitan municipalities, cities and large towns.

The National Pricing Strategy for Waste Management [DFFE, 2016], is a deterrent to disposal to landfill, which is currently considered the cheapest technical "solution" for general waste in SA.

Table 5.15: Potential SA partners in landfill operations.

Organisation	City
Gauteng	
Interwaste	Jhb
Pikitup	Jhb
EnviroServ	Jhb
Waste Management Division	Pta
Waste Wise Services	Jhb
Free State	
DESTEA	Blm
Solid Waste Management Services	Blm
KwaZulu-Natal	
Planet Care Waste	Dbn

Organisation	City
Dolphin Coast Landfill Management (DCLM)	Dbn
Cleansing and Solid Waste	Dbn
Eastern Cape	
EP Waste Management Services	PE
DNFWaste	EL
Western Cape	
Waste Management Service	CT

It is recommended that Dutch firms collaborate with the relevant city departments and private landfill operators to explore specific needs and to undertake a thorough due diligence of any specific opportunities in this sector.

5.6 Construction and demolition

One of the largest waste streams generated in SA (by weight) is construction and demolition (C&D) waste which has not been a focus for circularity or diversion from landfill.

There is a lack of good and accurate statistics on the volumes of C&D waste disposed. On the one hand many municipalities that operate landfill do not keep records and on the other hand most C&D waste is used as cover material at landfills. It is estimated that C&D waste makes up 30% of the 26 million (M) tons of Municipal Solid Waste (MSW) disposed per year and so equates to 7,8 M tons [SoWR, 2018]. The bulk of C&D waste can be found at landfills in the 9 Metro areas. C&D waste is made up of many components, but the bulk is cement and concrete, bricks, wood, glass and plastics. Another big component is soil waste from local cut-and-fill operations, but often used as cover material in landfill operations.

Potential "circular" raw material/s

Concrete and brick waste is an ideal medium for crushing back into an aggregate. Cement products can also be reactivated back into cement – although not as strong as virgin cement, it can be used for a multitude of applications in the sector. There is still a little hesitation in using recycled aggregate for new stressed concrete forms but can be used as sub-base in the interim. Aggregate can be used in-situ in the sub-base of new developments.

Aggregates can also be used as sub-base for roads and are perfectly suited to this application.

Wood waste (beams, trusses, flooring and decking) can be reused if not damaged but is often not the case. Wood waste can then be used for biochar or energy.

Glass can be separated and crushed either as an aggregate or for use in filtration mediums.

Plastics in C&D waste usually include industrial plastics like Polyvinyl chloride (PVC) and Acrylonitrile butadiene styrene (ABS). Both can be recycled into new products.

Steel is often recovered from rebar in concrete, piping, housing and steel frame supports.

Another big potential in demolition waste is recovered materials like bricks, blocks, wood and window/door frames with usable life. This is the greatest potential but has significant impacts on demolition time and costs if salvage is required first. Currently, this is done on a very small scale providing affordable materials to poor communities that cannot afford to buy new.

Potential markets for the raw materials

Concrete can often be utilized again as an aggregate in subbase applications. Where possible, there should be systems in place to separate cementitious products for reactivation. This can be done chemically by adding small activators to old cement that will create a subgrade cement for new applications. Generally, one finds that the existing construction industry is still suspicious of the engineering application of recycled concrete, but this should not stop the application in terms of utilization for sub-base or as non-critical fill material. Both concrete and clay brick products can be crushed using conventional crushing and sieving equipment that is widely available in the market.

Sub-base in roads constitutes millions of tons of material per annum on new road infrastructure or upgrades. Addressing issues around procurement to specify this material has a preferred subbase would create a sustainable market that would be able to utilize all the construction demolition waste annually in roads. About 50 to 60% of the construction and demolition waste landfilled annually could be converted back into an aggregate. If this percentage of the 7.8 million tons could be achieved, the immediate impacts would be massive landfill diversion and cost savings. What is required is private sector crushing and screening companies to take up positions at landfills to process this waste. There are also opportunities for using this aggregate in more high-end applications in the construction industry. Currently we are already seeing applications in this through the likes of Cape Brick who recycle aggregates and successfully use these in new building products for distribution into the market. This kind of initiative should be replicated and supported.

Recovered steel from rebar and other building components is simple enough to redirect into the scrap metal market.

Flat glass recovered from windows in construction demolition waste as well as from distributors of flat glass can be processed through crushing and sieving plant to create a multitude of new products. The easiest of these would be as an aggregate and can be successfully used in any brick or block manufacturer. However, a higher value can be extracted from this material in applications such as in water filtration and sandblasting medium.

There are already available markets for these kinds of products so the requirement would simply be to install crushing and sieving operations for this recovery.

Wood waste recovered from construction and demolition material can be converted into a bio char where energy can be recovered that may facilitate the electrical operational requirements of landfills. The greatest return value on wood waste would be reutilization where there is not too much damage – this is often the case for roof dressing and door frames as well as flooring systems. This wood can be recovered and sold at its highest value back into the original application it was designed.

Most of the plastics that are recovered from construction and demolition waste are related to guttering, conduits, pipes and plastic sheets. The bulk of these plastics are either PVC or ABS. PVC is increasingly being recycled back into new building products such as green bricks and blocks.

Potential economic outputs

Creating material specifications for using recycled crushed aggregate as subbase would create a market for the private sector to invest in crushing and sieving operations that would have no burden on the state. The direct benefit would be a massive diversion of a problematic waste stream from national landfills.

Crushed glass is highly suitable for water filtration systems as a replacement to river sand, the extraction of which is causing major environmental and safety issues for local communities. Benefits include water savings, longer-lasting filtration aggregate, reduced backwash, better water clarity, reduced costs of filtration chemicals, reduced pump stress and related electricity savings, etc. Policies on materials specification for water filtration for all water treatment works and wastewater treatment works need to be amended to include glass.

Applicable Technology or process

Several existing technologies are available for processing C&D waste. These are divided into large-scale applications for large volumes at regional landfill sites; or small-scale operations that can be deployed in small towns, communities or at on-site demolitions. Technology is simple crush and sieve applications for both rubble and glass. There are no new innovations required for the C&D waste streams.

Challenges in implementation

There are no certification and standards for using recycled aggregate in construction. The SA State (through CSIR or SABS) would need to take on this responsibility for testing and developing Quality Check systems and procedures to ensure consistency. This could be an area for technical co-operation with the Dutch Government.

There is no legislation that compels construction firms to use C&D waste in construction projects. A change of the material specifications for road subbase to include minimum 30% recycled aggregate would create an instant high volume market for the rubble.

It is recommended that Dutch firms collaborate with the relevant city departments and waste management services handling C&D waste and to undertake a thorough due diligence of any specific opportunities in this waste stream.

Table 5.16: Potential SA partners in C&D waste.

