Mapping South Africa's Waste Electrical and Electronic Equipment (WEEE) Dismantling, Pre-Processing and Processing Technology Landscape

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Executive Summary

This report provides an assessment of waste electrical and electronic equipment (WEEE) recycling technology, in operation in South Africa, in 2016. The report, prepared by Mintek on behalf of the Department of Science and Technology (DST), aims to –

- Assess local technology solutions and treatment capacity for the dismantling, pre-processing and processing of WEEE; gaps in local technology solutions that could support increased local processing of WEEE; and opportunities for new areas of technological innovation;
- Support future WEEE research, development and innovation in South Africa to ensure that opportunity areas, and key gaps are addressed;
- Capacitate the sector through public access to information, in order to improve the understanding of the potential business opportunities in recycling of WEEE;
- Support the diversion of WEEE away from landfill towards reuse and recycling; and
- Support the development of a local, regional, secondary resources economy that provides maximum local social and economic benefit.

The study, undertaken between May 2016 and March 2017, involved a strong research component. Primary data was collected by means of a structured questionnaire (comprising 20 questions) distributed to WEEE recycling firms and followed by face-to-face interviews with 27 firms. These firms are engaged in the dismantling, pre-processing and processing stages of the WEEE value chain, across the three prioritised waste streams – ICT & consumer electronics; lamps; and large and small household goods (including temperature exchange equipment). In sampling these firms, a balance between type, size of firm, position on the value chain, and geographical location was made. Given the constraints in the project budget and timeframes, the study areas were limited to Gauteng, KwaZulu-Natal (KZN), Western Cape, Eastern Cape and Mpumalanga. In this way, data collection activities were optimised to ensure coverage of the bulk of WEEE flows in South Africa.

A summary of the main findings and recommendations arising from the study are presented below.

Notable sector dynamics and trends:

- The South African WEEE industry has become more integrated, formalised and diversified over the past decade[1].
- Over 100 formerly registered companies operate across the WEEE recycling value chain (from collection to processing) in South Africa.
- The WEEE recycling sector remains dominated by a few well-established 'consolidator' companies (85% of volumes handled in 2015).
- Most small- to medium-sized firms concentrate in earlier stages of the value chain (i.e. dismantling). The number of firms offering location-specific[2] collection, dismantling and refurbishment activities have increased over the past five years.
- Gauteng remains the central 'hub' for the collection, consolidation, pre-processing and processing of WEEE in South Africa (±55% of volumes handled in 2015). The Western Cape, KZN and Eastern Cape are important provincial aggregation and sourcing nodes.
- The SADC region is emerging as an important supplementary source of WEEE inputs to the South African recycling sector and is expected to increase in importance as competition for local inputs intensifies.
- Barriers to entry are high at the pre-processing and processing stages and in specialised waste streams (e.g. lamps), but comparatively lower

[1] "Integrated" – refers to the fact that firms are no longer just restricting their activities to one stage in the value chain, but are increasingly straddling two or more. "Diversification" – refers to the fact that firms are increasingly broadening their product focus (focusing on more than one waste stream), service offering (engaging in complementary activities such as refurbishment) and geographic footprint (within South Africa and neighbouring countries) in response to increased competition and variable flows of WEEE.

[2] For example, companies focusing on specific geographical markets include *inter alia* Bolunga Enterprise (Pty) Ltd (Eastern Cape), Electronic Cemetery e-Waste Management Ltd (KZN), Sibanye Recycling Ltd (KZN) and Virgin Earth Ltd (Western Cape).

at the dismantling stage. Skills and technology are not the determining factors, rather access to WEEE volumes is.

- WEEE recycling is not profitable as a standalone business for small firms, with 58% regarding it as a secondary activity. Most small dismantlers complement WEEE recycling with refurbishment, which is regarded as being more profitable (making up to 60% of revenues).
- In 2015, approximately 17,733t of WEEE was handled by the 27 firms[3], with the largest source of inputs being from government departments (45%). ICT & consumer electronics made up the largest contributing waste stream (79%).
- The WEEE recycling sector is currently not a significant employer, with approximately 677 people employed across 18 firms in 2015. However, at 25 jobs/1,000t handled, the sector has the potential to increase this number as more WEEE is unlocked into the value chain.
- The main output fractions produced by firms in 2015 were ferrous (47%) and non-ferrous (16%) metals, and printed circuit boards (PCBs) (16%). PCBs remain the most valuable fraction.
- Firms are committed to process locally as far as possible, but complex fractions are exported – 90% PCBs, 60% phosphor powders, and some ferrous and non-ferrous metals are exported to Asia and Europe.
- The local re-manufacturing of WEEE plastics and glass fractions is still limited in South Africa. Approximately 80% of the 7,500t of electronic plastic fraction produced in South Africa in 2015 was exported, while the remaining 20% was beneficiated locally. In the case of glass, 90% (mostly from lamps) of the 800t produced in 2015 was beneficiated locally, while the other 10%, composed of mainly cathode ray tube (CRT) glass, was landfilled.
- The co-treatment of WEEE by pyrometallurgical processes is an established means of deriving value from precious and other metals contained in dismantled WEEE, specifically PCBs. However, the high levels of capital investment required, volumes of WEEE needed to ensure sufficient economies of scale, and associated environmental impacts, suggest that it is currently an unviable business opportunity in South Africa.

Overall, it is evident that the current growth and dynamism of the WEEE recycling sector in South Africa is not determined by the availability, sourcing and operation of technology per se, but by the availability and volumes of WEEE released into the system to process and recycle. Access to sufficient volumes of WEEE appears to be the most significant constraint to growing the South African WEEE recycling industry and in moving firms from their current manual dismantling and limited pre-processing, to greater processing and local value recovery. The result is that firms are starting to tap into easily accessible WEEE from the SADC region to utilise available, local treatment capacity. Yet recycling of WEEE generated in South Africa remains low at only 11% (DEA, 2012a).

For South Africa to strengthen its local and regional WEEE dismantling, pre-processing and processing capacity, and invest in additional technology, will require greater efforts by the public and private sectors to access WEEE out of the waste stream. Advancing the environmental, socio-economic and technological objectives of reducing the volumes of WEEE landfilled annually, expanding the base of recyclers and employees engaged across all stages of the value chain, and enhancing R&D and innovation in managing complex fractions will require a collaborative, committed and focused approach by all stakeholders to address this challenge going forward.

The key findings are presented schematically in the following Figures and Tables.

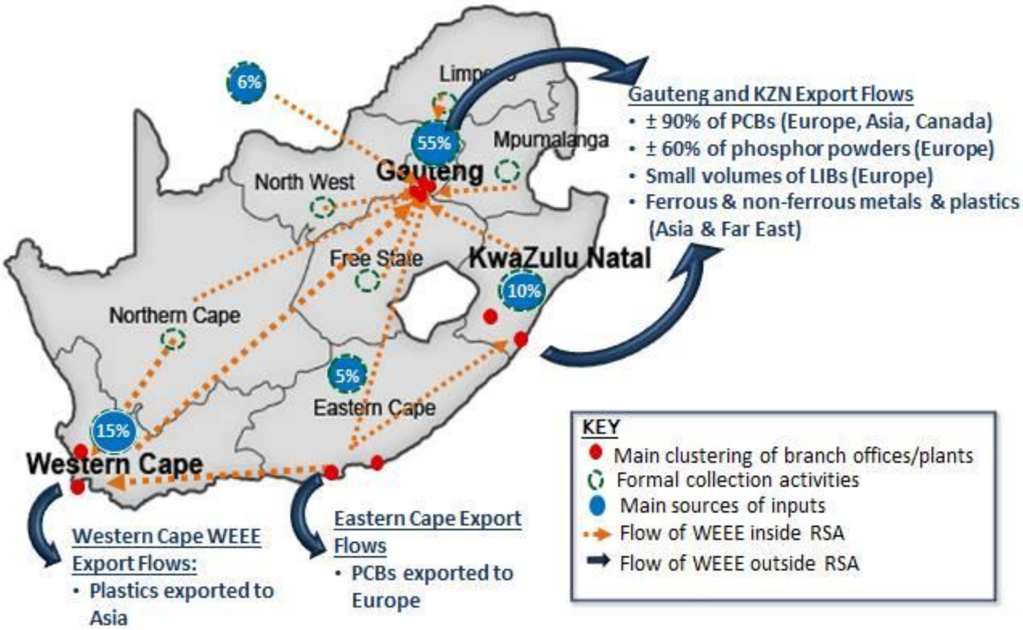
Key recommendations and interventions, based on the findings of this research as well as recommendations put forward by the firms interviewed, are presented in the last Table.

[3] This is equivalent to 23.6% of the estimated 74,923 t of WEEE produced in 2015 (see Section 2.2).

SOUTH AFRICA WEEE TECHNOLOGY ANALYSIS: MAIN FINDINGS

Geographic Scope of WEEE Activities: Inputs & Outputs

(94% of WEEE inputs sourced nationally, 6% from sub-Saharan Africa)



Study sample – 27 firms

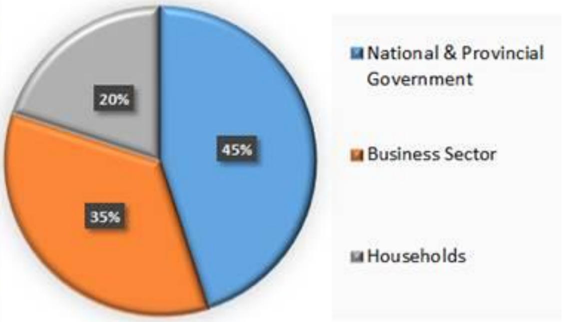
The four stages comprising the South African WEEE value chain

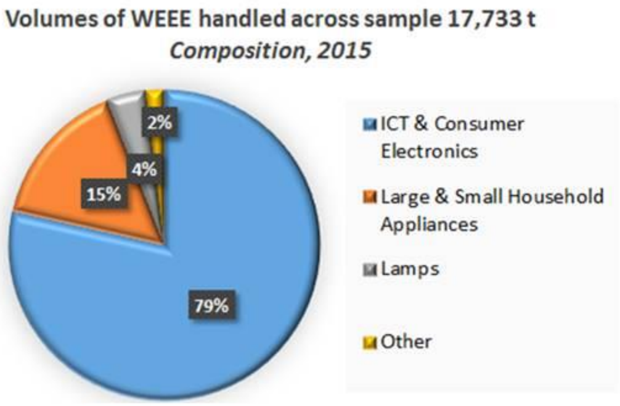
677 people employed in WEEE activities (across 18 firms)
- Dismantling firms = typically 5-25 people employed
- Pre-processing firms = >100 people
- ± 25 jobs/1,000t handled

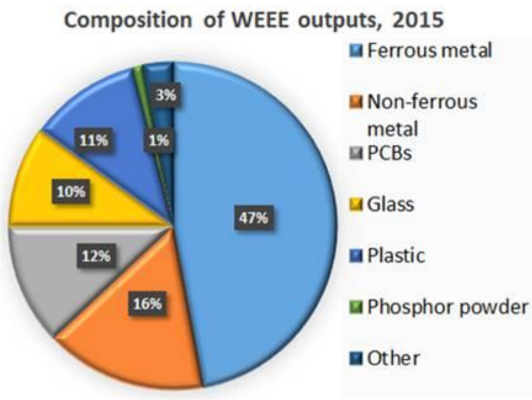
Firm participation across the WEEE value chain

Company	Collection	Dismantling	Pre-processing	Processing
Africa E-Waste	●	●		
Bolunga Electronic Waste	●	●		
Cape E-Waste	●	●		
Computer Scrap Recycling	●	●		
Desco Electronic Recyclers	●	●	●	
Effortless Computer Recycling	●	●		
Electronic Cemetery	●	●		
eWaste Africa	●		●	
E-waste Technologies	●	●		
Inca Metals	●	●		
Indalo Resources	●	●		
Just PC	●	●		
Javco			●	
Metrex	●	●		
Rand Refinery				●
Reclam	●	●		
RecLite	●		●	
SA Metals Group	●	●	●	
SA Precious Metals				●
Sibanye Recycling	●	●	●	
Sims Recycling	●	●	●	
Sindawonye	●	●	●	
SmartMatta (Re-Ethical)	●			
Tshwane Electronic Waste	●	●		
Universal Recycling Company	●		●	
Virgin Earth	●	●		
Waste Plan	●			

Sectoral sources of WEEE in South Africa, 2015







Local and foreign end-user market split for outputs

Company	PCBs	Ferrous Metals	Non-ferrous Metals	Glass	Phosphor Powders	Plastic	Other
Africa E-Waste	PP	PP	PP	▲		PP	
Bolunga Electronic Waste	PP	PP	PP			PP	
Cape E-Waste	PP	PP		PP		PP	
Computer Scrap Recycling	FP	FP	FP			FP	
Desco Electronic Recyclers	FP	PP	PP	PP		FP	▲ FP
Effortless Computer Recycling	PP	PP	PP			PP	
Electronic Cemetery	PP	PP		▲ PP		PP	▲
eWaste Africa	PP	PP	PP	PP	▲ (orange)	▲ (orange)	▲
E-waste Technologies Africa	FP	PP	PP			PP	
Inca Metals		PP	PP				
Indalo Resources	PP	PP	PP	▲		PP	
Javco						PP	
Metrex	PP	PP	PP			PP	
New Reclamation Group	FP	PP FP	PP FP	PP		PP	▲ FP
RecLite	PP	PP	PP	PP	FP	PP	FP
SA Metals Group	PP	PP	PP			PP	PP
Sibanye Recycling	PP	PP	PP	▲		PP	FP
Sims Recycling	FP	PP	PP FP	▲		PP FP	
Sindawonye	FP	PP FP	PP FP			PP	▲
SmartMatta (Re-Ethical)	PP	PP	PP			PP	
Tshwane Electronic Waste	PP	PP	PP	PP		PP	
Universal Recycling Company	FP	PP FP	PP FP			▲	
Virgin Earth	PP	PP	PP	▲		FP	▲

Key: PP = Local pre-processor/Processor FP = Foreign Processor ▲ = Landfilled ▲ (orange) = Stockpiled

Note: Local Pre-Processors (LP) are predominantly intermediary companies in South Africa that consolidate WEEE fractions, particularly PCBs and plastics produced by small- and medium-sized recyclers, before pre-processing and exporting them to Europe, America and Asia.

Foreign Processors (FP) are integrated smelting, refining and plastics recycling companies in Europe, America and Asia that recover valuable secondary materials from WEEE fractions produced in South Africa.

Key findings from the technology assessment are presented in the table below.

Technology Assessment Criterion	Dismantling Stage	Pre-processing Stage	Processing Stage (Local)
Technologies & equipment currently in use across stage and waste stream	**ICT & Consumer Electronics**		
	• Done manually using pneumatic or electric screwdrivers, pliers, drills, chisels, hammers and grinders	• Shredders, mills, hammers, grinders and pulverisers • Dense media separators, rotatory magnets and eddy current separators • Water separation tables • Scrubbers	PCBs (shredded or whole) • Completely automated, modular hydrometallurgical process • Pyrometallurgical processing possible in a gold refinery
	Large & Small Household Goods (Including Temperature Exchange Equipment)		
	• Done manually using pneumatic or electric screwdrivers, hammers and chisels, pliers and grinders • De-gassing pumps	• Static and mobile shears, high density ferrous and non-ferrous metal balers • Briquetting machines • Shredders, croppers, grinders, gas cutting equipment, raspers and granulators • Rotatory magnets, eddy current separators, cyclones • Water separation tables • Scrubbers	Ferrous and Non-ferrous Metal • Argon-oxygen decarburisation technology used to recover ferrous metal fractions from scrap metal in foundries • Pyro- and hydrometallurgical processing for non-ferrous metal fractions in smelters and refineries
	Lamps		
	• No dismantling required	• Mechanised lamp crushing, separating and cleaning systems (MRT or Balkan)	Phosphor Powders: • No REE refinement undertaken locally
	Other (e.g. Cables)		
	• Pneumatic or electric screwdrivers, pliers, cable jacket strippers, 'Kevlar' scissors	• Super croppers, croppers, rippers, grinders, granulators and water tables to separate the metallics from the inorganics and contaminants	Plastics • Incinerated or processed further by means of pyrolysis or extrusion Glass • High temperature smelting
Adequacy of current technologies & current capacity utilisation rates	• Equipment is rudimentary but sufficient for current firm requirements • Firms consider it uneconomic to invest in mechanised dismantling or to diversify into automated pre-processing without a significant increase in WEEE volumes received	• Technologies and solutions used to pre-process input WEEE are aligned with international best-practice and considered satisfactory to manage current WEEE streams handled • Most firms operating below capacity (30-50%) due to variable and low volumes.	• Emerging technologies for complete PCB recycling and metal recovery in South Africa. Local refinery operating at current capacity, but can be scaled up if volumes increase. • Local technology solutions lacking for CRT, LIB and temperature exchange equipment recycling – local volumes do not justify the establishment of such plants • Local WEEE plastic and glass cullet market is very small and unpredictable.
Biggest challenges affecting sourcing, operating and implementing technologies	• Low and inconsistent WEEE volumes • Insufficient investment in refurbishment infrastructure and skills development • Regulatory uncertainty, high costs of compliance, and time taken to secure a hazardous waste license • High logistics, transportation and warehousing costs	• Low WEEE collection volumes in South Africa – results in the inability to achieve economies of scale, remain profitable and invest in upgrading and expanding operations • Export restrictions and duties levied on particular WEEE fractions	• Tendency by local pre-processors to export PCBs than to process them locally (due to higher prices received and presence of a captive market for shredded fractions). • Locally-available technology for the hydrometallurgical processing of whole PCBs is available, but is proprietary and will be used solely by the owner. There may be scope for the development of competitive hydrometallurgical technologies by others, but this will likely be a standalone process rather than one capable of co-processing WEEE and other feedstocks. • In the case of the possible pyrometallurgical treatment of PCBs to recover gold, the current smelter can be reconfigured provided there is a consistent supply of feedstock material and that PCBs are incinerated off-site and delivered as ash to the refinery.