Organisation	City
Basadi Solutions	Dbn
WHBO	Jhb
SANDOP	Dbn
Green Building Council South Africa (GBCSA)	CT
Cleansing and Solid Waste	Dbn

Table 5.17: Top construction firms in South Africa.

Name of Construction Firm	Web Address
Fikile Construction South Africa	www.fikile.co.za
CSV Construction South Africa	www.csvconstruction.com
Concor – Construction South Africa	www.concor.co.za
Motheo Construction Group South Africa	www.motheogroup.co.za
Renov8 Construction	www.renov8sa.co.za
Isipani Construction	www.isipani.co.za
Power Group	www.powergrp.co.za
CAPECON	www.cape-con.co.za
Temi Construction	www.temi.co.za
Iguana Projects	www.iguana.co.za
Ruwacon	www.ruwacon.co.za
WCB Construction	www.wcbcon.co.za
Grid Co	www.gridco-construction.co.za
Tiber Construction	www.tiber.co.za
Roycher Group	www.roycher.co.za
Domingo Construction	www.domingo-construction.capetown
Lemay Construction	www.lemay.co.za
JVZ Construction	www.jvzconstruction.co.za
Tri-Star Construction (Pty) Ltd	www.tri-starconstruction.co.za
Stefanutti Stocks	www.stefanuttistocks.com
SA Construction Group	www.sa-construction.co.za
Nejeni Construction and Project Management (Pty) Ltd	www.nejeni.co.za
Pretorius Structures	www.pretoriusstructures.co.za
Umdla Civils	www.umdla.co.za

Name of Construction Firm	Web Address
Ukhasi Construction	www.ukhasi.co.za
Murphy Projects	www.murphyprojects.co.za
Renico Construction	www.renicoconstruction.co.za
The Metric Group Pty (Ltd)	www.metricgroup.co.za
JNA Group	www.jnagroup.co.za
HW Builders	www.hwbuilders.co.za
Dalmar Construction	www.dalmar.co.za
Group Five	www.g5.co.za
ASLA Group	www.asla.co.za

5.7 Waste of Electrical and Electronic Equipment

At a per capita rate 7.1 kg [Solving The E-waste Problem, STeP Initiative, 2019], and given the South Africa, currently generates approximately 422,000 tons of e-waste each year [StatsSA]. In SA, while it is illegal to dispose e-waste to landfills, it nevertheless happens as it is included in municipal waste bags. Furthermore, the release of WEEE by their owners, seems to be a major challenge in accessing this resource [Lydall, 2017]. Consequently, e-recycling rates are below the global average and not as high as in some western countries, where bans on e-waste disposal to landfills is strictly adhered to. In South Africa, the e-waste collection and recycling rate is around 5% (Solving The E-waste Problem, STeP Initiative, 2019). Recycling rates will improve with the introduction of EPR levies on e-waste and through initiatives such as the Sustainable Recycling Industry.

Potential “circular" raw material/s

A significant percent of waste of electrical and electronic equipment (WEEE) devices still have some workable life, which can be extended even further with minor repair, component replacement or a software upgrade. These second-life WEEE’s could be made available to members of society that cannot afford the latest or any technology. Learners and university students for instance, who depend on access to mobile phones and e-tablets, especially during pandemic or disaster lock-down situations, would welcome access to affordable and upgraded devices to access learning resources. For example, if 5% of all redundant mobile phones alone in SA could be collected and refurbished, this would be equivalent to approximately 1 million mobile phones becoming available for re-sale [Statista, 2019].

E-waste is also extremely valuable as a rich source of secondary raw material. From every one million recycled mobile phones, approximately 16,000 kilograms of copper, 350 kilograms of silver, 34 kilograms of gold and 15 kilograms of palladium can be recovered [Go Legal, 2019].

E-waste that cannot be refurnished still has significant economic value in the form of recovered raw materials and components. Devices that cannot be upgraded are disassembled to extract re-usable components and parts such as screens, hard-drives, power units, power cables, memory chips, mouse, USB drives, and printed circuit boards (PCBs), etc, which are used to upgrade, fix or rebuild other devices.

E-waste contains a number of high value metals such as gold, silver, copper, palladium and indium. Approximately 320 tons of gold and more than 7,500 tons of silver are used in new electronic and electrical products worldwide [Baldé et al., 2015]. This alone equates to approximately $21 billion worth of valuable metals locked inside e-waste, which can be recovered through a form of “urban-mining”. The United States’ Environmental Protection Agency (EPA) has reported that recycling one million cellular phones can recover about twenty-four kilograms of gold, 250 kilograms of silver, nine kilograms of palladium, and more than 9 tons of copper [Eurekalert, 2011].

When printed circuit boards from computers, phones, TV’s, and other electronic devices are processed mechanically, products like mixed metal powder and resin fibre powder are obtained [Henan Renewables, 2022].

Potential markets for WEEE circular products

The demand for refurbished electrical and electronic devices (REEDs) continues to grow as more people get access to electricity and data networks but cannot afford new EEEs [Statista, 2023]. This demand is evidenced through the growth of second-hand goods retail chains such as Cash Convertors and Cash Crusaders and online e-commerce platforms such as *Gumtree*, *OLX*, *Junk Mail*, etc. in South Africa.

Potential markets for refurbished EEEs include scholars, university students, indigent homes, hostels, old age homes, lower economic sectors of the population as well as for export into Africa.

Precious and rare-earth metals, extracted from e-waste, is sold to metal traders or directly to end-users such as EEE and jewellery manufacturers.

Potential market channels for e-waste components and recovered metals include:

- Metal refineries
- Plastic recyclers
- Steel mills and foundries
- Circuit board manufacturers
- Jewellery manufacturers
- Glass manufacturers.

Potential economic outputs

Apart from the refurbished EEEs and extracted raw materials that are circulated back into the economy, the e-waste CE also results in other economic and environmental benefits such as:

- Employment in the collection, transportation, disassembly, refurbishment and/or recycling and sale of products
- Income generation through the sale of operational units, spare parts, components and recovered materials
- Reduction in the impact of mining of virgin materials
- Reduction in the carbon emissions associated with manufacturing of virgin plastic
- Reduction in imports of new devices
- Reduction in the generation of e-waste
- Access to affordable ICTE devices by people with low disposable incomes
- End of life components and raw materials.

Applicable Technology or process

A large EEE refurbishment centre comprises of several work stations and technicians, each responsible for a particular task, such as initial inspection and making safe, extraction of usable components (if device cannot be repaired), refurbishment of device, erasing or destroying the hard-drive, software upgrade, sanitation and packaging before despatch to a sales team. The operator of the refurbishment centre actively solicits non-functioning and obsolete devices by either collecting directly from donors or establishing drop-off bins at strategic locations such as at large shopping centres or office complexes. The refurnished devices are sold into the second-hand market with or without a short-term carry-in warranty.

EEE devices and components that cannot be repaired are recycled. The process involves disassembly of parts (such as metal frames, power supplies, circuit boards, plastic enclosures, cabling and screens). Further separation of these materials results in the basic raw materials such as copper, gold, glass, plastic, etc. being produced. The purity of extracted precious metals can reach 99.99%. [Henan Renewables, 2022].

Large formal e-waste recyclers use more sophisticated tools and equipment to separate the e-waste as much as possible into simple waste categories such as glass, plastic, copper, rubber, steel, etc. A fully integrated e-waste recycling plant would have crushers, grinders, cord strippers, copper wire recycling machines, aluminium and plastic separating machines, precious metal extraction devices, waste plastic sorting, waste battery treatment equipment, etc.

In the case of complex e-waste types such as circuit boards and hard-drives, these are crushed, shredded or ground into finer particles and the various metals, plastics and glass are separated by using either chemicals[1] or specialised extraction equipment.

A precious metal recovery and refining plant is used to extract precious metals such as gold, silver, palladium and platinum from shredded mobile phones, circuit boards, computer CPU, motherboard, VCD, CD, TV, gaming consoles, fax machines, telephones, mobile communication and other household appliances.

Potential reduction in Greenhouse gases

Greenpeace [2010] indicated that the high demand for electronic equipment globally contributes to a tremendous increase in e-waste, and this is becoming a significant threat to the environment. E-waste contains several persistent, bio-accumulative and toxic substances including heavy metals such as lead, nickel, chromium, mercury and organic pollutants such as polychlorinated biphenyl (PCBs) and brominated flame resistant retardants. The refurbishment of e-waste prevents (or at least delays) these toxic substances from entering the general waste streams until large scale sustainable recycling and recovery solutions can be found. [Gaidajis, Angelakoglou, Aktsoglou, 2010]

By recycling raw materials from discarded EEEs, natural resources, energy and water are conserved in the value chain. Furthermore, air and water pollution caused during mining of raw materials, manufacturing or disposal of e-waste are avoided. E-waste in landfills and in the environment slowly emit methane over many decades. Methane is 25 times more effective than carbon dioxide at trapping heat in the atmosphere, thereby worsening global warming.

Refurbishment and/or recycling of e-waste instead of producing more virgin raw materials and new EEEs will reduce the overall energy and water consumption, avoid direct greenhouse gas emissions, and reduce the environmental impacts of EEEs [United Nations Climate Change, 2022].

Challenges in implementation

Access to good quality e-waste with potential for re-use or recycling as well as the cost-effective collection of units remains major challenges to refurbishment or recycling. Other observed challenges include:

- Companies (and Government) holding on to e-waste instead of disposing of them due to the difficult asset disposal procedures (especially in the public sector).
- Concerns around privacy and security of information embedded in hard drives.
- The added expense and inconvenience of transporting e-waste to proper recyclers.
- Perceptions that there is still some value in the device causing owners to hold on to them or wanting to sell them.
- Costs for the establishment of a network of drop-off points.
- Hazardous nature of handling and processing of e-waste.
- No special additional gate fees or fines imposed on e-waste sent to landfill.

- “Product complexity”, i.e. e-waste contains many different types and nature of raw materials (metals, glass, plastics, rubber, ceramics, etc.). Electronic components are also made up of multiple materials, often embedded into one another. This makes material separation and sorting difficult and expensive.
- The solutions are labour intensive as a result of the logistical requirements for collection, physical inspection of devices and initial dismantling into large components. [AEI Screens, 2022].

Opportunities for Dutch firms

The generation of e-waste in South Africa is predicted to increase over the foreseeable future, necessitating the introduction of efficient and sustainable solutions, apart from landfill. Given the perceived demand for affordable EEEs in South Africa, there is a potentially viable business proposition for a network of refurbishment centres in the larger metropolitan areas of South Africa to repair and upgrade devices with potential economic life.

Refurbishment centres should be supported by e-waste recycling plants at the provincial level to process end-of-life EEEs to extract all useful raw materials and to responsibly dispose any residual material.

Opportunities also exist for supply of equipment, technology as well as off-take markets for the extracted raw materials.

Table 5.18: Potential SA partners in WEEE.

Organisation	City
Gauteng	
Desco Electronic Recyclers	Jhb
Effortless Computer Recycling (Boksburg)	Jhb
AST Recycling	Jhb
Oricol Environmental	Jhb
Go Green Electronic Recycling (Pretoria)	Pta
Western Cape	
Desco Electronic Recyclers	CT
Go Green Electronic Recycling (Pretoria)	CT
Oricol Environmental	CT
AST Recycling	CT
KwaZulu-Natal	
Desco Electronic Recyclers	Dbn
AST Recycling	Dbn
e-Waste Association of SA	Dbn
Recycle X	Dbn
E-Waste Africa	Dbn
Electronic Cemetery (Hillcrest)	Dbn

Organisation	City
E-Waste Technologies	Dbn
Mpact Recycling (Umbilo)	Dbn
Oricol Environmental	Dbn
Ecoholic Recyclers	Dbn
IT Recycling Solutions	Dbn
SW Collectors	Dbn
IT Liquidators Computer Recyclers	Dbn
Eastern Cape	
PE Metals E-Waste Recyclers	Gqeberha (PE)

5.8 Absorbent hygienic products

Source and quantification of the waste

Absorbent hygiene products (AHPs) such as infant and adult diapers and feminine hygiene products are regarded as general waste and as a result are discarded into the municipal waste collection system. Approximately 5% of MSW consists of other materials such as composite materials including AHPs [SoWR, 2018]. This is equivalent to approximately 240,000 tonnes per annum of AHP waste being disposed to landfills in South Africa [SoWR, 2021]. According to EPA, it is estimated that it takes 500 years for AHP to decompose, making them the third most common consumer product in landfill [Plotka-Wasylka, 2022]. For AHP circularity to be successful, solutions for S@S, collection and processing systems would be essential. These solutions would include clearly marked and re-sealable bins (or bags), drop off points (such as at creches and shopping centres), a reliable pick-up service and efficient processing of the waste.

Potential circular raw materials

AHPs consist of plastic, wood fibre, superabsorbent polymer (SAP) and adhesives. After use, a large proportion of the AHP weight is made up of human waste and liquids.

Table 5.19: AHP Raw materials by weight (kg/ton) [Espinosa-Valdemar et al., 2015].