Recommendations to address these challenges are presented in the table below.

Recommendation	Potential Impact/s	Responsible Department/ Organisation
Expediting the implementation of the Extended Producer Responsibility (EPR) scheme in WEEE Industry Waste Management Plan	• Regulatory certainty • Establishment of a nation-wide, properly financed WEEE collection scheme and increased WEEE collection volumes • Financing the development of WEEE collection infrastructure to reduce costs and the recycling of negative value products	• Department of Environmental Affairs
Establishment of concessionary funding windows for the mechanisation of the WEEE sector	• Given the low margin nature of the recycling business, government funding support will help to lessen the financial burden/costs associated with mechanising operations	• Department of Trade & Industry, IDC
Removal of restrictions on access to export markets	• Enable recyclers to get full value for WEEE fractions from export markets, rather than compel them to sell to domestic markets where the prices they receive are lower than prevailing international market price • While incentivising the establishment of local markets to attract recyclers to sell locally instead of exporting	• Department of Trade & Industry
Promoting the use of non-hazardous WEEE plastics in plastics products designed for markets such as plumbing pipes and gutters for low cost houses	• Preferential certification of WEEE plastics products with South African Bureau Standards (SABS)	• Department of Trade & Industry
Incentivising the development of EEE refurbishment infrastructure	• Encouraging the re-use of WEEE, particularly PCs and fridges, which ranks higher than recycling in the waste hierarchy and has the potential to create more jobs than recycling • Capacitating small and medium recycling companies that currently derive 60% of their revenues from refurbishment compared to the 40% from recycling activities	• Department of Environmental Affairs • Department of Trade & Industry
Embarking on greater public awareness campaigns aimed at communicating the benefits of recycling WEEE in order to grow collection volumes	• Reduce the perception of high residual value of WEEE (R1/kg in South Africa) but is free in developed countries	• All stakeholders (government, industry, associations, academia, public) • DEA to champion the clarification of PFMA & MFMA provisions on WEEE
Business and government consider changing business model with respect to EEE ownership, e.g. moving from purchasing to leasing to support greater return of end-of-life products to the value chain	• Reduce the high storage rates of obsolete WEEE in government departments due to issues around assets, security and the PFMA and MFMA provisions	• All stakeholders (government, industry, associations, academia, public)
Creation of a 'one stop shop' for hazardous waste licensing and other compliance requirements for WEEE recyclers	• Regulatory certainty by providing support to the WEEE recycling industry (from a single department or entity) • Issuance of hazardous waste licenses, transport and WEEE export permits under one roof • Timeous finalisation of hazardous waste licenses (currently taking between 2-4 years to be concluded) • Convenience to recycling companies and investors	• Department of Environmental Affairs

Establishment of EEE data management system	• Establish the quantities of EEE put on the market per annum:
	  ○ Imports and exports of WEEE
	  ○ Installed capacity of EEE in government, business and household
	  ○ Average useful lives of EEE
	  ○ Storage & recycling rates of WEEE
		• Statistics South Africa

Capacitate and strengthen collaborative R&D work on the processing of complex WEEE fractions, e.g. phosphor powders containing REE, PCBs, plastics and CRTs	• Through uptake of R&D and technologies, unlock resources (and value) back into the economy • Mintek and the universities have already done some exploratory work on the establishment of a refinery for REE in South Africa • Future R&D activities should determine the feasibility of using lamp phosphor powders as one of the alternative secondary source of REE materials in South Africa.	• Department of Science and Technology • Universities • Science Councils • Recycling companies

Contents

List of Figures

List of Tables

Abbreviations

Abbreviation	Definition
Al	Aluminium
AOD	Argon Oxygen Decarburisation
Au	Gold
BOF	Basic Oxygen Furnace
CAGR	Compound Annual Growth Rate
CCFTs	Cold compact fluorescent lamps
CFC	Chlorofluorocarbon
CFL	Compact Fluorescent Lamp
CRT	Cathode Ray Tube
Cu	Copper
DEA	Department of Environmental Affairs
DST	Department of Science and Technology
EEE	Electrical and Electronic Equipment
EoL	End of Life
EPR	Extended Producer Responsibility
EU	European Union
eWASA	E-waste Association of South Africa
E-waste	Electronic Waste
Fe	Iron
HCFC	Hydrochlorofluorocarbons
HIDL	High Intensity Discharge Lamp
ICT	Information and Communication Technology
IDC	International Data Corporation
IT	Information Technology
kg	kilogram
Kg/hr	Kilograms per hour
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LIB	Lithium Ion Battery
LSM	Living Standards Measure
MRA	Metal Recyclers Association
Mt	Million tonne
MVA	Mega Volt Amp
NEMWA	National Environmental Management Waste Act
NiCd	Nickel Cadmium
NiMH	Nickel Metal Halide
NRA	National Recycling Association
NRF	National Recycling Forum
ODS	Ozone Depleting Substances
OECD	Organisation for Economic Cooperation and Development
OEM	Original Equipment Manufacturer
PCB	Printed Circuit Board
Pd	Lead
PGM	Platinum group metals
RDI	Research, Development and Innovation
REE	Rare Earth Elements
SADC	Southern African Development Community
Sb	Antimony
Se	Selenium
SMME	Small, medium and micro enterprise
Sn	Tin
StEP	Solving the E-waste Problem
t	tonnes
Te	Tellurium
TSL	Top Submerged Lance
UNEP	United Nations Environment Programme
WEEE	Waste Electrical and Electronic Equipment
Zn	Zinc

Introduction

Assessing the WEEE dismantling, pre-processing and processing technology landscape in the formal WEEE recycling economy in South Africa is a necessary first step in establishing a benchmark of South Africa's current recycling capacity, what technology gaps and constraints exist, and what interventions are required to unlock potential business opportunities in the sector

1.1 Purpose of the study

The Council for Scientific and Industrial Research (CSIR) has been contracted by the Department of Science and Technology (DST) to implement the 10-year Waste Research, Development and Innovation (RDI) Roadmap for South Africa. The Roadmap aims to maximise the diversion of waste away from landfill towards value-adding opportunities, as a means of supporting the implementation of policy, strategy and planning on waste and secondary resources management in South Africa. This includes the prevention of waste and the optimised extraction of value from reuse, recycling and recovery, in order to create significant social, economic, and environmental benefit, through the investment in research, development and innovation.

One of the five priority waste streams to be addressed under the *Waste RDI Roadmap (2015-2025)* is waste electronic and electrical equipment (WEEE). Due to increased consumer demand, perceived obsolescence, rapid changes in technology and inventions of new electronic devices, WEEE has emerged as one of the fastest-growing waste streams globally[4]. WEEE encompasses a range of products, from refrigerators to small toys, as well as a diversity of fractions including metals, plastics, wood, glass, chemicals and other substances. Aside from the environmental benefits of redirecting end-of-life (EoL) WEEE from landfill sites (many of which contain hazardous materials), the recovery and processing of WEEE represents an important source of secondary metal supply, particularly for critical 'strategic' high-value, hard-to-access metals[5]. Further, the metallic value of components and the rate at which WEEE is being generated also presents a significant opportunity to expand and diversify the small- and medium-sized business sector, particularly in developing countries[6].

Despite these advantages, however, the percentage of WEEE currently successfully recycled globally remains small. In South Africa, it is estimated that 11% of WEEE is currently recycled annually, with a significant percentage of the valuable metals, contained in complex fractions, exported for subsequent processing[7]. Most of the WEEE generated in South Africa is stored in national and provincial government departments, business entities and households, while some leaks into the waste system and is eventually disposed of in municipal landfill sites. Valuable WEEE items are salvaged by informal collectors operating on these landfill sites.

To date, the focus of WEEE recycling activities in South Africa has largely been on the recovery of ferrous and non-ferrous metal fractions mainly due the well-developed state of the downstream metals recycling sector. The non-availability of technology and lack of investment in local WEEE recycling technology are often cited as explanations for the low levels of recycling in South Africa, particularly for certain components (e.g. cathode ray tubes [CRTs]) and complex fractions such printed circuit boards (PCBs), phosphor powders, and certain types of plastics and glass.

Developing appropriate strategies and interventions

[4] Widmer et al., 2005; van Nos & Cramer, 2006; Allwood et al., 2010; Baldé et al., 2015

[5] See Gramatyka et al., 2007; Goodship & Stevels, 2012

[6] Hicks et al., 2005; Widmer et al., 2005; Babu et al., 2007

[7] DST, 2012

has also been limited by the lack of available data. Although various studies have been conducted reviewing the nature of the WEEE situation in South Africa, and analysing case studies of various product streams and national flows[8], no single comprehensive assessment of WEEE dismantling, pre-processing and processing technology currently in operation has yet been undertaken for the country. From a policy perspective, such an assessment is regarded as a critical first step in establishing a benchmark of what our current recycling capacity is, what technology gaps and constraints exist, and what interventions are required to unlock potential business opportunities in the sector.

1.2 Aims and objectives

The overall objective of this research was to assess the WEEE dismantling, pre-processing and processing technology landscape in the formal WEEE recycling economy in South Africa, focusing specifically on three pre-identified WEEE streams and their resultant secondary material fractions. The envisaged outcomes from the study are as follows:

- To assist the DST in assessing local technology solutions and WEEE treatment capacity, gaps in local technology solutions that could support increased local processing of WEEE, and opportunities for new areas of technological innovation;
- To support future WEEE research, development and innovation in South Africa to ensure that opportunity areas, and key gaps, are addressed;
- To capacitate the sector through public access to information, in order to improve the understanding of the potential business opportunities in recycling of WEEE;
- Support the diversion of WEEE away from landfill towards reuse and recycling; and
- To support the development of a local, regional, secondary resource economy that provides maximum local social and economic benefit.

1.3 Research approach

A three-pronged approach was employed for collecting and validating the data used in this study:

- **Primary data collection** – A priority of the study was to advance primary data collection in the WEEE recycling sector in South Africa. As such, the distribution of an electronic questionnaire (see Appendix A), supplemented with face-to-face and telephonic interviews, comprised the main research tool used in the study. The research sample comprised of 27 recycling companies. Firms were selected according to where they are positioned in the WEEE value chain; the type of waste managed and output fraction produced; the scale of activities undertaken locally; evidence of technology utilisation; and whether the firm is a member of an accredited association. Firms were consulted over a five month period, between August 2016 and January 2017.
- **Secondary research** – A desktop review of past work and reports of relevance and publicly-available secondary sources was adopted to establish the broad trends and dynamics influencing the WEEE recycling industry in South Africa; the scope and nature of the various WEEE waste streams; end user markets for fractions; and the nature and availability of technology used in the dismantling, pre-processing and processing sub-sectors.
- **Leveraging off existing internal expertise** – Mintek has been involved in research and development (R&D) around the treatment of complex waste for a number of years. It has also led research into various aspects of 'urban mining' and the development of an e-Waste Implementation Toolkit (EWIT), funded by the European Commission. This past work and expertise was leveraged in the execution of this project, particularly around determining

[8] See for example Finlay, 2005; Widmer & Lombard, 2005; Zumbuehl, 2006; Finlay & Liechti, 2008; Muzenda, 2014; Nyanjowa et al., 2015

the viability of establishing co-processing/integrated treatment plants in South Africa to process complex WEEE.

1.4 Parameters and delimitations

1.4.1 Value chain parameters

Typically, the formal WEEE value chain consists of four stages – collection, dismantling, pre-processing, and processing (Figure 1).

Figure 1: The four stages of the WEEE value chain

This study explored the technologies used in dismantling, pre-processing and processing WEEE in South Africa. The refurbishment stage was excluded from the analysis, as an entirely different range of technologies and set of skills is required. Although there is an intricate web of informal activities characterising the WEEE recycling sector, only formal activities were reviewed given their technology focus.

1.4.2 Definition of WEEE

'Electronic waste' or 'e-waste' for short is a generic term embracing various forms of electric and electronic equipment that have ceased to be of any value to their owners without the intent of reuse. Although there is no standard definition for WEEE as yet[9], this study adopts the definition provided by the European Union (EU) Directive - "*Electrical or electronic equipment … is waste… including all components, sub-assemblies and consumables, which are part of the product at the time of discarding*." Directive 75/442/EEC, Article 1(a) defines "waste" as "*any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force*[10]."

[9] See the following for different definitions: Basel Action Network (Puckett & Smith, 2002); OECD, 2001; StEP (2005), Widmer et al. (2005)
[10] EU, 2002

1.4.3 Geographic scope

From a geographic perspective, the scope of the study was limited to dismantling, pre-processing and processing activities in five provinces – Gauteng, Western Cape, KwaZulu-Natal (KZN), Mpumalanga and Eastern Cape. These provinces were selected based on current recycling activities, population and the scale of economic activities within them.

1.4.4 Product scope

From a product perspective, the study focused on six categories of WEEE (Table 1).

Table 1: The six categories of WEEE

Category	Definition
Temperature exchange equipment	Also referred to as cooling and freezing equipment. Encompasses refrigerators, freezers, air conditioners, heat pumps.
Screens and monitors	Equipment containing screens having a surface greater than 100cm^2. Includes televisions, monitors, laptops, notebooks, and tablets.
Lamps	Typical equipment comprises straight fluorescent lamps, compact florescent lamps (CFLs), high intensity discharge lamps (HIDLs), and light emitting diode (LED) lamps.
Large equipment	Typical equipment comprises washing machines, clothes driers, dish washing machines, electric stoves, large printing machines, copying equipment, and photovoltaic panels.
Small equipment	Typical equipment comprises vacuum cleaners, microwaves, ventilation equipment, toasters, electric kettles, shavers, scales, calculators, radio sets, video cameras, electrical and electronic toys, small electrical tools, small medical devices, and small monitoring and control equipment.
Small IT and telecommunication equipment	External dimensions of such equipment are less than 50cm and typically includes items such as mobile phones, GPS, pocket calculators, routers, personal computers (PCs), printers and telephones.

While all six product categories are prevalent in South Africa, they enter three distinct WEEE value chains. These three waste streams were prioritised for review in the study:

- Information communication technology (ICT) and consumer electronics recycling;
- Lamps recycling; and
- Large and small household appliance (including temperature exchange equipment) recycling.

Each of the three value chains generate a variety of different WEEE fractions (secondary materials), which vary in terms of mineral content, volume, economic value, processing complexity and environmental toxicity[11]. Only those fractions which offer the greatest economic value were reviewed through to their downstream processing stage. In this regard, emphasis was placed on locally-based processing plants and technology capabilities. Fractions which are currently exported were traced as far as possible and the respondents' willingness to share market related information.

1.4.5 Data availability and disclosure challenges

In developed countries Electrical and Electronic Equipment (EEE) sales data, WEEE generation, collection, refurbishment and recycling volumes are readily available from national statistical bodies. While there is growing interest and acknowledgement of the WEEE challenge in South Africa, the recycling industry is still in its infancy and there is no central repository or database of quantitative data pertaining to the volumes of WEEE generated, held in stock and/or processed, the lifespan of obsolete goods and trade flows of WEEE[12]. Aggregated sales data from retailers regarding electronic goods sales is largely unavailable and recycling companies are not required by law to disclose the quantities and the markets that WEEE fractions are sold to.

Although the emphasis of the study was on primary data collection, some companies were reluctant to share specific details they consider proprietary to their operations, notably on markets, competition, suppliers of WEEE, volumes processed/produced, cost of technology solutions currently in use, and technology innovations developed in-house. In addition, some firms elected to complete the questionnaire without an interview, while others preferred to just have the interview.

In an effort to address these challenges, Mintek supplemented the data it gathered from interviews through approximations derived from its previous projects on WEEE sector activities, previous industry interviews (conducted in 2014 and 2015), comparison with industry peers, and information available on corporate websites. However, the researchers could not independently verify the information supplied by recycling companies.

1.4.6 Report structure

The report commences with a brief overview of WEEE production in South Africa and demand trends across the three prioritised waste streams. Cognisance is given to the metallic composition and value of each waste stream and the international best-practice in the treatment and management of fractions. At the end of Chapter 2, the structure of the South African WEEE value chain is unpacked. Profiles of key firms underpinning each stage are presented and other stakeholders commented on.

Chapter 3 presents the findings from the primary data gathering process. The discussion comprises three sections – formulating an organisational profile of the recycling firms reviewed; analysing WEEE technologies and processes used across stages of the value chain and different WEEE streams; and WEEE outputs and main end-user market dynamics.