Material Type	Mass (kg)/ton of Soiled AHP
Wood Fibre/Cellulose	150
Mixed Plastic	75
SAP	75
Liquids and bio-waste	700
Total	**1,000**

All of the AHP raw materials can potentially be recovered and converted into raw materials for the production of other value-added products:

Table 5.20: AHP Raw Material Types [Espinosa-Valdemar et al., 2015]

AHP Component	Potential raw material
Back sheet, top sheet, non-woven fabrics, adhesive tags	Plastic
Cellulose pulp	Wood fibre
SAP	SAP
Waste	Biomass/methane

Table 5.21: Potential market outlets for AHP Raw Materials [Saifudeen et al, 2022; Somers et al., 2021; Velasco et al., 2021]

Potential raw material	Potential markets
Plastic for plastic extrusion	Plastic recyclers and extruders
Pulp/Wood fibre for compost or combustion	Pulp factories, fossil fuel boilers
SAP for agricultural applications	Compost and topsoil suppliers, plant nurseries, farmers and horticulturalists
Biomass/methane	Gas to energy in bio-digester plants

Economic outputs from use of raw materials

When processed, the raw material could be used either separately or in combination to produce the following range of saleable products:

Table 5.22: Potential economic products from AHP [Saifudeen et al., 2022; Somers et al., 2021; Velasco et al., 2021]

Potential raw material	Potential products
Plastic	Extruded plastic products such as tool handles, bin bags, disposal utensils, straws, etc.
Pulp/Wood fibre	Recycled paper, liner board, paper board, sanitary paper, AHP etc.
SAP	moisture retention additives in soil, second generation AHP, etc.
Human waste	Methane for heating and power generation
Combo + waste	Sanitised and deodorised fuel pellets for fossil fuel boilers and kilns

Required Technology or process

A number of proven technologies are available to treat AHPs. These include incineration (complete destruction using plasma technology), composting (and recovery of plastic), autoclave (for recovery of AHP raw materials). The process that recovers the most amount of re-useable AHP material is the autoclave process, which when combined with a material separation unit, can separate the recovered materials into wood fibre, plastic and SAP. This technology is used by Fater Spa, in Italy, in a joint venture with Kimberley-Clark Corporation as well as previously by Knowaste in the United Kingdom (UK).

There is also technology (e.g. by the Superfaiths Diaper Corporation, Japan) that can process a batch of soiled AHPs and produce a deodorised fuel pellet, potentially suitable for use in boilers and kilns or for other heating purposes. The SFD unit does not require AHPs to be pre-cleaned or dried and processes even the plastic bag in which the soiled nappies are collected. This makes handling much safer and more hygienic.

Similar or other technologies available from the Netherlands would be welcome.

Potential reduction in greenhouse gases

The production of plastic, wood fibres and SAP from virgin raw materials generate greenhouse gases (GHG). Hence the use of these recycled materials would reduce the use of virgin raw materials and hence the generation of GHGs. One of the major greenhouse gases (GHGs) is CO_2 emitted from industrial plants using coal in boilers and kilns as an energy sourceThe use of solid fuel pellets, derived from AHPs, in boilers would also reduce GHGs as demand for coal reduces.

It is estimated that for every ton of AHPs produced (or recycled and re-circulated into the economy), approximately 6.67 tons of GHGs are avoided [Lindon, 2021].

Challenges in implementation

Identified challenges in the recycling of waste AHP include:

- Reluctance of consumers to separate out and drop off the used AHP at collection bins.
- Logistics associated with weekly collection from drop off points.
- Odours, flies and health risks during handling, processing and storage.
- Immature market for recyclables such as RDF, etc.;
- Achieving an acceptable price point for recyclables to make processing economical.

Table 5.23: Potential SA partners in AHP circularity.

Organisation	City
EDANA (Association of non-woven firms)	Jhb
Kimberly-Clark	Jhb
Kimberly-Clark	Jhb
Proctor & Gamble	Jhb
DFFE – CE	Pta
DFFE – CWE Phakisa	Pta

5.9 Glass

Glass makes up approximately 4.9% (2.7 million tonnes) of the general waste generated in SA [*SAWIC*, 2017]. About 4.5% of commercial and industrial waste is glass. Packaging glass such as bottles and jars, and flat/sheet glass such as windows, windscreens, and mirrors are the main types of glass waste in SA.

Table 5.24: Tonnages of Waste Glass by Type [SAWIC, 2017].

Type of glass	Approximate quantity
Packaging glass	964,424 tonnes
Float glass	260,000 tonnes

It is estimated that 305 590 tonnes of crushed glass to be used in the furnace is recycled in SA and at least 40% recycled glass is contained in bottles and jars annually. The amount of glass generated decreased by 189 816 tonnes from 959 816 tonnes in 2011 to 770 000 tonnes in 2017. The recycling rate however increased by 10% in recent years [SAWIC, 2017].

Table 5.25: Potential SA Partners in Glass Recycling [*SAWIC, 2017].*

Organisation	City
NAMPAK	Jhb
Coca-Cola Beverages SA (CCBSA)	Jhb
The Glass Recycling Co.	Jhb

5.10 Tyres

It has been estimated that approximately 174, 640 tonnes of waste tyre is generated in SA annually. Added to this is the estimated 350 000 to 650 000 tonnes of waste tyres stockpiled over the past few years [SAWIC, 2017].

Tyres are not permitted to be disposed to landfill sites under current SA regulations. A levy is imposed on all new tyres sold to fund the recycling of tyres. Of the estimated 76, 737 tonnes of waste tyres collected by the *Recycling and Economic Development Initiative of South Africa* (REDISA), only about 54% were processed. The REDISA was subsequently replaced by the Waste Tyre Bureau. However, the system is not operational, as none of the collected tyres are currently being recycled. Waste tyres are being stockpiled at the waste tyre depots or tyre retailers. The major tyre manufacturers in SA include:

- Apollo Tyres Africa (Pty) Ltd,
- Auto And Truck Tyres (Pty) Ltd,
- Bandag Southern Africa (Pty) Ltd,
- Bridgestone South Africa (Pty) Ltd,
- Bridgestone South Africa Commercial (Pty) Ltd,

- Bridgestone South Africa Retail (Pty) Ltd,
- Continental Tyre South Africa (Pty) Ltd,
- Goodyear South Africa (Pty) Ltd,
- Hi-Q Automotive (Pty) Ltd,
- Kwik Fit Brands (Pty) Ltd,
- Leader Rubber Company Sa (Pty) Ltd,
- Michelin Tyre Company South Africa (Pty) Ltd,
- Nuvo Solid Tyres (Pty) Ltd,
- Protea Versoolwerke (Ermelo) (Pty) Ltd,
- Sumitomo Rubber South Africa (Pty) Ltd,
- Tiauto Investments (Pty) Ltd,
- Trentyre (Pty) Ltd.

Table 5.26: Potential SA partners in tyre recycling.

Organisation	City	Province
South African Tyre Manufacturers Conference (SATMC)	Jhb	Gauteng
National Association of Automotive Component and Allied Manufacturers (NAACAM)	Jhb	Gauteng
The Automotive Business Council	Pretoria	Gauteng
Retail Motor Industry (RMI)	Jhb	Gauteng
Tyre, Equipment, Parts Association (TEPA)	CT	Western Cape
Tyre Importers Association of South Africa (TIASA)	Jhb	

5.11 Fly ash

Resource availability

Fly ash is produced during the combustion of coal in industrial boilers. Eskom alone produces in the region of 36 million tons of fly ash every year [Eskom, 2021], and there is an estimated 2 billion tons stockpiled in ash "dams", which pose an ongoing and significant environmental problem, apart from occupying space and causing a public nuisance.