The report concludes with a discussion of the main findings and list of recommendations and interventions.

[11] Baldé et al., 2015, p14
[12] Some preliminary data on the quantities of WEEE generated in South Africa is available from estimates made by international organisations including the United Nations Environmental Programme (UNEP), United Nations University (UNU) and Swiss Federal Laboratories for Material Science and Technology (EMPA) but the data is not easily verifiable and often conflicting in many cases.

The South African WEEE Industry

The management of WEEE is governed by the 3R principle which advocates 'Reduction, Reuse and Recycling' before any other disposal alternatives. While the promulgation of the *National Environmental Management Waste Act* (NEMWA) (Act 59 of 2008), is prompting change within the South African waste sector, the country remains largely at the periphery of the global transition towards a circular economy with only 11% of all WEEE treated and recycled[13].

Against this background, this chapter provides a brief overview of the South African WEEE industry focusing specifically on how WEEE is defined and categorised, production trends and volumes, and demand and supply trends within each of the three prioritised WEEE waste streams – ICT and consumer electronics, large and small household goods, and lamps. This discussion includes consideration of the composition and value of WEEE comprising each waste stream and international best practice trends with regard to its treatment and processing. The structure of the local WEEE value chain is also reviewed, with profiles of selective firms engaged in each stage provided.

2.1 Definition and categorisation of WEEE in South Africa

In South Africa, WEEE is defined as EEE that uses electric power supply to perform its functions and has been discarded by its original owner. In addition to the six categories identified by the EU, the categorisation of WEEE in South Africa takes cognisance of two additional groupings of obsolete goods – security and healthcare equipment, and mixed WEEE[14] (Table 2).

Table 2: Categorisation of WEEE in South Africa

Category	Description
Small household appliances	Vacuum cleaners, coffee machines, toasters, irons
Large household appliances	Washing machines, refrigerators, dryers, air conditioners
Office, information and communication technology (ICT) equipment	PCs, laptops, mobile phones, fax machines, printers and photocopiers
Consumer electronics and entertainment equipment	Televisions, VCR/DVD/CD players, hi-Fi sets, radios, train sets, coin slot machines, parking ticket equipment
Lighting equipment	Fluorescent tubes and lamps, sodium lamps
Electrical and electronic tools	Drills, electric saws, sewing machines, lawn mowers, large stationary tools, machines
Security and healthcare equipment	Surveillance & control equipment, medical instruments & equipment
Mixed waste electrical & electronic equipment	Various WEEE

There are significant differences in the original function, weight, size, and material composition of WEEE which have a direct bearing on resultant waste quantities, recovery rates, economic values and treatment technologies[15].

2.2 WEEE production trends and dynamics

In South Africa WEEE is generated by three major sectors – government, business and households. These are the major consumers of EEE items who in turn make them available for recycling when they become obsolete[16]. As can be seen in Figure 2, currently the main source of WEEE 'inputs'[17] (waste) to the recycling sector in South Africa is derived from local and provincial government departments (45%), followed by the business sector (35%) and households (20%).

Accurate data regarding the type, rate and volume of WEEE being generated, in circulation and released for recycling is largely lacking in South Africa. A study by Finley (2005) estimated that

[13] DEA, 2012a

[14] DEA, 2012b

[15] Baldé et al., 2015, p14

[16] Nyanjowa, James & Lydall, 2015

[17] By volume

South Africa was generating between 1.12 Mt and 2.1Mt of WEEE annually. StEP (2013) suggested a much lower figure of 300,000t of which 18% was recycled. They estimated that electronic waste in South Africa increases by 10% each year with each person generating around 6.6kg of WEEE. In 2011, the DEA estimated that South Africa generated approximately 64,045t of WEEE. If an annual growth rate of 4% is applied to the DEA's estimates, total volumes produced in 2015 would be around 74,923t.

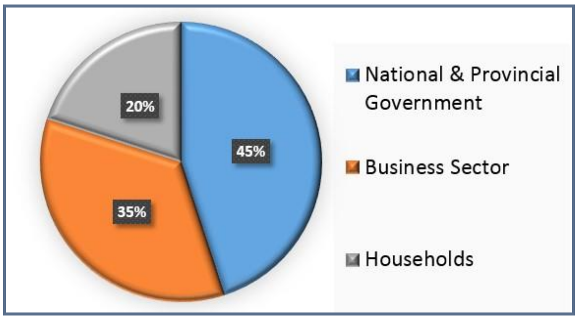


Figure 2: Sectoral sources of WEEE in South Africa, 2015

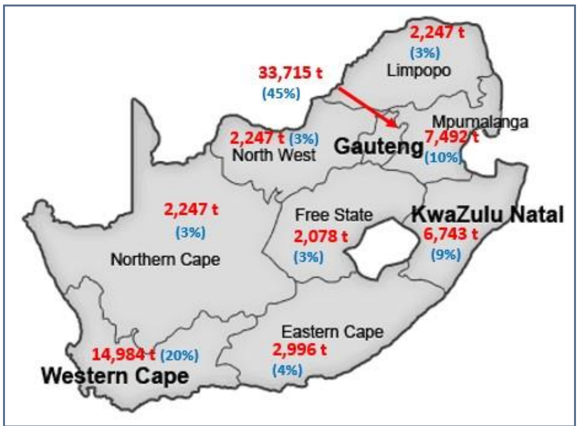


Figure 3: WEEE distribution across South Africa, 2015 (using DEA estimates of municipal waste as a proxy)

Using population distribution and the gross domestic product (GDP) contribution per province to the South African economy, the *DEA's National Waste Baseline Information Report* (2012a) estimated that in 2011 Gauteng had the highest municipal solid waste generation capacity of 761 kg/capita (45%). The Western Cape (675 kg/capita, 20%) and Mpumalanga (518kg/capita, 10%) were ranked second and third, respectively. In the absence of more recent and nationwide waste characterisation studies, these provincial percentage contributions to total municipal solid waste generation trends were used as a proxy for modelling the geographic distribution of WEEE generation in the country. This is because the factors that are driving municipal solid waste generation (growing population, rising household disposable incomes, increasing industrialisation and urbanisation) are essentially the same factors that are driving the increasing generation of WEEE in the country.

On this basis, it can be estimated that Gauteng accounted for 33,715 t of the estimated 74,923t of WEEE produced in South Africa in 2015, followed by the Western Cape (14,984t) and Mpumalanga (7,492t) – Figure 3.

2.3 Trends and dynamics (three prioritised waste streams)

South Africa is a well-established source of demand for electronic goods including ICT and luxury consumer electronics products, temperature exchange equipment, lamps, and large and small household goods[18]. By 2019, it is forecast that 11 million households will have annual incomes of about R89,500 – a level that gives them discretionary spending for a far wider range of consumer goods, as in other emerging markets[19].

2.3.1 ICT & consumer electronic equipment trends

Examples of WEEE falling within the ICT and consumer electronics waste stream include end-of-life (EoL) computers, laptops, tablets, notebooks, servers, uninterrupted power supply (UPS) units, computer accessories (including cables and screens), televisions, in-car entertainment equipment, portable and home audio equipment, cameras, and playback devices.

[18] Wesgro, 2014
[19] PWC, 2015

2.3.1.1 Demand and supply trends in South Africa

South Africa imports ICT and consumer electronic equipment from Europe, Asia and North America[20]. Accenture's Consumer Electronics Study (2012) maintains that South Africans spend approximately 2.6% of their annual salary on consumer electronics, with the most popular being personal computers (PCs), laptops, tablets, gaming devices, and mobile phones.

South Africa's consumer electronics spending is forecast to grow at a Compound Annual Growth Rate (CAGR) of 7.3% to reach US$10.6 billion by 2018[21]. The demand in all product categories will be driven by new releases and technologies. Increased demand for mobility, lower prices and channel expansion will fuel demand for notebook computers, as well as digital lifestyle products such as digital cameras, plasma displays, LCD and plasma TV sets, LCD monitors and mobile handsets (Figure 4) .

A more detailed analysis of trends in PCs, laptops and mobile phones is provided in Appendix D.

2.3.1.2 Composition and value of the waste stream

Products within this waste stream are typically comprised of different metals, plastics, ceramic material, glass and other substances[22]. The real value of end-of-life ICT and consumer electronics, however, lies in their PCBs:

- Typically PCBs contain 40% of metals, 30% of organics (such as fibres, rubber, stabilisers etc.) and 30% of ceramics. PCBs are an important source of base and precious metals such as gold, platinum, palladium, silver, and copper.
- Although PCBs are found in virtually all electronics products, they are unique to their application, and therefore vary in size, complexity and metallic value. Older PCBs contain gold in electronic contacts, bonding wires and microchips while significant amounts of palladium are also available in capacitors. Newer PCBs are usually coated with metals such as tin, silver or copper to make them conductive. As such, there is a great variance in the precious metal content of waste PCBs that comes from different appliances, from different manufacturers and of different age.

Table 3 illustrates the value share of precious and base metals in select ICT and consumer electronic products and components.

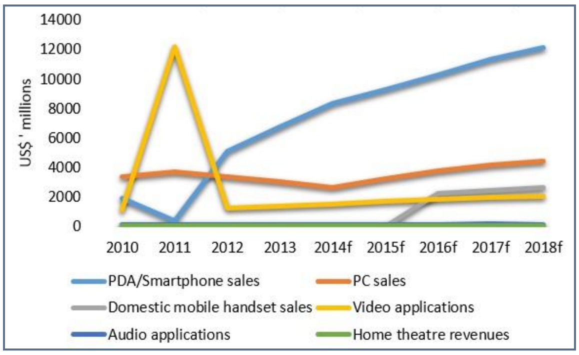


Figure 4: South Africa sales of selected consumer electronics products, 2010-2018f[23]

Table 3: Value distribution of different materials in various electronic devices[24]

Device	Value Share						
	Base Metals Content			Precious Metal Content			
	Fe (%)	Al (%)	Cu (%)	Ag (%)	Au (%)	Pd (%)	Total
Monitor Board	4	14	35	7	33	7	47
PC-board	0	1	13	5	69	12	86
Mobile phone	0	0	6	11	71	11	93
Portable audio	3	1	73	4	16	3	21
DVD-player	15	3	30	5	42	5	52
Calculator	1	4	10	6	76	3	85

2.3.1.3 International best-practice in the treatment and management of fractions

In addition to the possibilities of recovering critical strategic metals for secondary supply, recycling of EoL ICT and consumer electronic products is also being driven by the need to effectively manage

[20] Wesgro, 2014
[21] PWC, 2015
[22] UNEP, 2013

[23] PWC, 2015; http://iceesa.co.za/index/lists/catid/50.html
[24] Hageluken, 2009 (based on March 2010 prices)

hazardous fractions/components contained within them, such as ink cartridges, cathode ray tubes (CRTs), light crystal display (LCD) screens, batteries, and PCBs. [25]

The treatment processes for ICT and consumer electronic equipment varies according to the nature of the feed material received, the volumes being processed, capacity of the plant and the core focus of the business. In general, the main steps include (Figure 5):

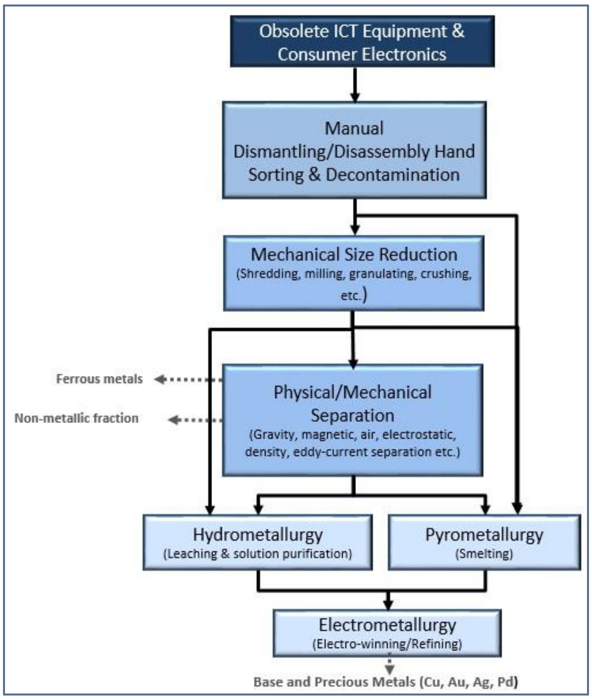


Figure 5: Simplified flowsheet for ICT & consumer electronics recycling[26]

- **Assessment, categorisation and decontamination** – Upon arrival at designated collection facilities, WEEE is first weighed, evaluated and categorised according to its potential for refurbishment, onward sale to pre-processors, or on-site dismantling. WEEE that is designated for dismantling has to first be rendered non-hazardous. This involves the removal of all types of hazardous components. In the case of computers and laptops, before dismantling occurs, data destruction is performed using designated equipment. Appropriate data destruction certificates are issued.

- **Manual dismantling, stripping and sorting** – Sorting and dismantling of equipment is generally a dry process involving a high degree of manual labour. Tools like electric or pneumatic screwdrivers can be applied to accelerate the speed of dismantling equipment. The benefit of carrying out manual dismantling is that the products after the disassembly can be easily grouped into different fractions in their complete and intact forms, which could reduce the separation effort in the end-processing phase and also be able to reclaim the reusable parts. The ability to discern between the vast combinations of materials also helps to ensure a much higher yield during end-processing. Although automated sorting and mechanical removal methods can be employed in this stage, it is often advised against due to the unintended co-separation of trace elements such as precious metals with major fractions such as ferrous, aluminium or plastics. This results in the incomplete liberation of the complex materials and thus significant losses in the quality (and value) of the resultant fractions[27].

- **Mechanical shredding and separation** – Various crushing and shredding methods are used to reduce the size of dismantled components (cabinets, casings, cables, etc.) into smaller and more manageable waste fractions. Material is then subjected to a series of sorting and separation techniques to refine the fractions into designated output streams for further processing.

- **Fraction recovery and processing** – Plastic fractions are sent to downstream treatment plants. Removed CRTs and LCDs are recycled in designated facilities as glass after a sequential process of separation, crushing and cleaning[28]. While there is no single processing technique that is capable of handling and processing all

[25] Schreiber, Sheane & Holloway, 2012
[26] Cui & Forssberg, 2003; Froelich et al., 2007; UNEP, 2007; Goodship & Stevels, 2012
[27] UNEP, 2013
[28] For a detailed review of the process, costs and equipment used in CRT recycling see Marshall & Henderson, 2001; Icer, 2003; Yu et al., 2016. A review of the LCD dismantling process is provided by Ryan et al., 2011.

types of waste PCBs, due to their heterogeneous nature, they are generally processed in integrated base and precious metals smelting and refining facilities located in established recycling centres[29].

2.3.2 Large and small household goods trends

Examples of WEEE falling within the large and small household appliances waste stream encompasses items such as washing machines, cookers, dishwashers, tumble dryers, microwaves, temperature exchange equipment, irons, toasters, clocks and watches.

2.3.2.1 Demand and supply trends in South Africa

Large and small household electrical equipment (also termed 'white goods') consumed by South Africans are imported from Asia, USA and Europe[30]. According to the *2014 General Household Survey*[31], in 2013, approximately 80.2% of households in South Africa owned electric stoves, while less than 32.4% owned washing machines. Households in urban and metropolitan areas were much more likely to own more than one major household asset than households in rural areas. Between 2012 and 2016, demand for white electrical appliances and houseware and household audio and video equipment grew by around 16% and 18%, respectively in South Africa. Demand for television sets also increased over the same period, exceeding R1 billion in sales in 2014[32].

Demand for dishwashers, air treatment equipment, microwaves, laundry appliances, refrigerators, stoves/ovens, small food preparation items, irons and vacuum cleaners in South Africa is forecast to grow at a CAGR of between 3 and 5% between 2016 and 2020[33].

The average appliance life expectancy for equipment in this waste stream varies from 2-20 years, depending on the item. Consumers often replace appliances long before they become worn out due to changes in styling, technology and consumer preferences[34]. However, there is also a significant refurbishment and second-hand market for large and small household appliance in South Africa[35], which makes their entry into the recycling stream difficult to predict, monitor and quantify.

2.3.2.2 Composition and value of the waste stream

Large household equipment are typically comprised of metals (steel, copper, aluminium, stainless steel and their alloys), diverse plastics, additives, fillers, stabilisers and organic materials (such as rubber, wood, textile and fibres), inert materials such as glass and concrete, and low value PCBs and electronics containing precious metals. Table 4 illustrates the metallic composition for select household appliances.