Potential raw materials

Fly ash consists primarily of oxides of silicon, aluminium, iron and calcium. Magnesium, potassium, sodium, titanium, and sulphur are also present to a lesser degree. These elements make it a useful admixture to concrete.

When used as a mineral admixture in concrete, fly ash is classified as either Class C or Class F ash, based on its chemical composition.

The American Association of State Highway Transportation Officials (AASHTO) M 295 [*American Society for Testing and Materials (ASTM) Specification C 618*] defines the chemical composition of Class C and Class F fly ash.

Class C ashes are generally derived from sub-bituminous coals and consist primarily of calcium alumino-sulfate glass, as well as quartz, tricalcium aluminate, and free lime (CaO). Class C ash is also referred to as high calcium fly ash because it typically contains more than 20% CaO.

Class F ashes are typically derived from bituminous and anthracite coals and consist primarily of an alumino-silicate glass, with quartz, mullite, and magnetite also present. Class F, or low calcium fly ash has less than 10% CaO.

Table 5.27: Sample oxide analyses of ash and portland cement [ASTM, 2023].

Compounds	Fly Ash Class F	Fly Ash Class C	Portland Cement
SiO_2	55	40	23
Al_20_3	26	17	4
Fe_2O_3	7	6	2
CaO (Lime)	9	24	64
MgO	2	5	2
SO_3	1	3	2

Value Added products

Fly ash could be used with the blast furnace slag to produce geopolymers as alkali silica hybrid cement replacement with 90% lower CO_2 emissions. Just replacing imported cement, would save South Africa close to R1 bn per year, adding 1.3% to GDP [Aggregates Business, 2022].

Fly ash could offset cement usage annually and will still not deplete the total volume of fly ash produced each year as well all the ash in storage in ash dumps or dams. South Africa could become an exporter of low carbon ("green") cement to Africa and compete with more competitively priced products against countries such as France, Malaysia and China.

Using Eskom fly ash, would assist in decarbonising Eskom allowing it to continue using coal to meet the countries base load energy demand.

Greenhouse Gas reduction/carbon offset

SA currently uses 20Mt ordinary Portland cement (OPC) per year, with 13Mt manufactured locally and the balance of 7 million tons imported each year. The carbon footprint of locally produced cement is an average of 600kg/ton. The footprint for imported cement is higher due to the additional transport requirements.

Just meeting the local cement needs would save almost 11 million tons CO_2 emissions per year and meet most of South Africa's Nationally Determined Contribution (NDC) offset requirements. On the flip side, the carbon offset using a geopolymer cement for all our domestic requirements in the infrastructure sector, could offset the carbon emissions from coal-powered power stations to make coal-fired power essentially carbon neutral.

The diversion of fly ash from ash dams will not only have substantial cost savings but would gradually reduce their devastating impact on groundwater [Eskom, 2021].

Table 5.28: Potential SA partner in fly ash resources.

Organisation	Sector	Province
Eskom Waste Centre of Excellence	Power generation	Gauteng

Initiatives or interest in fly ash would invariably require discussions with Eskom, the national electricity utility.

5.12 Waste water and/or biogas

Wastewater treatment works (WWTWs) are increasingly regarded as water resource recovery facilities (WRRFs). Water resource recovery from wastewater using advanced treatment technologies is becoming increasingly understood and adopted in SA, especially by water-intensive industrial businesses that produce organic effluents such as in the agro-processing sector (food, beverage and abattoirs) and, increasingly, municipal effluent treatment departments. Apart from the recovered water, the other most common value-adds from organic effluents are biogas that is mostly used onsite, composting material, and a few organic products such as whey and starch (from agro-processing). Ironically, RSA remains one of the top importers of fertilisers and natural gas globally.

WWTPs at mines recover process water for reuse and the search for cheaper, effective and efficient metals and sulphur recovery techniques from mining effluents is ongoing.

Challenges to bear in mind

One of the prominent barriers in resource recovery at industrial scale is limited effluent availability, due to water recovery initiatives. The availability of higher effluent volumes, >6 500 minimum liquid discharge (MLD), at publicly owned municipal WWTWs nationwide presents a better business case. However, the lack of capital investment, ageing infrastructure, technical capacity and political support at RSA municipalities and impediments to public private partnerships (PPPs) have led to the poor adoption rate of resource recovery initiatives at municipal WWTWs [*NBI*, 2019]. Furthermore, legal frameworks governing the use and disposal of wastewater in RSA, particularly mining effluents, is onerous.

Main drivers

The main driver is the legal requirement and corporate social responsibility to treat effluents to compliance standards for disposal. The eutrophication of SA's natural water resources is one of the major threats and the Department of Water and Sanitation (DWS) is in the process of establishing an Anti-pollution Task Team (APTT) which will deal with escalating incidents of pollution across the country. There are punitive measures such as fines for non-compliance by industrial businesses while DWS is mandated to take all the necessary steps before taking any legal action against noncompliant municipalities. The ban on the landfilling of liquid (as of 29th August 2019) and initiatives by provincial authorities such as 100% biodegradable waste by 2027 (50% to be realised in 2022) in the Western Cape, has unlocked the potential for biogas and resource recovery projects at WWTWs. The national quest for water security has further improved the potential for investment in advanced wastewater treatment and/or water reclamation at municipalities.

Market opportunities

The food and beverage sector (mainly fruit and vegetable, yeast, dairy, animal slaughtering, wine, malting and brewing) plays an important role in RSA's economy, contributing ±24 % of the manufacturing sector's contribution of 13.53% towards gross domestic product (GDP) [StatsSA, 2018]. The sector is earmarked for national growth and development in various policies and mandates. It is mainly located in the water scarce metropolitans (eThekwini, Cape Town, Port Elizabeth & Johannesburg). However, the sector's growth is threatened by water and energy security, and levels of waste and wastewater management. Depending on the facility, between 70-95% of the feed water ends up as organic laden wastewater which attracts disposal costs, fines and possibly corporate brand damage if not meeting the discharge standards. Accordingly, wastewater and organic waste (including sewage sludge) treatment and resource recovery is becoming increasingly adopted across RSA. The treated wastewater can either be reused onsite for non-potable purposes, or further treated (e.g. using reverse osmosis) for potable purposes and any resultant biogas produced can be used for electricity generation to offset costs.

Opportunities within the sector

- Improved monitoring and metering systems
- Wastewater reuse schemes with/without energy (biogas) recovery
- Biogas projects for onsite use (heating and/or electricity generation)
- Recovery of phosphate (struvite), ammonia/nitrogen and compost/fertiliser material
- Digestate value add technology/processes, water and energy efficient equipment

- Improving feedstock quality – source separation, removal of contaminates such as packaging

Potential leads

The following effluent generators and technology providers may invest, partner and/or engage with interested parties interested in collaborating on recovery of resources such as water, nutrients, biogas, metals, ascetic acid or sulphates.

Table 5.29: Potential SA partners in wastewater treatment.

Description
Organic effluent generators
Municipal WWTPs:
City of Tshwane
City of Cape Town
EThekwini Municipality (City of Durban)
Ekurhuleni
City of Johannesburg
Buffalo City
Nelson Mandela Bay
Mangaung Metro
Private WWTPs:
Illovo Sugar Africa Mills
Tongaat Hullett Sugar
Langeberg and Ashton Foods
Fair Cape Dairies
Rhodes Food Group
Robertson Winery
Anchor Yeast (Lallemand)
Sappi Pulp and Paper
Mondi Pulp and Paper
Inorganic effluent generators
Anglo American Mining Corporation
Palabora Mining
Exxaro Resources
Umbogintwini Industrial Complex
Modderfontein Industrial Complex
Solution / technology providers
Proxa Water
Veolia Water Technologies South Africa
Memcon Filtration
Grundfos pumps

WEC Projects
Aquest Colsen (a South African subsidiary of Colsen BV)
BioGas Solutions
Green Create
Bio2Watt
GCX Africa
Agreenco
Botala Energy Solutions
Global Energy
Cape Advanced Engineering
Anaergia
Logical Waste
SustainPower
Fountain Green Energy

6. General risks and mitigation measures

South Africa is a developing country, grappling with the legacy of economic inequality, poor waste management service delivery and general lack of public awareness of the impact of waste on the environment. Furthermore, the CE is relatively immature and may appear disorganised to outsiders when compared to the Global North. Incoming businesses should therefore be aware of the following risks relating to doing business in SA's CE:

- Unstable market supply and demand
- Unavailability of accurate data on waste
- Operational limitations on processing facilities as a result of electrical loadshedding
- Financial and political instability
- Licensing and certification complications (environmental authorisations and technology licensing)
- Chinese influence – huge influx of Chinese buyers into the market destabilizing the pricing
- Energy reliability and escalating costs
- 90% energy comes from fossil fuels and may affect available markets for alternate energy sources
- Current instability of PRO and EPR schemes
- Government insistence on black shareholding of local enterprises that do business with the government sector (51% may not appeal to investors)
- Current grey-listing of SA financial markets
- Competitors in both recyclable materials, processing technology (local and international) and for markets of the outputs
- Onerous SA National Treasury supply chain management requirements and specifications to tender for contracts with state owned entities and national, provincial and local governments
- Delays in awarding tenders
- Reluctance of SA companies to share information due to risk of non-compliance or commercially confidential information
- Competition between waste service providers
- Bribery and corruption in tender processes
- Service delivery and worker protests that can stop or delay projects

While some of these risks may be out of the control of investors, many of the risks can be managed and even mitigated through a formal Dutch – SA CE partnership that would focus on aspects such as:

- Collection of the required CE and waste data
- CE market intelligence gathering
- How to establish a business in South Africa,
- Identifying and introduction to local partners and funders

- Support of capacity building of the sector through exchange programmes, short courses, etc.
- Partnerships with NGOs involved in the CE sector
- Accessing decision makers in the CE
- Consultations with stakeholders in all CE initiatives
- Making Dutch businesses aware of the different cultural and business practices
- Informing Dutch businesses about SA laws regarding business and the environment, provincial ordinances and municipal bylaws
- Supporting Dutch businesses wishing to enter South Africa with hand-holding through the business establishment process

7. Conclusion

The CE, which deals with the prevention of waste generation and minimisation of wastage across a resource's value chain, is now an essential part of SA's National Waste Management Strategy [2020]. Not only does the CE have a net positive environmental benefit, it can also create new enterprises, introduce new technology and skills, attract fixed investment, create employment and support the local and national fiscus.

A number of waste streams have for some time been used as economic resources, and in the process have created significant markets for themselves. These include for example leather (waste products from abattoirs), bagasse (waste from sugar and timber milling) and black liquor (from paper making) inter alia. Other waste streams, although of significant and growing volumes, have not been given much attention. These include waste from construction and demolition, fly ash from coal power stations, absorbent hygiene products (such as diapers), leather off-cuts, food waste (including oils & fats), waste from electrical and electronic equipment, automobile tyres, plastic waste and waste water.

This market assessment, undertaking by Lindon Corporation on behalf of ACEN and RVO, identified potential CE opportunities in the following waste streams for consideration by Dutch firms interested in doing business in South Africa's CE:

Table 6.1: Selected waste streams and economic products.

Waste	Economic Product/s
Abattoir waste	Waste to energy (biogas) Pet food Pharmaceutical applications
AHP	Plastic, wood fibres, SAP Refuse derived fuel
FTPP - Black liquor	Bio fuel
FTPP - Pulp sludge	Substrate for organic fish feed
C&DW	Aggregate for construction projects and roads Glass for water treatment and sand-blasting
WEEE	Precious metals and second-life components
Fly ash	Cement replacement, filler in cement-based adhesives, brick making, extraction of aluminium
Leather offcuts	Reconstituted leather for consumer goods
Waste water	Second class/industrial and/or irrigation water, toilet flushing, etc.
Bio-based effluent	Water, recovered solids and biogas

There are several other end-of-pipe waste streams that also present economic opportunities for Dutch firms to consider, such as:

- Multilaminate packaging
- Mining and mine processing waste fractions (blast slag from steel industry, coal slurry dumps, mine tailings, etc.)
- Agricultural residues (including forest residue, sugar molasses)
- Tyres and other rubber waste
- Industrial waste (chemicals and solvents)
- Flat glass
- Energy and heat loss from industrial and agro-processing

In order to take advantage of CE opportunities in South Africa, it is recommended that a multi-year programme, consisting of Dutch and South African partners, be established to identify and facilitate CE opportunities for Dutch businesses to take advantage of.

References

Additional references were added to the reference list for further reading.

Abubakar, I.R., Maniruzzaman, K.M., Dano, U.L., AlShihri, F.S., AlShammari, M.S., Ahmed, S.M.S., Al-Gehlani, W.A.G. and Alrawaf, T.I., 2022. Environmental sustainability impacts of solid waste management practices in the global South. International Journal of Environmental Research and Public Health, 19(19), p.12717.

African CE Alliance (2021). Five Big Bets for the CE in Africa, Insight Report African CE Alliance (2021). Five Big Bets for the CE in Africa, Insight Report.

Adeniran, A.A. and Shakantu, W., 2022. The health and environmental impact of plastic waste disposal in South African Townships: A review. International Journal of Environmental Research and Public Health, 19(2), p.779.