Table 4: Material composition of select household appliances

Material	Washing Machine (%)	Dryer (%)	Dishwasher (%)	Oven (%)
Iron/Steel	52.1	68.8	45.2	81.3
Copper	1.2	2.3	1.5	0.2
Aluminium	3.1	2.1	0.8	1.9
Stainless Steel	1.9	1.2	23.2	0.7
Brass	0.1	0.1	0.2	0.5
Plastics	6.8	15.9	12.6	0.7
Rubber	2.8	0.9	1.6	0.4
Wood	2.6	4.5	2.1	0.0
Other Organic	0.1	-	5.3	0.0
Concrete	23.8	-	1.9	0.0
Other Inert Material	1.9	1.3	0.9	12.6
PWB	0.4	0.4	0.1	0.1
Cables (Internal/ external)	1.1	1.8	1.5	1.3
Other Materials	2.2	0.8	3.2	0.3
Total	**100**	**100**	**100**	**100**

2.3.2.3 International best-practice in the treatment and management of fractions

The general recycling process for large household appliances (such as washing machines, clothes dryers, air conditioners and refrigerators) units comprise the following steps (Figure 6)[36]:

- **Manual dismantling, sorting and separation** –

[29] Ladou & Lovegrove, 2008; StEP, 2009
[30] Wesgro, 2014
[31] Statssa, 2014
[32] Statssa, 2014, p. 55
[33] Euromonitor, 2016
[34] Van Schaik & Reuter, 2004
[35] Finlay, 2005
[36] ERP, 2012; Japan Products, 2016

Major components are first recovered by manual dismantling, sorting and separation and harmful substances disposed of.

- **Washing machines** – Units are loaded into separate containers. After removing motors and PCBs, top covers are removed. To keep shredding machines and recycled materials from rusting, salt water in the ring element at the top of the washing element is taken out by the cutting machines. Washing tanks are then removed from the washing machine.
- **Dryers** – Cables, motors and other electrical components are first removed, and ballasts, plastics, iron compounds and other metals are separated and recovered. These materials are then sent for further processing and recovery.
- **Air conditioners** – Indoor and outdoor units are loaded into separate cargo containers. Refrigerant fluorocarbons are recovered by dedicated equipment and destructed at designated treatment facilities. Major components of outdoor units such as circuit boards, compressors and heat exchangers are manually removed after recovering refrigerant fluorocarbons and sent off for subsequent recycling at designated facilities.
- **Refrigerators and freezers** – Units are loaded in separate cargo containers. Refrigerant fluorocarbons are recovered by dedicated equipment. Recovered fluorocarbons are destructed at designated treatment facilities. After recovering refrigerant fluorocarbons, compressors are removed by cutting pipes. Removed refrigerant oil, door packaging, and plastic parts etc. are recovered and recycled separately to recover materials.

- **Mechanical shredding and separation** – Residual parts (such as cabinets) are then recovered by mechanical shredding and separation (magnetic, pneumatic, eddy current, gravity, etc.).
- **Fraction recovery and processing** – Output fractions include plastics, non-ferrous materials, ferrous materials, urethane and dust. Only the dust fraction is disposed of in designated landfill sites, while the other fractions are treated further in approved secondary processing plants.

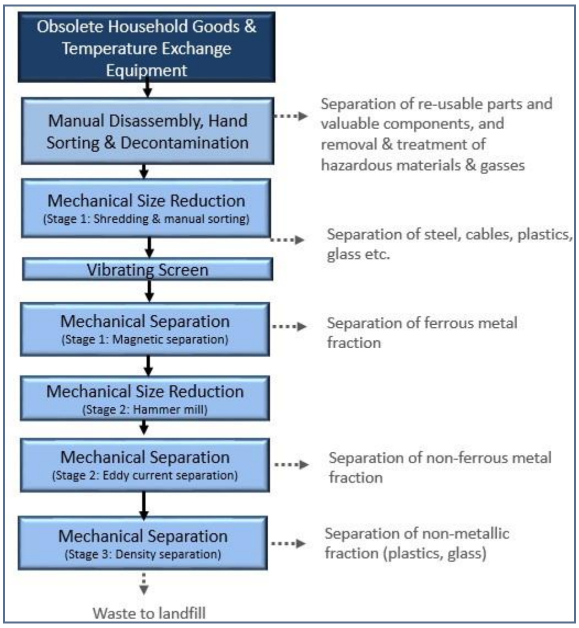


Figure 6: Simplified flowsheet for household and temperature exchange equipment recycling

Flowsheets for the recycling process across various household goods is provided in Appendix E.

Small domestic appliances is a much more complicated WEEE stream as many possible materials can be recovered in addition to valuable ferrous and non-ferrous fractions (wood, plastic, glass and cardboard).

- Initial de-contamination may include removal of ink toners, cartridges, batteries and cables. While smaller recycling facilities may sort and manually dismantle appliances further, larger facilities tend to shred/granulate appliances directly.
- Plastic and metal fractions are then separated in various stages to first separate out coarse from fine materials, and ferrous from non-ferrous metals. Output fractions usually include ferrous and non-ferrous metals and plastic[37].

[37] ERP, 2012

2.3.3 Lighting trends

This WEEE stream includes low energy light bulbs commonly known as compact fluorescent lamps (CFLs), high intensity discharge (HID) lamps, light emitting diode (LED) lamps, high pressure lamps and other fluorescent lamps including straight and round tubes. Old-style filament light bulbs and halogen lights are not categorised as WEEE.

2.3.3.1 Demand and supply trends in South Africa

South Africa has got a relatively small (in comparison to the markets in Europe) but growing lighting equipment market with over 100 million lamps in circulation and with annual sales of approximately R5 billion in 2010[38].

Demand for CFLs experienced a significant upward trend between 1994 and 2010 in response to Eskom's roll-out of 60 million energy-saving light bulbs[39]. Due to the energy challenges that South Africa has been experiencing over the past decade, there has been a shift towards the use of CFLs in residential properties, and HID and LEDs in business and industrial properties. In recent years, the lighting equipment market has benefited from the infrastructure boom and the construction of new residential, business and industrial properties throughout the country.

2.3.3.2 Composition and value of the waste stream

Lighting equipment is very lightweight, fragile, is of small size and has low metallic value[40]. Lamps represent a very small percentage of the total weight of WEEE produced globally. However, collection and recycling costs tend to be higher than in other waste streams due to the presence of hazardous substances such as mercury and arsenic which require appropriate collection, handling and disposal[41].

Lamps are typically composed of glass (88%), metals (5%), plastic (4%), lamp phosphor powders (3%) and mercury (0.005%). Depending on their usage, lamps have a lifespan of a few years and although today's lamps and bulbs have a lower mercury content than before, there are still many in circulation and disposed of each year which contain much higher levels of mercury. Apart from the environmental concerns relating to the presence of mercury, the recycling of EoL lamps is also being driven by the recovery of rare earth elements (REEs) used in phosphor powders for providing fluorescent effects and efficiency[42].

2.3.3.3 International best-practice in the treatment and management of fractions

Various methods have become established for the recycling of discharge lamps, most notably the shredder method, end-cut method, glass-washing method, other product-specific stripping method, and centrifugal separation (See Appendix F for more detail). These methods can be carried out either in a mobile or fixed system. To prevent any danger to humans and the environment, all lamp treatment processes are conducted in vacuum-sealed environments and all plants have special waste air purification systems.

2.4 Structure of the South African WEEE Value Chain

The WEEE value chain in South Africa, as elsewhere in the world, comprises four distinct stages: collection; dismantling; pre-processing; and end processing (e.g. final metals recovery). The first stage involves sourcing and transporting the WEEE to designated process sites, while the latter three are centred on its treatment. While this sequence of activities is largely generic across different waste streams, considerable variation exists in the choice of treatment technologies employed and complexity of process design used across (and within) different waste streams.

[38] Naidoo, 2015
[39] TMG Digital, 2016
[40] ERP, 2012; Binnemans et al., 2013; Reuter et al., 2013
[41] For example, lamps represent about 1% of the total weight of WEEE in the EU, but more than 25% of total WEEE collection and recycling costs.
[42] REEs of interest in lamp phosphor powders include Europium (Eu), Terbium (Tb), and Yttrium (Y). Other EoL WEEE contain Lanthanum (La), Gadolinium (Gd) and Cerium (Ce) in their phosphor powders (Binnemans et al., 2013; Binnemans & Jones, 2014). See also Lamptech, 2016.

The three stages of treatment are based on the sequential flow of material from one stage to the other – outputs from the first stage of treatment provide the input to the second stage. After the third level treatment, the residues are disposed of. Each level of treatment consists of a specific set of activities and equipment and the efficiency of each stage determines the quantity and quality of fractions being beneficiated further or being landfilled.

Technological innovations in the treatment of WEEE aim at –

- Maximising the recovery and beneficiation of all fractions of WEEE (starting with the high value fractions);
- Retaining this value within the local value chain for as long as possible before entering the global market;
- Reducing the volumes of WEEE (and associated fractions) sent to landfill;
- minimising the environmental impact of hazardous fractions and metals contained in WEEE; and
- Protecting employee health and safety.

The total volume of waste directed away from landfill is determined by the efficient operation and performance of each stage as well as how the industry operates collectively as a system.

2.4.1 The Collection Stage

Collection is the first critical step in the process and determines the amount of material that is actually available for recycling. In established recycling markets, the primary modes for accomplishing collection are permanent drop-off facilities, special drop-off events and door-to-door pick-up[43]. Currently the collection of WEEE in South Africa is done via informal and formal channels distributed across the country, all of which lead to various forms of final disposal.

2.4.1.1 Informal Collection

Informal WEEE collectors, commonly known as 'waste pickers' are a regular sight in South Africa's major cities. These are unlicensed and unregistered individuals that pick up WEEE together with other recyclables (metals, cardboard, plastics) from municipal landfill sites, shopping malls and refuse bins in suburban centres for onward sale to entry-level recyclers. eWASA estimates that they account for approximately 25% of the total volume of WEEE recycled in South Africa[44].

2.4.1.2 Formal Collection

There are three types of role players who act as formal collectors of WEEE in South Africa. Firstly, large integrated waste management companies, such as Interwaste (Pty) Ltd, Oricol Environmental Solutions, SmartMatta (formerly Re-ethical) and Waste Plan (Ltd), who have an extensive logistic system and diversified network of clients. Secondly, smaller operators that collect, refurbish and process WEEE collected directly from consumers. Such operators include private companies (e.g. Cape E-waste Ltd as well as municipal waste collectors (e.g. Pikitup). Lastly, consumers who drop-off their old equipment at designated collection sites.

2.4.2 The Dismantling Stage – First level of treatment

Dismantling is the second stage in the WEEE recycling value chain and the first level of treatment. Dismantling involves breaking down or liberating obsolete EEE into components, fractions or materials such as PCBs, ferrous and non-ferrous fractions that are in turn made available for further processing. Depending on EEE type, hazardous substances such as batteries, capacitors and condensers have to be removed and safely stored away while valuable components may be taken out for reuse.

In South Africa, this activity is performed by various companies; the number of which has grown significantly over the past few years in response to increased volumes of collected WEEE. In general,

[43] StEP Initiative, 2009

[44] eWASA, 2014

such firms collect, dismantle, sort and classify WEEE received and sell/broker individual components and WEEE fractions onto local and international companies for subsequent pre-processing and processing. A small percentage of the final waste is landfilled. Some of these firms are also involved in the refurbishment and resale of select WEEE, particularly ICT equipment.

The recycling activities of small- to medium-sized recycling companies typically end at the dismantling stage of the WEEE value chain. Examples of firms involved in this stage include Africa E-Waste, Bolunga Enterprise (Pty) Ltd, Cape e-Waste Recyclers Ltd, Computer Scrap Recycling, Effortless Recycling Company, Electronic Cemetery e-Waste Management (Pty) Ltd, Indalo Resources Ltd, Inca Metals (Pty) Ltd, Tshwane Electronic Waste Company (Ltd), and Virgin Earth Ltd.

Key features of firms involved in the dismantling stage include:

- Formally registered and licensed small- and medium-sized businesses in the WEEE recycling sector;
- Principally focus on WEEE collection, dismantling and refurbishment activities in the WEEE value chain and after which they sell the fractions produced;
- Have off-take agreements with large recyclers who further process WEEE fractions produced before selling them to domestic and export markets;
- Refurbishment accounts for a significant portion of their revenue (approximately 60%) while recycling accounts for the remaining 40%;
- Niche players that are based in particular geographic locations or focus on specific WEEE streams;
- Process between 10t and 500t of WEEE per annum;
- Operate between 1 and 2 trucks for WEEE collection activities;
- Have revenues of between R1-R10 million per annum; and
- Employ between 5-25 people.

2.4.3 The Pre-processing Stage – Second level of treatment

The second level of treatment, pre-processing, involves two steps: liberating complex, multi-material WEEE components from each other through the application of physical force; and separating valuable metal and non-metal fractions from each other into distinct recyclate streams (iron and steel, copper, aluminium, plastic, PCBs, glass, etc.). The techniques and equipment used in pre-processing are similar to those used in mineral dressing and often involve automated, multi-stage operations depending on the feed material. The choice of equipment and processes used has a determining impact on the quality and quantity of feed material entering the subsequent metal recovery stage and the amount of waste material that is ultimately landfilled[45].

- **Liberation** – A key objective of liberation is to reduce bulky input WEEE to a consistent size. Processes include hammering, crushing, grinding or shearing (generically called 'shredding'), though this rarely leads to complete liberation.

  It is normal that different materials remain stuck to each other, or are broken apart but still remain together. The methods used are usually determined by the material behaviour of the input WEEE.

  The resulting output from size reduction is a mix of broken pieces with different size distributions and chemical and physical properties. The physical properties will dictate the subsequent separation method selected, while the chemical properties will influence the choice of metallurgical processing route followed. Material is first screened and de-dusted before being sent for separation.

- **Separation** – Material separation may be based on the magnetic, electrostatic, density, visual, or other characteristics of the shredded/input WEEE. While manual or physical sorting processes can be used for separating materials from waste, in general pre-processing

[45] UNEP, 2009

separation is a mechanical process that takes place in either a dry or a wet environment[46].

- Dry separating technologies include laser and sensor sorters, rotating/vibrating screens, high-intensity magnetic separators, and eddy current, corona electrostatic, and triboelectric separators.

- Technologies requiring a wet environment include jigs, sink-float separators, hydrocyclones, aero-chutes and tables, etc. While dry processes can produce dust, containing both metals and other possible hazardous compounds, in wet processes the medium has to be cleaned, creating a waste sludge stream[47]. In general, pre-processing plants use a combination of different technologies and methods to produce as clean an output fraction as possible.

The main outputs from the pre-processing stage are: ferrous metal scrap; non-ferrous metal scrap (mainly copper and aluminium); precious metal scrap (mainly silver, gold and palladium/platinum); plastic (consisting of sorted plastic, plastic with flame retardants, and plastic mixture); and glass cullet.

Despite the relatively low percentage of WEEE that is recycled in South Africa, there are well established pre-processing systems in place. The number of players active in pre-processing is considerably less than in the dismantling stage. However, this level of specialisation is consistent with international experience, especially in Europe, where only a few and select companies pre-process WEEE in order to achieve economies of scale. Typically these firms operate as consolidators/ integrators, providing a critical intermediary step in the flow of sorted and dismantled fractions through to the final processors.

Leading pre-processors of WEEE in South Africa include Desco Electronic Recyclers CC, E-Waste Africa, New Reclamation Group (Pty) Ltd (Reclam), RecLite (Pty) Ltd, SA Metal Group (Pty) Ltd, Sims Recycling Solutions Ltd, Sindawonye Granulators & Processors (Pty) Ltd (Sindawonye), and Universal Recycling Limited (URC).

In the past few years a number of newer, smaller pre-processors have emerged, most notably E-waste Technologies Africa Ltd, Javco Ltd, Metrix Metal Recovery and Extraction Ltd (Metrix), and Sibanye Recycling Ltd.

In summary, key features of firms involved in the pre-processing stage include:

- Large-scale WEEE recycling companies that exist as standalone or subsidiaries of established metal recycling companies and corporates;
- Possess a considerable degree of market power in local recycling industry by owning a large fleet of WEEE collection trucks, warehousing and storage facilities and pre-processing facilities;
- Diversified geographic presence in South Africa either through wholly-owned provincial operations or strategic alliances with smaller recycling companies;
- Refurbishment is not the core focus of their business operations;
- Account for a significant portion of total WEEE handled and processed in South Africa;
- Process between 1,000t and 5,000t of WEEE per annum;
- Have WEEE recycling revenues of between R10 - R100 million per annum;
- Pre-processing operations are done in line with end-customer's specifications for each WEEE fraction;
- Employ over 100 people; and
- Have ambitious project pipelines that will enable them to transition into world class (cradle-to-cradle) recyclers.

[46] Goodship & Stevels, 2012
[47] Cui & Forssberg, 2003

2.4.4 The Processing/Metal Recovery Stage – Third level of treatment

The resultant fractions from the pre-processing stage are directed to various end-user markets for final resource recovery and processing. In general, WEEE recycling is focused on the recovery of ferrous, non-ferrous and precious metals contained in complex fractions which need to be treated in designated smelting and refining plants using either hydrometallurgical or pyrometallurgical methods or a combination of both.

- **Hydrometallurgical processing** – Hydrometallurgy is the branch of extractive metallurgy that involves reactions in (mainly) aqueous solutions at much lower temperatures for the treatment of base and metallic inputs. With their relatively low capital cost, reduced environmental impact (e.g. no hazardous gases/dusts), potential for high metal recoveries and suitability for small-scale applications, hydrometallurgical processes are promising options for the extraction of base and precious metals contained in WEEE, particularly PCBs[48] (see Appendix G).