Adeleke, O., Akinlabi, S.A., Jen, T.C. and Dunmade, I., 2022. Environmental impact assessment of the current, emerging, and alternative waste management systems using life cycle assessment tools: a case study of Johannesburg, South Africa. Environmental Science and Pollution Research, 29(5), pp.7366-7381.

Agriportal. 2023. Only 60% of a cow is actually used for food — here's the weird stuff that happens to the other 40%. Available at https://agricultureportal.co.za/index.php/agri-index/86-other/7338-only-60-of-a-cow-is-actually-used-for-food-here-s-the-weird-stuff-that-happens-to-the-other-41. Accessed 05 August 2023

American Society for Testing and Materials. 2023. ASTM Specification C 618-23 Standard Specification for Coal Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. Available at: https://www.astm.org/standards/c618

Bandaw, T. and Herago, T., 2017. Review on abattoir waste management. Global Veterinaria,19(2), pp.517-524.

Brambila, K.G. 2010. Recycle Your Gadgets: Do Your Part To Eliminate e-Waste. Nebraska: Smart Computing. Available: https://archive.org/details/smart computing-magazine-v21i9, Accessed 20 October 2014.

European Parliament, 2023. News. *CE: definition, importance and benefits*. Available at www.europarl.europa.eu. 2015-02-12. Accessed 10 July 2021.

NREL. 2021. Circular Economy for Energy Materials. Available at https://www.nrel.gov/docs/fy21osti/78908.pdf Accessed 10 July 2021.

AEI Screens. 2022. The Challenges of E-Waste Recycling. Available at https://aeiscreens.com/news/the-challenges-of-e-waste-recycling/ Accessed 10 July 2021.

Circle Economy, 2023. The Circularity Gap Report 2023. Amsterdam. Available at: https://www.circularity-gap.world/2023. Accessed 13 July 2023.

Crickmay & Associates, 2004. Supply and demand Study of softwood sawlog and sawn timber in South Africa

CSIR. 2021. ‘Science, Technology and Innovation for a CE’ (STI4CE) Project. Pretoria, South Africa

Debrah, J.K., Teye, G.K. and Dinis, M.A.P., 2022. Barriers and challenges to waste management hindering the CE in Sub-Saharan Africa. Urban Science, 6(3), p.57.

Deme, G.G., Ewusi-Mensah, D., Olagbaju, O.A., Okeke, E.S., Okoye, C.O., Odii, E.C., Ejeromedoghene, O., Igun, E., Onyekwere, J.O., Oderinde, O.K. and Sanganyado, E., 2022. Macro problems from microplastics: Toward a sustainable policy framework for managing microplastic waste in Africa. Science of the Total Environment, 804, p.150170.

Department of Environmental Affairs. 2018. South Africa State of Waste. A report on the state of the environment. Final draft report. Department of Environmental Affairs, Pretoria. 112 pp.

Department of Environment, Forestry and Fisheries and Department of Science and Innovation (2020). Waste picker integration guideline for South Africa: Building the Recycling Economy and Improving Livelihoods through Integration of the Informal Sector. DEFF and DST: Pretoria.

Ecycleflorida, 2020. E-waste-recycling-facts-and-figures.com. Available at: https://ecycleflorida.com/ewaste-recycling-facts-and-figures/. Accessed 22 May 2022

Eskom. 2021. Eskom Integrated Annual Report 2021. Johannesburg.

Espinosa-Valdemar, R.M., Vázquez-Morillas, A., Ojeda-Benítez, S., Arango-Escorcia, G., Cabrera-Elizalde, S., Quecholac-Piña, X., Velasco-Pérez, M. and Sotelo-Navarro, P.X., 2015. *Assessment of gardening wastes as a co-substrate for diapers degradation by the fungus Pleurotus ostreatus*. Sustainability, 7(5), pp.6033-6045.

Eurekalert, 2011, US EPA joins alliance to curb global e-waste. Available at: https://www.eurekalert.org/news-releases/871105#:~:text=The%20US%20Environmental%20Protection%20Agency,with%20the%20United%20Nations%20University. Accessed 22 May 2022

Gaidajis, G., Angelakoglou, K. and Aktsoglou, D. 2010. E-waste: Environmental Problems and Current Management. Journal of Engineering Science and Technology Review, 3 (1): 193-199.

Go Legal. 2019. Electronic waste – The toxic legacy of our digital age. Available at: https://www.golegal.co.za/e-waste-treatment-facilities/ Accessed 24 May 2022

Godfrey, L.K., Gorgens, j.F. and Roman, H. (eds). 2018. Opportunities for Biomass and Organic Waste Valorisation: Finding Alternative Solutions to Disposal in South Africa. Pretoria: Unisa Press

Godfrey, L.K., Nahman, A., Oelofse, S.H., Trotter, D., Khan, S., Nontso, Z., Magweregwede, F. & Sereme, B.V. et al. 2021. The Circular Economy as Development Opportunity: Exploring Circular Economy Opportunities across South Africa's Economic Sectors. CSIR: Pretoria. http://hdl.handle.net/10204/12233.

Grandbio AVAP technology. Accessed online on 05.05.22. Available at: http://www.granbio.com.br/en/site/conteudos/avap-biorefinery-technology/

Charis, G., Danha, G. and Muzenda, E., 2019. A review of timber waste utilization: Challenges and opportunities in Zimbabwe. Procedia Manufacturing, 35, pp.419-429.

GreenCape. 2019. MAT19ZA05: Market Study for the CE of South Africa.

Henan Renewable. 2022. E-Waste PCB Recycling Machine. Available at: https://www.hnrenewable.com/Production-Line/Pcb-Recycling-Machine.html Accessed June 2023

Khan, R.L., Khraibi, A.A., Dumée, L.F. and Corridon, P.R., 2023. From waste to wealth: Repurposing slaughterhouse waste for xenotransplantation. Frontiers in Bioengineering and Biotechnology, 11, p.1091554.

Khurrum, M., Bhutta, S., Omar, A. and Yang, X. 2011. Electronic Waste: A Growing Concern in Today's Environment. Ohio: Ohio University Press.

Linnenkoper, K., 2018. Recycling International. Scottish researchers find way to target gold in e-scrap. Recycling International. Available at https://recyclinginternational.com/e-scrap/scottish-researchers-find-way-to-target-metals-in-e-scrap/17364/#:~:text=Researchers%20at%20the%20University%20of,project%20leader%20Professor%20Jason%20Love. Accessed 13 June 2023

Lindon Consulting. 2022. Research And Market Assessment to Determine Waste Streams with High Potential for Circularity in the South African Context. Durban. South Africa

Lindon Consulting. 2021. Processing of AHP into RDF and other raw materials. Durban. South Africa

Lindon Consulting Corporation. 2019. Business Plan: Electronic and Electrical Goods Refurbishment Centre. KZN Government Press.