- **Pyrometallurgy processing** – Pyrometallurgy involves the use of heat to process the concentrate. At high temperatures the relative stabilities of metals and their compounds change dramatically, and the rates at which chemical reactions occur increase considerably. Compared to hydrometallurgical treatment processes, pyrometallurgical methods tend to be comparatively more energy intensive and costly to operate. They also require a much higher-grade metallic feed (rich in copper and precious metals), and produce hazardous gases that require removal from the air with appropriate flue gas cleaning systems[49]. However, pre-processing of WEEE is not always required for pyrometallurgical routes[50]. Pyrometallurgical treatment of WEEE consists of several processes such as smelting, pyrolysis, incineration, combustion, and molten salts processes. The choice of approach varies worldwide with respect to the type of the WEEE, physical shape and size of the feed materials, and the plant operating parameters (see Appendix G).

Leading global processors of WEEE (particularly PCBs), such as Aurubis (Germany), Boliden (Sweden), Dowa (Japan), Gencore (Canada) and Umicore (Belgium), employ smelting in their systems, with high recovery rates (Table 5). Boliden and Umicore are integrated operations, combining both copper and lead smelting methods in their flowsheets and can recover up to 17 different metals from PCBs.

Table 5: Integrated industry methods for the recovery of WEEE[51]

Process	Recovered Elements	Description
Aurubis (Germany)	Gold, silver, copper, lead, zinc, tin, PGMs	Kayser recycling system: Smelting in TSL reactor → black copper + ZnO flue dust → converting + (Sn-Pb rotary furnace) → Cu anodes + SnSb alloy → Cu electrorefining → Cu + anode slime (bearing PGMs) → PGMs refinery → PGMs
Boliden (Sweden)	Copper, silver, gold, lead, nickel, selenium, zinc, lead	Copper line: Smelting → zinc fume (to clinkering) + molten black copper (to converter) → converting → Cu electrorefining → Cu + residue containing PMs → PMs refinery → PGMs + Se Lead line: Kaldo furnace → PMs containing fraction (fed to Cu converting step) + Pb fraction → Pb refinery → Pb
Dowa (Japan)	Copper, gold, platinum group metals (PGMs), silver, gallium	TSL copper smelting in conjunction with lead/zinc smelting and refining
Gencore (Canada)	Copper, gold, platinum, palladium, selenium, tellurium, nickel	Cu smelting → converting → anode casting → electrorefining → Cu + PMs → PM refinery → PMs + Se, Te
Outotec (Finland)	Zinc, copper, gold, silver, indium, cadmium, germanium, lead	Smelting (Ausmelt TSL reactor) of WEEE in copper/lead/zinc combined processes
Umicore (Belgium)	Copper, nickel, arsenic, lead, lead, tin, antimony, bismuth, gold, silver, palladium, platinum, iridium, ruthenium, rhodium, indium, selenium, tellurium	Copper line: Cu smelting (Isamelt) → Cu bullion → Cu refinery → Cu + residue containing PMs Lead line: Pb blast furnace → Pb bullion + spies (Ni, As) → Pb refinery → Pb, Sn, Sb, Bi + residue containing PMs PM recovery: Residue from Cu and Pb lines → cupellation → PGMs + In, Se, Te

[48] Tuncuk et al., 2012
[49] Judhav & Hocheng, 2015
[50] For example, complex electronic equipment such as mobile phones and MP3 players can be treated directly during smelting processes

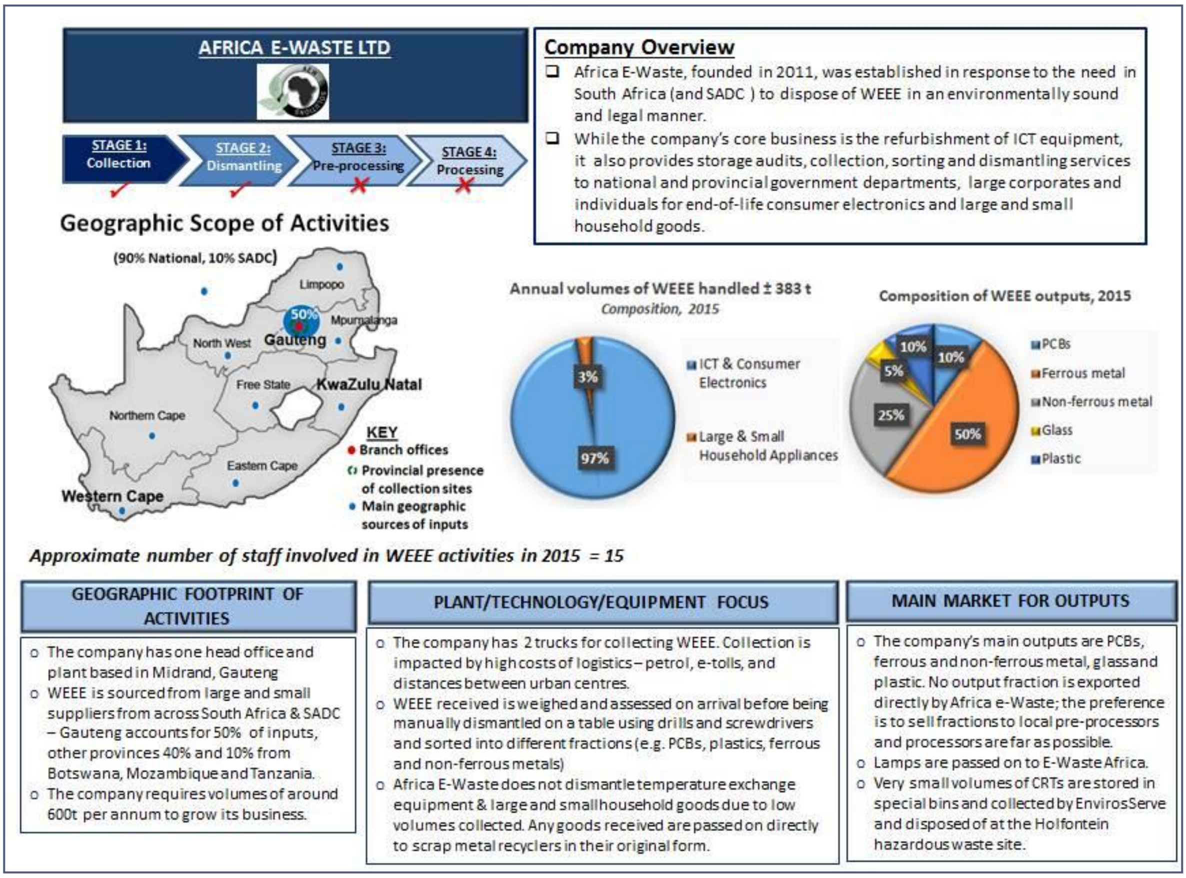
[51] StEP, 2009; Ebin & Isik, 2016, p. 110. Flowsheets for the various companies can be found in Khaliq et al., 2014

Other fractions produced during the dismantling or pre-processing stages, such as plastics, glass, paper, ferrous and non-ferrous metals are usually sold onwards to designated local or international processors or beneficiators for secondary material recovery, while CRTs are currently landfilled.

Although there is an established market for the recovery of ferrous and non-ferrous metals from WEEE scrap in South Africa, as is the case with many WEEE markets throughout the world, the final processing of complex WEEE locally, is still limited.There are currently only two companies in South Africa with the technical capability to extract precious metals from obsolete PCBs – SA Precious Metals and Rand Refinery. Currently, only SA Precious Metals is recovering metals from PCBs.

2.5 Profiles of Sampled South African Companies in the WEEE Value Chain

Although 27 recycling companies were interviewed in this study, only 17 companies were profiled in detail and are presented below[52]. It should be noted that the information provided is based on the outcomes of the questionnaire survey and interview process, supplemented with information sourced off company websites.



[52] Some recycling companies did not provide the researchers with sufficient information in order to profile them in detail. Further, some firms were not using WEEE dismantling, pre-processing and processing technologies to the extent required to permit detailed analysis and comparison.

BOLUNGA ENTERPRISE (PTY) LTD

STAGE 1: Collection ✓ | STAGE 2: Dismantling ✓ | STAGE 3: Pre-processing ✗ | STAGE 4: Processing ✗

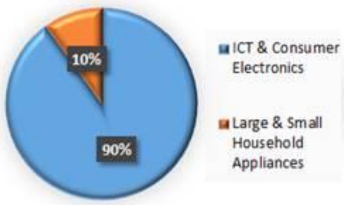
Company Overview

- Bolunga Enterprise (Pty) Ltd, trading as Bolunga Systems, is a level 3 B-BBEE company whose primary business is the installation, maintenance and repair of IT and telecommunications equipment. The company entered into WEEE recycling in 2014 as part of a process of 'closing the loop' in the management of obsolete ICT products.
- The company mainly operates in the collecting and dismantling stages of the WEEE value chain. WEEE accounted for around 38% of the company's activities in 2015,

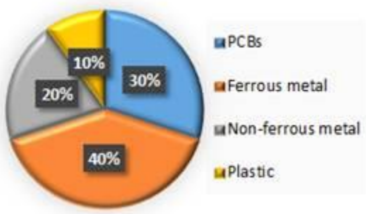
Geographic Scope of Activities

Annual volumes of WEEE handled ± 200 t

Composition, 2015



Compostion of WEEE outputs, 2015



Approximate number of staff involved in WEEE activities in 2015 = 12

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- The company's central branch office and factory/plant is in East London. Bolunga has collection sites located across the whole of the Eastern Cape, including Queenstown, King Williams Town, Butterworth and Bhisho. The company has a branch office in Gauteng and is exploring expanding its footprint in KZN and Gauteng.
- The company accepts large and small household goods and redundant ICT and consumer electronics.
- Bolunga partnered with Reclite in May 2016 to manage the collection of waste lighting in East London and surrounding areas.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- The company has stocks of PCBs, CRTs, monitors, printers, copper, cabling, ABS, aluminium, steel, and LDPE film.
- The dismantling of WEEE is performed manually using electric screwdrivers, hammers, chisels and grinders.
- WEEE is stripped and sorted into three major categories: PCBs, metal and plastics.

MAIN MARKET FOR OUTPUTS

- The main output fractions produced by the company are PCBs, ferrous metal, plastic, and non-ferrous metal
- Only a small amount of glass (CRTs) is landfilled, while the rest of the fractions are sold onto a range of pre-processors and processors based within KZN and Gauteng

CAPE E-WASTE RECYCLERS LTD

STAGE 1: Collection ✓ | STAGE 2: Dismantling ✓ | STAGE 3: Pre-processing ✗ | STAGE 4: Processing ✗

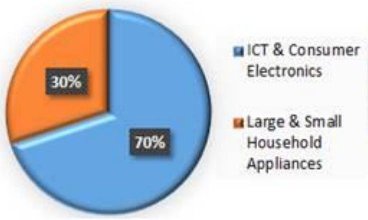
Company Overview

- Cape e-Waste Recyclers Ltd is an electronic scrap recycling company that commenced operations in 2012 as a Desco consolidation facility in the Western Cape.
- The company services primarily the IT and telecommunications industries, but also provide services to corporations, local and provincial government, educational and medical institutions for the disposal of redundant and obsolete WEEE.

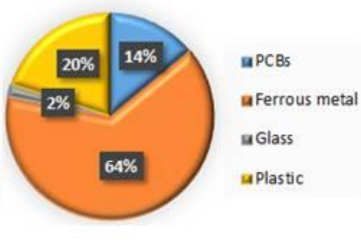
Geographic Scope of Activities

Annual volumes of WEEE handled ± 500 t

Composition, 2015



Composition of WEEE outputs, 2015



Approximate number of staff involved in WEEE activities in 2015 = 25

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- The company operates from its head office and dismantling plant in Bellville, Cape Town, but sources WEEE from individuals, corporate clients, retailers, schools and churches across the Western Cape, Northern Cape and Eastern Cape.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- Dismantling is predominantly manual using hammers, screwdrivers and grinders.
- WEEE is stripped, sorted and separated and packaged into specific categories of fractions.
- Secure data destruction services are offered, on special request and at an agreed cost, to ensure that valuable information is destroyed.

MAIN MARKET FOR OUTPUTS

- The company's main outputs are PCBs, ferrous metal, plastic, and glass. These fractions are all passed onto local downstream pre-processors and processors for treatment and re-use
- All lamps collected are passed onto local lamp pre-processors and dismantled computer components are resold.

COMPUTER SCRAP RECYCLING

Geographic Scope of Activities

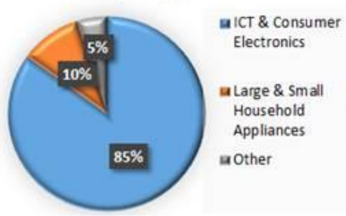
(100% Provincial focus)

Company Overview

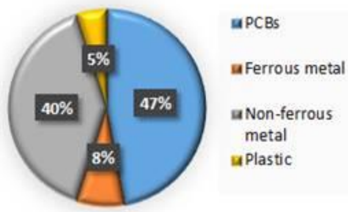
- Computer Scrap Recycling (CSR) was established in 1998 with the initial focus on recycling plastic and boxes and evolved into a drop-off and buy-back centre for EoL computer equipment.
- The company expanded into WEEE recycling in 2000; spurred by the growing emphasis on the environmental implications of landfilled e-waste and the potential revenues that could be gained from collecting, cleaning, dismantling and sorting and refurbishing redundant electronic products to retrieve the valuable metals contained within them.
- WEEE is a core business activity for the company.

Annual volumes of WEEE handled ± 240 t

Composition, 2015



Composition of WEEE outputs, 2015



Approximate number of staff involved in WEEE activities in 2015 = 10

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- CSR operates from two branches – its head office and main plant is located in Brakpan, Johannesburg, with a small outlet in KZN.
- The company accepts ICT and consumer electronics waste as well as large and small household equipment. CSR does not accept stolen goods, ferrous metals, contaminated medical equipment, and laboratory equipment containing radioactive isotopes.
- CSR obtains its inputs via its online collection service and through long-term bulk collection agreements around Gauteng and Mpumalanga. Suppliers include corporates, households and government departments.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- Waste that is dropped off or been collected is first weighed and categorised, and then sorted into scrap or items for refurbishment. Products sent for scrap are subject to a second round of stripping and sorting according to product, grade and metal/fraction – this is a manual function using handheld tools.
- The company issues a certificate and a letter of destruction for all waste that is recycled
- The company has an on-site training facility and internet café to assist its workers

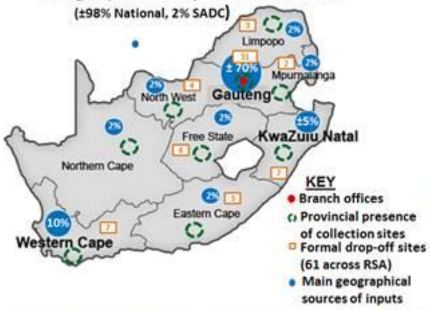
MAIN MARKET FOR OUTPUTS

- Main fractions include PCBs, ferrous and non-ferrous metals and plastic.
- Currently the company is exporting all outputs to markets in Asia and Europe.

DESCO ELECTRONIC RECYCLERS CC

Geographic Scope of Activities

(±98% National, 2% SADC)

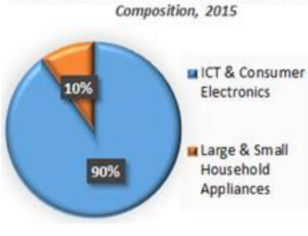


Company Overview

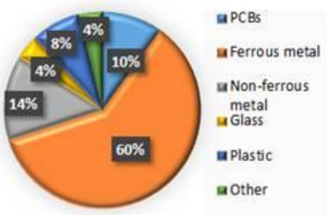
- Established in 1992, Desco is the largest integrated WEEE collection, dismantling, pre-processing and data destruction service provider to OEMs, national and provincial government departments, ICT industry, telecommunications industries, corporations and tertiary education institutions in South Africa.
- Desco offers a full range of recycling services for all e-waste types, with a key focus on the recovery and pre-processing of PCBs. Approximately 97% of all goods processed by Desco are recycled.

Annual volumes of WEEE handled ± 5,000 t

Composition, 2015



Compostion of WEEE outputs, 2015



Approximate number of staff involved in WEEE activities in 2015 = 100

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- Desco operates from its head office and main plant in Pomona, Johannesburg.
- Gauteng constitutes the main geographic market for the company, followed by the Western Cape and KZN
- Desco sources its WEEE inputs through various channels and a well-established network spanning across South Africa and neighbouring SADC countries.
- The company has formal contracts with large corporates, SOCs, manufacturers, scrap dealers and government departments, as well as smaller dismantlers and collectors. Collections are aided by formal drop-off sites at large retailers, academic institutions and schools.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- Desco's national collection activities are aided by a fleet of seven trucks with capacities ranging between 2.5t to 12t and four 1t trucks.
- Dismantling operations are predominately manual – WEEE fractions such as PCBs, plastics, ferrous and non-ferrous metals, glass and PVC cabling are removed using pneumatic screwdrivers, drills, grinders and hammers.
- Desco's pre-processing equipment includes four mechanical shredders as well as other sophisticated equipment which liberate and sort WEEE fractions according to end-user client specifications.

MAIN MARKET FOR OUTPUTS

- The main output fractions produced by Desco are ferrous and non-ferrous metals, shredded PCBs, plastic and batteries.
- Desco sells its pre-processed WEEE fractions to both domestic and export markets for final processing.
- LIB volumes that are being handled by Desco are small and are exported to Europe for further processing
- Approximately 200 t of hazardous substances, mainly CRTs, were landfilled by the company in 2015.

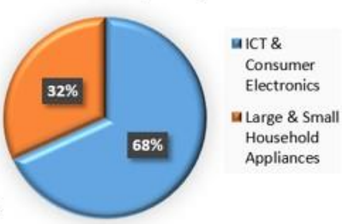
ELECTRONIC CEMETERY E-WASTE MANAGEMENT (PTY) LTD

Company Overview

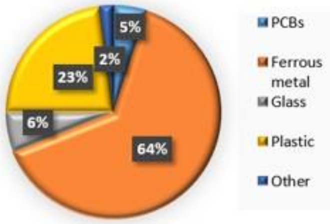
- Electronic Cemetery is a small WEEE recycling firm based in Pinetown, KwaZulu-Natal. It was established in 2010 focusing on the refurbishment of ICT equipment. The company commenced its formal WEEE activities in 2013.
- The company is involved in the collection and dismantling stages of the WEEE value chain. Refurbishment remains the main revenue driver for the business.

Geographic Scope of Activities

Annual volumes of WEEE handled ± 44 t
Composition, 2015



Compostion of WEEE outputs, 2015



Approximate number of staff involves in WEEE activities in 2015 = 8

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- The company's recycling activities are geographically concentrated in KZN. Facilities include a branch office in Pinetown and collection sites in Pietermaritzburg, Durban, Richmond, New Castle and Richards Bay.
- The company sources its WEEE from industry, universities, schools, private households and informal collectors. Informal collectors tend to focus on PCBs and higher-grade computers.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- The dismantling process is exclusively manual using screw drivers, drills, hammers (for ABS plastics), pliers and grinders.
- Rudimentary skills are required to perform these tasks.
- Staff are trained using online videos and by means of work-shadowing.

MAIN MARKET FOR OUTPUTS

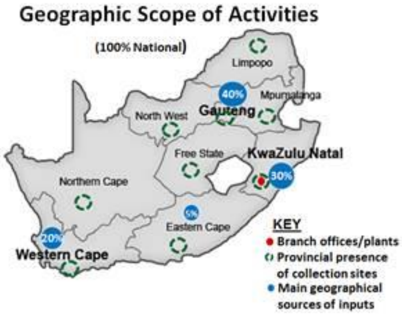
- The main outputs produced by the company are ferrous metals, plastic, PCBs, glass, and cable.
- With the exception of CRTs, which are landfilled, all separated fractions are passed onto local pre-processors for subsequent treatment and metal extraction.

E-WASTE AFRICA

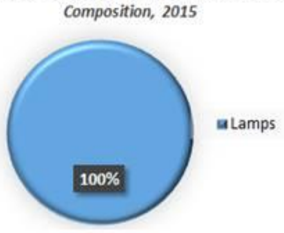
Company Overview

- Established in 2012, E-Waste Africa is a leading lamp recycler based in KZN, South Africa. The company's activities span the collection, storage and pre-processing of all types of mercury-containing lamps.

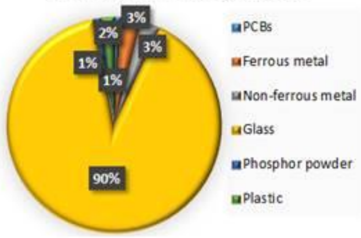
Geographic Scope of Activities



Annual volumes of WEEE handled ± 300 t
Composition, 2015



Compostion of WEEE outputs, 2015



Approximate number of staff involved in WEEE activities in 2015 = 11

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- E-Waste Africa operates from its head office and main plant in Pietermaritzburg, KZN.
- The company sources obsolete bulbs from across the country, with Gauteng, KZN, Western Cape and the Eastern Cape accounting for the largest volumes. The company is looking to expand into SADC.
- E-Waste Africa only accepts bulbs from an established base of private and public sector clients, as the logistics around the concept are fairly structured.
- E-Waste Africa has specially-designed disposal bins in Pick 'n Pay and Woolworths outlets across the country facilitating the safe and environmentally-friendly disposal of used CFLs by members of the public.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- No prior dismantling of lamps is undertaken. E-Waste Africa's prefers to crush lamps at collections sites prior to their transportation.
- Crushed or whole lamps are processed in a fully-mechanised, modular system sourced from Balkan, UK. The MP8000 system has the capacity to handle 5,000 linear tubes (4ft) and other lamps per hour (around 200 kg/hour) and operates 4-5 days a week.
- The entry level qualification at the company is a Matric. E-Waste Africa spends around 5% of its revenue on training.

MAIN MARKET FOR OUTPUTS

- The main output fractions produced by E-Waste Africa are PCBs, glass, end caps (metal or plastic depending on lamps processed), and mercury-bearing phosphor powder.
- The company endeavours to ensure that all these fractions are appropriately treated and reused locally as far as possible.
- Currently plastics and phosphor powders are stockpiled.

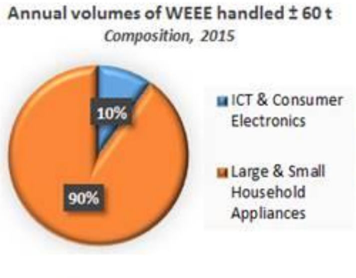
INCA METALS (PTY) LTD

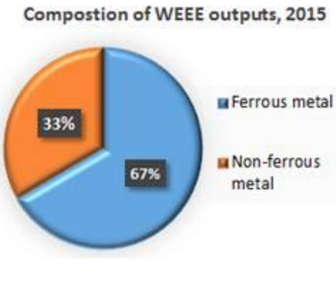
STAGE 1: Collection ✓ | **STAGE 2:** Dismantling ✓ | **STAGE 3:** Pre-processing ✗ | **STAGE 4:** Processing ✗

Company Overview

- Inca Metals (Pty) Ltd is a scrap metal trading company based in East London, dealing in ferrous and non-ferrous metals, specifically copper and brass. The company has been involved in WEEE recycling activities since 2007, but it remains a secondary activity for the company.
- The company operates in the collecting, sorting, and dismantling stages of the WEEE value chain with an emphasis on large and small household goods for onward sale to metal recyclers.

Geographic Scope of Activities





Approximate number of staff involved in WEEE activities in 2015 = 8

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- The company's operations and geographical market is restricted to the Eastern Cape. It has a branch office and factory/plant in East London with collection sites distributed across the province in King Williams Town, Butterworth, Port Elizabeth, and Mthatha.
- The company buys all types of metals/metal products including copper, brass, aluminium, lead, batteries, exhausts with catalytic converters, ceramic/plastic CPUs, raw cards, cellphone motherboards, and all grades of computer PCBs.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- Operations are predominantly manual involving the use of drills, grinders and electric screwdrivers.
- In terms of skills and qualifications required, the entry level requirement is a Matric Certificate.
- On-the-job training is provided on inspection and collection of waste, recording weights, sales, waste handling, and health and safety.

MAIN MARKET FOR OUTPUTS

- The main output fractions produced by the company are ferrous and non-ferrous scrap, all of which was sold onwards to locally pre-processors and processors for further treatment.

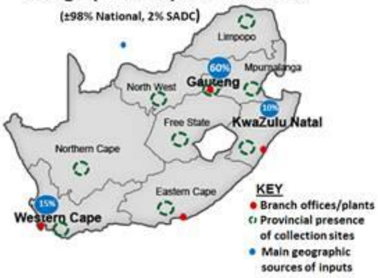
RECLITE (PTY) LTD

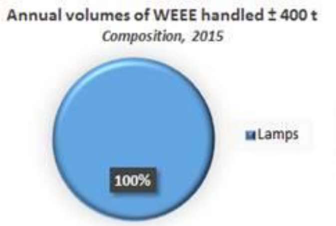
STAGE 1: Collection ✓ | **STAGE 2:** Dismantling ✗ | **STAGE 3:** Pre-processing ✓ | **STAGE 4:** Processing ✗

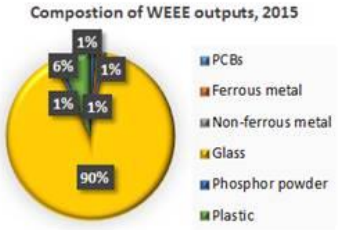
Company Overview

- RecLite is a leading South African collector and pre-processor of fluorescent lamps, HID Lamps and other products that contain mercury lamps. The company commenced operations in 2008 and received its first HH Waste Management Licence for e-waste and lamp processing in October 2013.

Geographic Scope of Activities







Approximate number of staff involved in WEEE activities in 2015 = 16

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- RecLite's head office and plant is based in Germiston, Gauteng. The company has three additional branch offices in the Western Cape, KZN and the Eastern Cape.
- RecLite sources lamps from across the country and SADC via a well-established network of large and small companies, strategic partnerships and formal drop-off sites. Gauteng, Western Cape and KZN account for the highest volumes. Free State, Mpumalanga and North West are serviced from Gauteng. Reclite does not pay for the lamps that they receive due to the high recycling costs.
- The company is in the process of developing a small black entrepreneur in Nelspruit to be an e-waste collecting centre in Limpopo and entered into a partnership with Bolunga e-Waste to cover the East London region. In 2016, Reclite entered into a partnership with Contrawaste, in Swaziland, to commence the collection of waste lighting in the country.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- The company collects whole, uncrushed lamps in lamp collection bins as well as crushed, untreated lamps in sealed drums. Lamps are transported to the Johannesburg facility where they are weighed and sorted.
- There is no dismantling step. Pre-processing is performed using the MRT (LP400) lamp crushing, sorting and cleaning technology from Sweden.
- The plant's capacity is 6,000 tubes per hour. The separation plant has a design capacity of 800kg/hour.

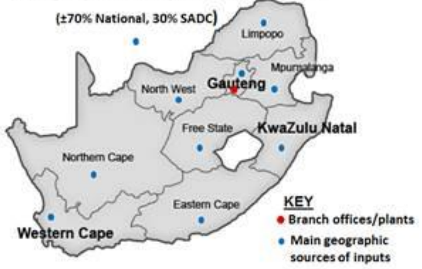
MAIN MARKET FOR OUTPUTS

- The main output fractions produced are small amounts of PCBs, glass, plastic, phosphor powder, aluminium, ferrous & non-ferrous metal, and mercury (>99% purity).
- Recovered PCBs, glass, plastic and metals are dispatched to local processors for further treatment, while mercury and phosphor powder are exported to specialised processors internationally.

SA PRECIOUS METALS (PTY) LTD

STAGE 1: Collection ✗ | STAGE 2: Dismantling ✗ | STAGE 3: Pre-processing ✗ | STAGE 4: Processing ✓

Geographic Scope of Activities



Company Overview

- SA Precious Metals (Pty) Ltd, is a South African company, specialising in the manufacture of precious metal fine chemicals, the refining of precious metals, as well as the fabrication of precious metal products.
- The company has developed a (proprietary) environmentally-friendly, fully-automated hydrometallurgical solution to process PCBs in South Africa. The refinery is based in Wadeville, Gauteng.

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- The company's head office and plant is based in Wadeville, Gauteng.
- The company procures the majority of its PCBs from approved small- to medium-sized recycling companies in South Africa. The balance is sourced from neighbouring countries such as Zambia, Botswana, Namibia and Mozambique.
- Given the modular design of the plant it can be set up anywhere in the country. As such, the company is looking to expand its geographic footprint to Cape Town and Durban and to process PCBs at the feedstock site, via joint venture agreements with local firms.

Approximate number of staff involved in WEEE activities in 2015 = 48

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- The refining technology was developed over a period of 16 years and is currently in the commercial demonstration phase.
- The company prefers to buy un-shredded PCBs in order to avoid losses of valuable secondary materials contained within them. Whole PCBs are milled on-site and fed into the plant. The plant uses a batch production system and has capacity to treat 2t per day of high, medium and low grade PCBs. The plant's capacity can easily be expanded to 4t per day provided there is enough feedstock material and of consistent quality. The plant produces zero waste. Gases produced from the refining process are scrubbed whilst process water is sold to a paper recycler on its premises.
- The company has also developed a technology for the processing of LIBs, but volumes are currently too small to warrant establishing such a plant.

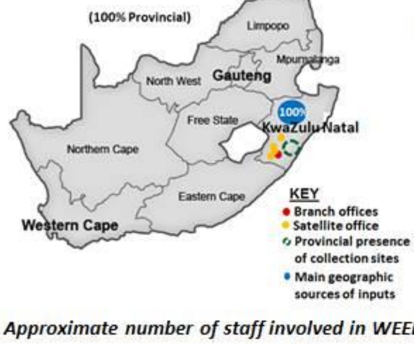
MAIN MARKET FOR OUTPUTS

- The PCB refining plant has the capacity to extract 100% of the metals contained in PCBs.
- The main outputs are high-valued intermediate products (e.g. copper cathode, PGM chemicals, silver nitrate, etc.) which can be used in various precious and base-metal downstream industries both locally and internationally.

SIBANYE RECYCLING LTD

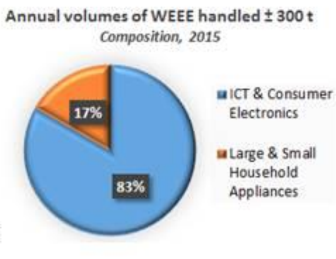
STAGE 1: Collection ✓ | STAGE 2: Dismantling ✓ | STAGE 3: Pre-processing ✓ | STAGE 4: Processing ✗

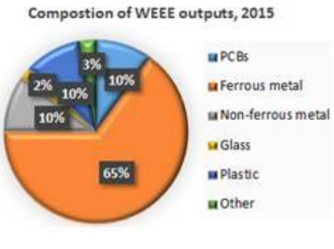
Geographic Scope of Activities



Company Overview

- Sibanye Recycling Ltd is a small, service-based recycling company operating in the Pietermaritzburg area, KZN. Operations began in 2010 with the company focusing on the recycling of paper and plastics. The company broadened into WEEE in 2012. A subsequent joint venture with Ukuwanje has enabled it to expand into ferrous and non-ferrous metal recycling.
- Sibanye's activities are largely focused on the collection and dismantling stages of the value chain; however, it also pre-processes plastics on-site.





Approximate number of staff involved in WEEE activities in 2015 = 7

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- The company operates from a head office in Pietermaritzburg, with branches in Grey Town, Richmond, Mooi River and Howick.
- Sibanye sources its inputs from large corporate companies and government departments as well from an established network of smaller recyclers and informal collectors distributed across KZN.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- The company currently has 2 trucks for collecting and sourcing its WEEE inputs.
- The dismantling of WEEE is performed manually using electric screwdrivers, grinders and hammers. WEEE is stripped and sorted into three major categories: electronics, plastics and metal. Plastics are pelletised using a second-hand shredder The company's long-term goal is to move into the mechanical stripping and dismantling of WEEE once collection volumes increase.
- The entry level qualification is a Grade 10. In-house training is provided on various aspects of the business

MAIN MARKET FOR OUTPUTS

- The company's main output fractions are ferrous metal, non-ferrous metal, PCBs, plastic, and glass and packaging material.
- Only glass (CRTs) are landfilled, while the rest of the fractions are sold onto a range of pre-processors and processors based within KZN and Gauteng

SIMS RCYCLING SOLUTIONS LTD

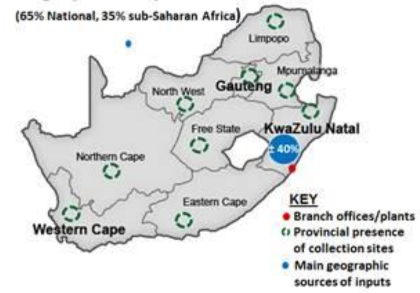
STAGE 1: Collection ✓ | STAGE 2: Dismantling ✓ | STAGE 3: Pre-processing ✓ | STAGE 4: Processing ✗

Company Overview

- SIMS Metal Management Ltd (in scrap metal recycling and trading business globally) is the holding company for SIMS Recycling Solutions Ltd (the subsidiary). SIMS Recycling Solutions Ltd is the a global e-waste recycling and IT asset management company with a local branch/operation in Durban, South Africa. The company set up its South African WEEE recycling operations in 2009.

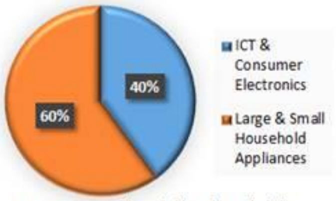
Geographic Scope of Activities

(65% National, 35% sub-Saharan Africa)



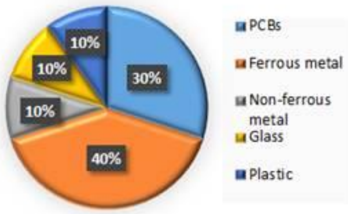
Annual volumes of WEEE handled ± 1,500 t

Composition, 2015



Note: Large & small household appliances includes industrial and manufacturing scrap

Compostion of WEEE outputs, 2015



Approximate number of staff of WEEE activities in 2015 = 50

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- The company's head office and plant is based in Ballito, KZN. The company is in the process of establishing branch activities in Johannesburg and Cape Town.
- The company accepts white goods, heating appliances, manufacturing scrap, and industrial machinery and equipment. Inputs are sourced from across South Africa with supplementary imports of obsolete goods from across sub-Saharan Africa. The company sources its WEEE primarily through formal contracts with leading IT and electronics firms, banks and companies.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- Dismantling is all performed manually to ensure maximum value in output fractions produced and to reduce maintenance costs of shredders. Equipment used include handheld electronic tools, screwdrivers, and drills.
- For certain fractions, pre-processing is not required as end-users require whole 'clean' units to ensure maximums grade and recovery. Plastic, ferrous and non-ferrous components are then sorted and sent for further pre-processing by means of shredding.