Linganiso, E.C., Tlhaole, B., Magagula, L.P., Dziike, S., Linganiso, L.Z., Motaung, T.E., Moloto, N. and Tetana, Z.N., 2022. Biodiesel production from waste oils: a South African outlook. Sustainability, 14(4), p.1983.

Maes, T. and Preston-Whyte, F., 2022. E-waste it wisely: Lessons from Africa. SN Applied Sciences, 4(3), p.72.

Acda, M. 2010. Sustainable use of waste chicken feather for durable and low cost building materials for tropical climates. Sustainable Agriculture: Technology, Planning and Management. 353-366.

Mitchell, A. 2016. The Poultry Site. Plucky Idea – Turning Waste Feathers into Sustainable Opportunities. Available at https://www.thepoultrysite.com/articles/plucky-idea-turning-waste-feathers-into-sustainable-opportunities. Accessed 13 June 2023

Modica, A., Klinkenbork, V. 2001. Discover Magazine. Mad cow disease could wreak havoc in the US because nearly everything we taste has cow in it. Available at https://www.discovermagazine.com/health/cow-parts. Accessed 13 June 2023

Nahman, A., Haywood, L., Oelofse, S., Blanchard, R. & Smith-Adao, L. 2022. The economic impact of marine plastic debris in South Africa: A preliminary estimate. CSIR: Pretoria.

Nandy, S., Fortunato, E. and Martins, R., 2022. Green economy and waste management: An inevitable plan for materials science. Progress in Natural Science: Materials International, 32(1), pp.1-9.

Powell, D. 2013. Our World. Finding Solutions to China's E-waste Problem. Available at https://ourworld.unu.edu/en/assessing-and-improving-the-e-waste-problem-in-china. Accessed 20 May 2022

Owojori, O.M., Mulaudzi, R. and Edokpayi, J.N., 2022. Student's knowledge, attitude, and perception (KAP) to solid waste management: A survey towards a more CE from a rural-based tertiary institution in South Africa. Sustainability, 14(3), p.1310.

Philipp, M., Masmoudi Jabri, K., Wellmann, J., Akrout, H., Bousselmi, L. and Geißen, S.U., 2021. Slaughterhouse wastewater treatment: A review on recycling and reuse possibilities. Water, 13(22), p.3175.

Plotz, C. What is a bio-fibre. Available at https://www.fiberjournal.com/what-is-a-biofiber/. Accessed 04 May 2023

Ragasri, S. and Sabumon, P.C., 2023. A critical review on slaughterhouse waste management and framing sustainable practices in managing slaughterhouse waste in India. Journal of Environmental Management, 327, p.116823.

Rao, MN., Sultana, R., Kota, S. H. 2016. Solid and Hazardous Waste Management ([edition unavailable]). Elsevier Science. Available at https://www.perlego.com/book/1833167/solid-and-hazardous-waste-management-science-and-engineering-pdf

Rwanda Green Fund Investment, National E-Waste Recycling Facility. Available at https://www.flickr.com/photos/127716409@N05/36337504854. Accessed 19 May 2022

Sadan, Z. and De Kock, L. Plastics: Facts and Futures: Moving beyond pollution Management towards a circular plastics economy in South Africa. WWF South Africa, Cape Town, South Africa

Saifudeen, A., Kumar, M. and Mani, M., 2022. Sustainability Assessment in Disposable Baby Diapers by Adopting A Systems Approach. Environmental Engineering & Management Journal (EEMJ), 21(11).

Schröder, P. 2020. Promoting a Just Transition to an Inclusive CE. London: Chatham House.

Stafford, William & De Lange, Willem & Nahman, Anton & Chunilall, V. & Lekha, Prabashni & Andrew, Jerome & K Johakimu, Jonas & Sithole, B. & Trotter, D. 2020. Forestry biorefineries. Renewable Energy. 154. 10.1016/j.renene.2020.02.002.

Stigsson, C., Furusjö, E. and Börjesson, P., 2022. A model of an integrated hydrothermal liquefaction, gasification and Fischer-Tropsch synthesis process for converting lignocellulosic forest residues into hydrocarbons. Bioresource Technology, 353, p.126070.

Statista. 2019. Forecast-of-smartphone-users-in-south-africa 2014 to 2023. Available at https://www.statista.com/statistics/488376/forecast-of-smartphone-users-in-south-africa/, Accessed 20 August 2023

Statista. 2023. Most common second-hand purchases by category in China as of June 2023. Available at https://www.statista.com/forecasts/1348226/most-common-second-hand-purchases-by-category-in-china. Accessed 30 August 2023

Somers, M.J., Alfaro, J.F. and Lewis, G.M., 2021. Feasibility of superabsorbent polymer recycling and reuse in disposable absorbent hygiene products. Journal of Cleaner Production, 313, p.127686.

Timm, S. 2021. The Tyre Industry in South Africa 2012. Who Owns Whom. Available at https://www.whoownswhom.co.za/store/tyre-industry-south-africa/

Greenpeace. 2010. Toxic Transformers - a review of the hazards of brominated & chlorinated substances in electrical and electronic equipment. Available at www.greenpeace.to/publications/Toxic-Transformers-2010.pdf. Accessed 30 June 2023

TRT World. 2019. Nigeria has become an e-waste dumpsite for Europe, US and Asia. Available at https://www.trtworld.com/magazine/nigeria-has-become-an-e-waste-dumpsite-for-europe-us-and-asia-24197. Accessed 22 May 2022

United Nations Climate Change. 2022. E-waste: From Toxic to Green, India. Available at cop23.unfccc.int/climate-action/momentum-for-change/lighthouse-activities/e-waste-from-toxic-to-green. Accessed 20 May 2022

United Nations University and Step Initiative. 2014. One global definition of e-waste. Bonn: United Nations University.

United Nations University, 2014, The Global E-waste Monitor 2014: Quantities, Flows and Resources, United Nations

Velasco Perez, M., Sotelo Navarro, P.X., Vazquez Morillas, A., Espinosa Valdemar, R.M. and Hermoso Lopez Araiza, J.P., 2021. Waste management and environmental impact of absorbent hygiene products: A review. Waste Management & Research, 39(6), pp.767-783.

von Blottnitz, H., Virag, D., Wiedenhofer, D., Haas, W., 2021. Challenging but promising: South Africa's transition towards a circular economy.

Wang, F., Kuehr, R., Ahlquist, D. and Li, J. 2013. E-waste in China: A country report. Bonn: United Nations University.

Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. Archived 2011-03-04 at the Wayback Machine EUCAR / Concawe /JRC Well-to Wheels Report Version 2c, March 2007

Western Cape Department of Environmental Affairs and Development Planning. State Of Waste Management Report 2020.

Western Cape Department of Environmental Affairs and Development Planning. 2022. Western Cape Integrated Waste Management Plan 2022-2027 (Draft)

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Contact
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