MAIN MARKET FOR OUTPUTS

- The main output fractions produced include PCBs, ferrous and non-ferrous metal, plastic, and glass.
- Shredded PCBs are exported to Asia.
- Ferrous and non-ferrous metals, plastic and glass are sold to local or foreign approved pre-processors and processors, while CRTs are landfilled.

SINDAWONYE GRANULATORS & PROCESSORS (PTY) LTD

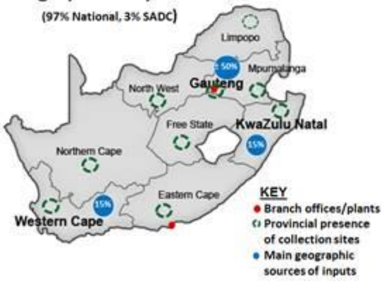
STAGE 1: Collection ✓ | STAGE 2: Dismantling ✓ | STAGE 3: Pre-processing ✓ | STAGE 4: Processing ✗

Company Overview

- Sindawonye, one of the largest WEEE recycling firms in South Africa, was established in February 1997 in order to fill a niche identified in the non-ferrous metal recycling field.
- The company's scope of services has evolved over time to cover the collection, sorting, dismantling and pre-processing of obsolete ICT and consumer electronics, household goods, scrap ferrous and non-ferrous metal, and cables (copper, aluminium and fibre optic).

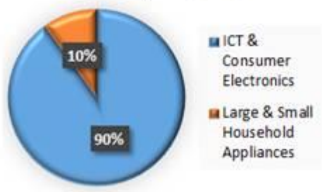
Geographic Scope of Activities

(97% National, 3% SADC)

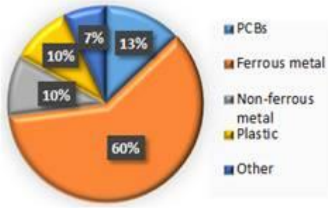


Annual volumes of WEEE handled ± 3,000 t

Composition, 2015



Compostion of WEEE outputs, 2015



Approximate number of staff involved in WEEE activities in 2015 = 200

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- Sindawonye operates from its head office and 25,000m² factory in Gauteng. It also has a 10,000m² factory in Port Elizabeth, Eastern Cape.
- The company acquires its waste through formal supply contracts with major SOCs and banks. It also has an established network of collection bins and arrangements with smaller private collectors and dismantlers across South Africa. Sindawonye does not deal with informal vendors. The company occasionally imports e-waste from neighbouring countries (Botswana, Mozambique and Lesotho). The volume imported is very small in comparison to that from RSA.
- Sindawonye has an extensive range of trucks and loading devices as well as various collection bins to undertake removal nationally.

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- Manual labour, together with chisels, drills and screwdrivers, is used to sort and dismantle e-waste into identifiable e-waste streams such as PC boards, plastics and the metals.
- The plastics and metals are then sent to the shredder that breaks them into smaller pieces. The shredder has capacity to shred ± 8 t of e-waste per hour.
- In 2004, Sindawonye established a one-of-a-kind Fibre Optic Cables recycling operation in Bedford, Eastern Cape – the Thembani Special Day Care and Women Project (Thembani). The company delivers around 10 t of redundant Telkom optic cable to Thembani monthly, which is manually stripped and sorted.

MAIN MARKET FOR OUTPUTS

- The company's main outputs are ferrous metals, non-ferrous metals, electronic plastics, PCBs, and batteries and cardboard.
- These are sold onto various domestic and international processors for subsequent treatment and beneficiation.
- Less than 100 t of waste is landfilled annually.

SMARTMATTA

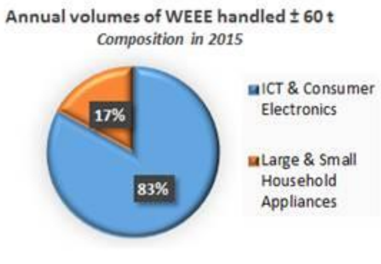
SmartMatta Reuse. Renew.

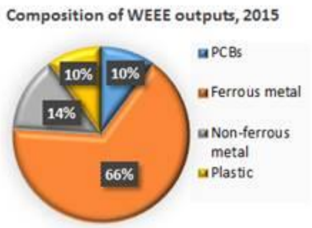
STAGE 1: Collection ✓ | STAGE 2: Dismantling ✗ | STAGE 3: Pre-processing ✗ | STAGE 4: Processing ✗

Company Overview

- SmartMatta is an integrated waste management company focusing specifically on the collection and recycling of paper, cardboard and cans
- The company started out in 1988 as 'Re-Ethical', an environmental specialist company, and branched into WEEE collection in 2010. In 2015, Re-Ethical was acquired by Barloworld Logistics, resulting in the formation of a new future-focused company called 'SmartMatta'. WEEE remains a secondary activity for the company.

Geographic Scope of Activities





Approximate number of staff involved in WEEE activities in 2015 = 20 (of total staff of 700)

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- SmartMatta has three regional centres of operations based in Durban, Johannesburg and Cape Town.
- The company services around 170 sites across South Africa. Clients include private sector firms in the FMCG manufacturing, heavy industry, retail, and packaging industries, as well as parastatal organisations and universities

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- Collections are aided by an outsourced transport contract with Barloworld Transport, which operates a fleet of 40 vehicles.
- SmartMatta also runs a dedicated training academy accredited by the Local Government (LG) SETA, and offers a variety of National Qualifications that are registered by the South African Qualifications Authority

MAIN MARKET FOR OUTPUTS

- WEEE fractions collected include PCBs, ferrous and non-ferrous metal and plastics, all of which is sold onto affiliated local dismantlers and pre-processors

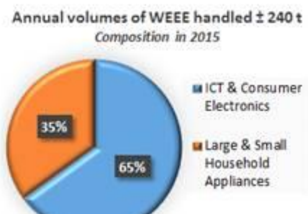
TSHWANE ELECTRONIC WASTE COMPANY LTD

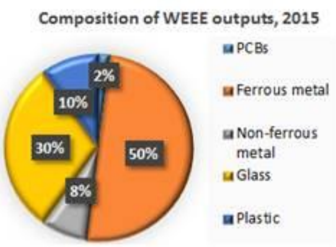
STAGE 1: Collection ✓ | STAGE 2: Dismantling ✓ | STAGE 3: Pre-processing ✗ | STAGE 4: Processing ✗

Company Overview

- Tshwane Electronic Waste Company has 20 years experience in the IT industry and extensive experience in e-waste recycling. The company started out in 1995 as Intelligent Computing focusing purely on the refurbishment and resale of ICT equipment. Company was re-established in 2012, in its current form, following the diversification into WEEE.
- The company's core business is refurbishment of salvaged equipment for resell. Equipment that cannot be refurbished is stripped and individual materials and components removed and sold to pre-processors and processors.

Geographic Scope of Activities





Approximate number of staff involved in WEEE activities in 2015 = 17

GEOGRAPHIC FOOTPRINT OF ACTIVITIES

- The company operates from three sites in Pretoria and sources waste mainly from within Gauteng, but also the Western Cape and KZN.
- WEEE is sourced through various direct and indirect channels, and suppliers include both formal and informal companies. The company is currently not importing WEEE, but has received interest from Botswana

PLANT/TECHNOLOGY/EQUIPMENT FOCUS

- The company uses bakkies to manage the pick-up and collection of the e-waste loads less than 1t.
- Dismantling is done manually using basic tools (screwdrivers, pliers, grinders, hammers etc.). Volumes are currently too small to warrant mechanisation.
- The company requires a minimum of 100t per month of WEEE to maintain and grow its operations.

MAIN MARKET FOR OUTPUTS

- The company's main output fractions are PCBs, ferrous and non-ferrous metal, glass and plastic.
- All dismantled, sorted and categorised WEEE is sold onto affiliated local pre-processors.
- Less than 1 t of WEEE is landfilled by the company annually.

UNIVERSAL RECYCLING COMPANY (PTY) LTD

STAGE 1: Collection ✓ | STAGE 2: Dismantling ✓ | STAGE 3: Pre-processing ✓ | STAGE 4: Processing ✗

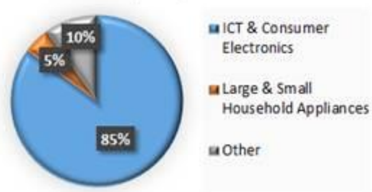
Geographic Scope of Activities

(National & SADC footprint)

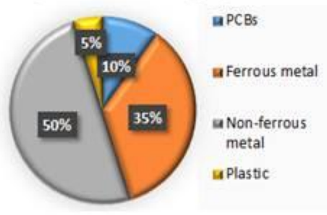
Company Overview

- Universal Recycling Company (URC) is a scrap metal recycling company, formed in 1992 with the merger of A. Loewenthal Metals (founded in 1938 by Alfred Loewenthal) and Universal Metal Holdings, an associated company of the Cape Gate Group.
- The company specialises in the processing of 'complex scrap', including WEEE, used electrical appliances, iron-contaminated aluminium, aircraft scrap and any end-of-life metallic material containing a mix of ferrous and non-ferrous metals, as well as inorganics such as paper, plastic and wood.

Annual volumes of WEEE handled ± 3,000 t
Composition, 2015



Compostion of WEEE outputs, 2015



GEOGRAPHIC FOOTPRINT OF ACTIVITIES	PLANT/TECHNOLOGY/ EQUIPMENT FOCUS	MAIN MARKET FOR OUTPUTS
o The company operates from two facilities in Industria, Johannesburg, and sources inputs from Gauteng, Western Cape, Free State and SADC (Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Zambia and Zimbabwe). A similar plant and recycling business has been established in Mozambique. o URC operates a closed door policy with regard to procuring its input material, which comes from a diverse range of industries, companies, scrap metal dealers and tenders. A collection service is offered for larger lots up to 500 km from Johannesburg.	o Operations are exclusively mechanical and encompasses a range of sophisticated technology such as mechanical shredders, pulverisers, rotatory magnets, granulators, shears and balers on disassembly lines. o The company also has a fleet of front end loaders, forklifts, cranes, and 30t trucks	o The company's main output fractions are ferrous and non-ferrous metals, shredded PCBs, and plastics. o PCBs are exported to an off-shore processor. Ferrous and non-ferrous scrap is sold locally as well as exported. o Non-metallic fractions are landfilled.

WASTE PLAN LTD

STAGE 1: Collection ✓ | STAGE 2: Dismantling ✗ | STAGE 3: Pre-processing ✗ | STAGE 4: Processing ✗

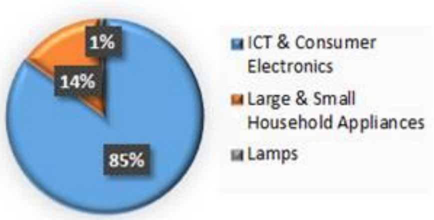
Geographic Scope of Activities

(100% National)

Company Overview

- Waste Plan Ltd is a national on-site integrated waste management company specialising in recycling and reducing waste to landfill.
- The company focuses on the collection of plastics, cardboard, metals, cans and e-waste recyclables
- WastePlan's operations commenced in 2004. It expanded into the collection of WEEE in 2010. WEEE collection remains a secondary activity for the firm.

Annual volumes of WEEE handled ± 200 t
Composition in 2015



GEOGRAPHIC FOOTPRINT OF ACTIVITIES	PLANT/TECHNOLOGY/EQUIPMENT FOCUS	MAIN MARKET FOR OUTPUTS
o WastePlan operates from three main branches based in Cape Town, Durban and Johannesburg. It has satellite branches in Port Elizabeth and Bloemfontein. o WastePlan has approximately 250 commercial customers situated across Gauteng, Western Cape and KZN. It also runs residential recycling collections in several areas in Cape Town and Pretoria, covering a total of 160,000 households.	o WastePlan has its own dedicated logistics fleet comprising 80 refuse collection trucks (with capacities of 2-4t and 10-12t), internal data management system, and three Material Recovery Facilities (MRFs). o The company also has its own plastics processing plant, which allows it to process plastic waste streams which are not directly recyclable. o No manual or mechanised dismantling takes place.	o WEEE is sold onto affiliated local dismantlers and pre-processors. o The company maintains that through its collections it is able to divert 2,000t of waste from landfills every month.

Presentation of Research Findings

This section presents the research findings of a questionnaire survey and interviews with 27 firms spanning the collection, dismantling, pre-processing and processing of ICT & consumer electronics, large and small household goods (including temperature exchange equipment) and lamps waste streams in South Africa, supplemented by a desktop review of companies engaged in the local WEEE industry.

3.1 Organisational profile of recycling firms

In order to formulate a picture of the structure and dynamism of the South African WEEE recycling industry, firms were asked a series of basic questions regarding the geographical scope of operations, company age and commencement of WEEE activities, employment and skills profile, nature of WEEE activities, and distribution of activities across the various stages of the value chain.

It is apparent that the sector consists of a diversity of large and small players engaged in a range of different activities. Some firms are niche oriented in focus, providing services in only select areas of the value chain, or within a restricted geographical area, or in particular waste streams. Others provide a more generic range of services in addition to recycling, or have a wide national and regional footprint, offer specialised activities over a number of different stages in the WEEE value chain, and do not discriminate according to type of waste received. Some companies distribute imported equipment and systems for local and regional markets, while others are active in the trading of specialised output fractions. For some firms, WEEE is a core activity, for others a critical but secondary service offering. While some firms have been in existence for a number of decades and have strengthened their local position through a combination of organic and acquisitive growth, others are fairly new and only just beginning to position themselves in the market. Key findings are discussed further below.

3.1.1 Age and year of commencement of WEEE activities

Data has been provided by 24 firms (Table 6):

- For most of the firms surveyed, WEEE activities commenced after the initial established date of the firm.
- Processors such as SA Metals Group and Rand Refinery can trace their origins back to the early 20th century with the commencement of mining activities in the country. Their subsequent growth and evolution has been influenced by the secondary recovery and processing of ferrous, non-ferrous and precious metal scrap.
- Pre-processing firms such as Desco, Reclam, and URC are very large and integrated companies who have been active in the recycling sector for two to three decades.
- The dismantling sector is characterised by a more diversified range of companies who have been operational for 5 to 10 years. Their move into WEEE recycling has also been a lot more recent (2-5 years).
- With the exception of some of the larger and specialised companies (Desco, RecLite, Sindawonye, and URC), who focused on WEEE recycling from the outset, most other firms involved in the sector commenced operations in a related field – waste management, computer refurbishment, ferrous and non-ferrous metal scrap processing – before diversifying into WEEE recycling.
- In most cases, firms regard the move into WEEE recycling as a natural progression from their

main activities; a complementary service offering, and an integral component in addressing their 'zero waste to landfill' environmental goals for South Africa.

3.1.2 Employment profile and skills base

Firms were asked to indicate the number of employees engaged in WEEE activities and their distribution across management, sales and administration, and plant/operational activities.

Table 6 captures the total number of people employed in WEEE activities in 2015 across the 18 firms who provided information. Of the 677 people employed, the majority were employed in production or plant-related activities with the balance in sales, management and administration.

- According to interview feedback, while WEEE recycling is currently not a large employer in South Africa, it has the potential to be a significant absorber of low-skilled labour in future, particularly as the culture of recycling becomes more entrenched and WEEE disposal volumes increase.
- Smaller firms indicated that their employment numbers are variable and strongly influenced by the volumes of WEEE received – new staff can be hired if volumes increase sufficiently to justify it and vice versa.
- Firms that are involved in both ICT asset management and dismantling activities maintain that WEEE recycling activities tend to be much more labour-intensive than their refurbishment activities.
- There is consensus amongst dismantling and pre-processing firms that skills and qualifications are not an issue in terms of sourcing and hiring new staff with the minimum entry requirement being a Matric (Grade 12) with Mathematics and Science being a significant advantage. A good work ethic, willingness to learn, fluency in English, and attentiveness to detail are much more valuable qualities at the entry-level.

Table 6: Age, commencement of WEEE activities, number of employees and job disaggregation in select firms

Company	Year of Commencement of Operations	Year of Commencement of WEEE Activities	Approximate Number of Employees	Number of Staff in Management, Admin & Sales	Number of Staff in Operational/ Production Activities
Africa E-Waste	2011	2011	15	Not specified	Not specified
Bolunga Electronic Waste	2014	2014	12	3	9
Cape E-Waste	2012	2012	25	3	22
Computer Scrap Recycling	1998	early 2000s	10	Not specified	Not specified
Desco Electronic Recyclers Ltd	1992	1992	100	Not specified	Not specified
Effortless Computer Recycling	2012	2012	-	-	-
Electronic Cemetery	2010	2013	8	3	5
E-Waste Africa	2012	2012	11	5	6
E-waste Technologies Africa	2000	2015	5	1	4
Inca Metals	2007	2007	8	Not specified	Not specified
Indalo Resources Ltd	2003	2003	-	-	-
Rand Refinery	1920	2004	-	-	-
Reclam	1980	2010	25	Not specified	Not specified
RecLite	2009	2009	16	8	8
SA Precious Metals Ltd	2000	2015#	48	Not specified	Not specified
Sibanye Recycling	2010	2012	7	2	5
Sims Recycling	2009	2009	50	15	35
Sindawonye Granulators & Processors	1997	1997	200	Not specified	Not specified
SmartMatta (Re-Ethical)	1998	2010	20	Not specified	Not specified
Tshwane Electronic Waste Company	1995	2012	17	7	10
Universal Recycling Company	1992*	+30 years ago	100	Not specified	Not specified
Virgin Earth	2008	2008	-	-	-
Waste Plan	2004	2010	-	-	-

* in its current form

\# Developed WEEE processing technology between 2000 and 2015. Pilot plant for PBC processing commissioned in latter half of 2015.

- Specialised pre-processors and processors do require more advanced skills (artisans, engineering, marketing, sales, computer technicians, etc.) in certain operational, plant and management activities.

- Most companies provide in-house training and skills upgrading on a continuous basis on various operational, production, and health and safety issues. Workers start off as labourers and are gradually trained up into various positions depending on the focus of the company. Some larger firms offer bursaries to staff to undertake tertiary education.

3.1.3 WEEE as a primary or secondary business activity

In order to assess the significance of WEEE recycling to firms, respondents were requested to comment as to whether they regard it as a core or secondary business activity for the firm. As can be seen from Table 7, of the 26 firms for which data was provided, 54% regard WEEE as a secondary activity. Only ten (38%) firms regard it as a core activity and only two indicated that the split is 50:50 between WEEE recycling and their other waste recycling activities.

Table 7: WEEE recycling as a primary or secondary business activity

Company	WEEE as a Primary (Core) Activity	WEEE as a Secondary Activity	WEEE as an Equal (50:50) Business Activity
Africa E-Waste	●		
Bolunga Electronic Waste		●	
Cape E-Waste	●		
Computer Scrap Recycling			●
Desco Electronic Recyclers	●		
Effortless Computer Recycling		●	
Electronic Cemetery	●		
eWaste Africa	●		
E-waste Technologies Africa		●	
Inca Metals		●	
Indalo Resources	●		
Just PCs		●	
Javco		●	
Metrex		●	
Reclam		●	
RecLite	●		
SA Metals Group		●	
SA Precious Metals	●		
Sibanye Recycling			●
Sims Recycling	●	●	
Sindawonye		●	
SmartMatta		●	
Tshwane Electronic Waste		●	
URC		●	
Virgin Earth	●		
Waste Plan		●	

- In small- to medium-sized recyclers focusing on ICT asset management and disposal, WEEE recycling is seen as a secondary (albeit complementary) business activity. Although refurbishment was not part of the scope for this research study, it was found to be a significant revenue driver for such firms accounting for 60-80% of annual revenues. Recycling (dismantling) accounted for the balance (20-40%). Business opportunities in the short-term are perceived to be greater in refurbishment than recycling owing to the growing market for second-hand laptops and personal computers (amongst other items) in households, internet cafes in suburban and township areas, rural schools, libraries, hospitals and public institutions etc.

- WEEE is also a secondary activity for scrap metal trading companies, integrated waste management providers, and end processors.

- Most integrated waste management companies are selling raw WEEE to large pre-processors at around R40/kg and maintain that they will consider investing in the WEEE business if they can get prices of between R60-80/kg.

- In the case of scrap traders, respondents argue that WEEE volumes are too low to warrant an exclusive focus on WEEE recycling. Prices offered locally for output WEEE fractions are much lower (70%)[53] than what can be obtained from exporting. This undermines the profitability of local business and their potential to expand and grow. Their business approach is to rather deepen existing product lines and diversify into other recyclable materials such as beverage cans and cables.

- WEEE remains a core activity for dismantlers and pre-processors specialising in particular waste streams and output fractions (such as Cape e-Waste, Desco, E-Waste Africa, Metrix, RecLite, Sims Recycling and Sindawonye).

[53] It is important to note that this figure was confirmed by a number of recyclers and applies specifically to non-ferrous fractions.

3.1.4 Participation across the value chain

An important aspect of the study was to gauge the distribution of firm activities across the different stages in the WEEE value chain. Respondents were asked to indicate which of the three stages – dismantling, pre-processing, or processing – they were involved in. Although not part of the research brief, during interviews it became apparent the collection stage plays a pivotal role in driving the overall performance of the sector and the majority of firms are involved directly or indirectly in it. As such, it was included as the first stage in the value chain. Table 8 summarises how the 27 firms who participated in the study categorise their various activities.

Table 8: Firm participation across the WEEE value chain

Company	Collection	Dis-mantling	Pre-Processing	Processing
Africa E-Waste	●	●		
Bolunga Electronic Waste	●	●		
Cape E-Waste	●	●		
Computer Scrap Recycling	●	●		
Desco Electronic Recyclers	●	●	●	
Effortless Computer Recycling	●	●		
Electronic Cemetery	●	●		
eWaste Africa	●		●	
E-waste Technologies Africa	●	●		
Inca Metals	●	●		
Indalo Resources	●	●		
Just PCs	●	●		
Javco		●	●	
Metrex	●	●		
Rand Refinery				●
Reclam	●	●		
RecLite	●		●	
SA Metals Group	●	●	●	
SA Precious Metals				●
Sibanye Recycling	●	●	●	
Sims Recycling	●	●	●	
Sindawonye	●	●	●	
SmartMatta	●			
Tshwane Electronic Waste	●	●		
URC	●		●	
Virgin Earth	●	●		
Waste Plan	●			

- There is no single firm that is active across all four stages of the value chain.
- As can be seen, with the exception of firms engaged in final metal processing, all firms are involved directly or indirectly in the collection of WEEE.
- Most small- to medium-sized firms active across the different provinces and waste streams participate in the collection and dismantling of WEEE and sell the fractions to downstream pre-processors and processors in domestic and export markets at a profit. Notably, the majority of small- to medium-sized recycling companies processing below 500t of WEEE per annum end at the dismantling stage of the WEEE value chain.
- Not all pre-processors are involved in the dismantling stage. Some pre-processors handling mixed WEEE prefer to receive it already dismantled, separated and characterised. Other more specialised activities, such as lamp recycling, do not require prior dismantling before processing in their plants.
- Firms active in the pre-processing stage are currently unlikely to venture into final processing and material recovery given the specialised nature of the plants and technologies required; the high levels of capital investment needed; the cyclical nature of the end-user markets for final products; and the lack of sufficient and steady volumes of WEEE available in South Africa and the sub-region (risk of supply).
- The categorisation depicted in Table 8 is quite generalised; some firms' activities cannot be easily categorised exclusively as 'dismantling' or 'pre-processing'. Some are only involved in selective aspects of the dismantling process, while others only partially pre-process fractions on site. For example, one firm collects WEEE at its facility and does very limited dismantling before passing it on to another dismantler for more selective manual separation. Two firms dismantle obsolete ICT and consumer products they receive, but only pre-process the plastic fraction (a very small percentage of their overall output volumes) on site. The latter firms are classified as 'pre-processors', but the scale of their activities is small in comparison with established firms such as Desco, Reclam, Sindawonye and URC.

3.1.5 Geographical footprint of operations

In order to assess the geographical footprint of WEEE recycling activities in South Africa, firms were asked to indicate which provinces they had active recycling operations within, and what the nature of these activities are – i.e. whether branch office, plant/factory, or collection sites. Table 9 captures the provincial distribution of the 27 respondents' activities, while Table 10 provides a description of the nature of these activities.

- The parameters of the study were restricted to profiling the recognisable recyclers within the five provinces of Gauteng, KZN, Western Cape, Eastern Cape and Mpumalanga. The findings confirm the concentration of WEEE operations in South Africa in the provinces with the highest populations, relatively higher disposal incomes, and greatest concertation of economic activities – Gauteng, Western Cape and KZN.
- Telephonic discussions with a recycler based in Nelspruit, Mpumalanga, indicated that WEEE volumes generated in the city are very low and have not warranted the establishment of a formal recycling operation in the province. The recycler (who recently closed his branch in Nelspruit due to low volumes and has subsequently moved to Pretoria) suggested that higher volumes of WEEE could potentially be sourced from Witbank and Secunda given the presence of large mining and processing industries in the area. However, this will require a more focused approach to the identification of WEEE and its formal collection going forward. Given the close proximity of these towns to Gauteng (±400 km), it is possible that they will continue to be served by the larger, more established WEEE pre-processors operating out of Gauteng.
- Smaller recyclers and processors remain geographically concentrated within their particular province.
- Most medium- and large-sized firms have branch offices and collection sites in two or more provinces.
- Currently, only Reclam has collection sites across all nine provinces. However, these sites receive all types of metallic scrap in addition to WEEE. Desco has approximately 61 collection sites (focused on WEEE) across eight provinces.

Table 9: Geographical footprint of WEEE recycling firm's main activities (active recycling operations) in South Africa

Company	GP	KZN	WC	EC	NC	FS	LP	NW	MP
Africa E-Waste	●								
Bolunga Electronic Waste				●					
Cape E-Waste			●						
Computer Scrap Recycling	●	●							
Desco Electronic Recyclers	●	●	●	●		●	●	●	●
Effortless Computer Recycling	●								
Electronic Cemetery		●							
eWaste Africa		●							
E-waste Technologies Africa				●					
Inca Metals				●					
Indalo Resources		●							
Just PCs	●		●						
Javco		●							
Metrex			●						
Rand Refinery	●								
Reclam	●	●	●	●	●	●	●	●	●
RecLite	●	●	●	●					
SA Metals Group	●		●						
SA Precious Metals	●								
Sibanye Recycling		●							
Sims Recycling		●							
Sindawonye	●			●					
SmartMatta	●	●	●						
Tshwane Electronic Waste	●								
URC	●			●					
Virgin Earth			●						
Waste Plan	●	●	●			●			

Table 10: Nature of firms' WEEE activities in South Africa

Company	Description of WEEE Activities Around South Africa
Africa E-Waste	The company has one head office and plant based in Midrand, Gauteng
Bolunga Electronic Waste	Operations consist of a central branch office and factory/plant in East London with collection sites distributed across the whole province – Queenstown, King Williams Town, Butterworth and Bhisho
Cape E-Waste	The company operates from its head office and dismantling plant in Bellville, Cape Town
Computer Scrap Recycling	The head office and main plant is located in Brakpan, Johannesburg, with a small outlet in KZN
Desco	Desco operates out of its head office and factory/plant in Kempton Park, Johannesburg and has more than 60 collection sites in SA
Effortless Computer Recycling	Head office and plant/factory based in based in Boksburg, Gauteng
Electronic Cemetery	The company is based in Pinetown, KZN with collection sites in Pietermaritzburg, Durban, Richmond, Newcastle and Richards Bay
E-Waste Africa	The company's main plant is based in Pietermaritzburg, KZN
E-waste Technologies Africa	The company has one head office in Port Elizabeth, with collection sites in East London, Mthatha, Bhisho and Queenstown
Inca Metals	The company's head office and factory/plant is based in East London with collection sites across the Province
Indalo Resources	Branch office in KZN
Just PCs	The company's main head office, warehouse and factory are in the Kuils River area, Western Cape. It also has a satellite branch in Durbanville, and regional office in Centurion (Gauteng)
Javco	Based in Pietermaritzburg, KZN
Reclam	Head office and refinery is based in Germiston, Gauteng
Metrex	Based in the Epping Industrial area, Cape Town
New Reclamation Group	The WEEE recycling division is located in Clayville, Olifantsfontein, Johannesburg. Reclam has around 100 branches spread across all major centres in the country.
RecLite	RecLite's head office and factory/plant, is based in Germiston, Gauteng. Additional branch offices are in in the Western Cape, KZN and Eastern Cape.
SA Metals Group	The company's head office and main scrap yard (70 000 m^2) is based in Cape Town. The company has 10 sites across South Africa concentrated in Cape Town, Johannesburg and Pretoria.
SA Precious Metals	Head office and PCB refinery is based in Wadeville, Gauteng
Sibanye Recycling	The company operates from a head office in Pietermaritzburg, with branches in Grey Town, Richmond, Mooi River and Howick.
Sims Recycling	Head office and plant/factory is based in Ballito, KZN
Sindawonye	Sindawonye operates from its head office and 25,000m^2 factory in Gauteng. It also has a 10,000m^2 factory in Port Elizabeth.
SmartMatta	The company has three regional operations based in Durban, Johannesburg and Cape Town
Tshwane Electronic Waste	The company operates from three sites in Pretoria, Gauteng
URC	Head office and two factory/plants are based in Industria, Gauteng
Virgin Earth	Head office and factory/plant based in the Somerset area, Western Cape.
Waste Plan	Operates from Cape Town with 2 other main branches in Durban and Johannesburg, and satellite offices in Port Elizabeth and Bloemfontein.

3.1.6 Sources of WEEE Inputs

The objective of this sub-section was to ascertain the type and volume of WEEE received annually, the main geographic market for inputs, and the flow of WEEE inputs within South Africa and from the SADC sub-region.

3.1.6.1 Volumes and types of WEEE handled

Firms were asked to indicate the tonnages of WEEE handled by their firm in 2015 and to disaggregate it according to type of waste stream – i.e. ICT and consumer electronics, small and large household goods, lamps, and other (e.g. cables).

- The 23 firms who provided data collectively handled 17,733t of WEEE. Of this, 85% was handled by 9 pre-processors. Large pre-processors handle between 500t and 5,000t of WEEE per annum, while the volumes processed by small and medium-sized dismantlers are much more variable and range from 20-500t.

- ICT & consumer electronics equipment is the biggest waste stream handled, accounting for 79% of all volumes handled by these firms in 2015. By comparison, the contribution of large and small household goods (including fridges and other temperature exchange equipment) and lamps is relatively small at 15% and 4%, respectively. Other waste (such as cables and LIBs) is negligible at around 2% (Figure 7).

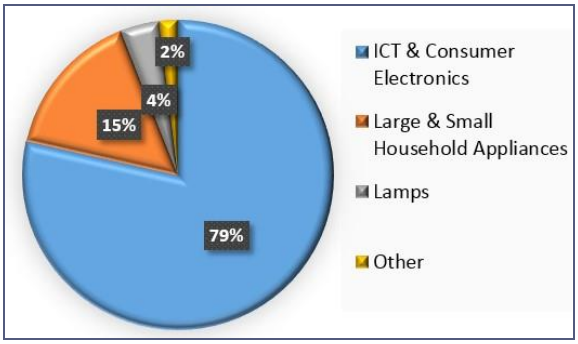


Figure 7: Composition of WEEE handled by firms, 2015

- Although some firms straddle two waste streams (notably ICT and consumer electronics and large and small household goods), there tends to be a considerable degree of specialisation across the firms sampled, particularly amongst the larger firms. In part this is influenced by the different handling and treatment processes required for different types of WEEE, but also the perceived value and secondary market opportunities for the resultant fractions.

- Large and small household goods are a source of ferrous and non-ferrous metal and thus a key input for metal recyclers and scrap traders.

- In addition to the revenue derived from refurbishment, the ICT and consumer electronics waste stream is targeted for the recovery of PCBs and CPUs – valuable sources of precious and strategic metals.

- Given the environmental hazards associated with lamps, they require a separate collection and treatment process. Similarly, the complex fractions resulting from their treatment (mercury and phosphor powders) require highly specialised and designated processing plants.

- Smaller, newer firms tend to be comparatively less discerning in the WEEE inputs that they source. One dismantler pointed out that WEEE recycling is a very low margin business and hence they will buy anything it can get at a bargain rate. They resell or pass on anything that they cannot process on site.

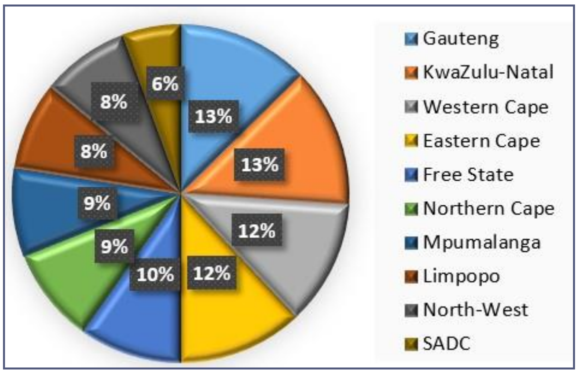
- Recycling companies in coastal provinces handle significantly higher volumes of large and small household goods as a proportion of total WEEE collected, compared to those based inland. In Gauteng, for instance, the emphasis is predominately on ICT and consumer electronics.

3.1.6.2 Geographic markets for inputs

Firms were asked to indicate the main geographical markets for sourcing their WEEE inputs (collections) within South Africa (by province) and in the broader SADC region.

Data was provided by all 27 firms. Notable findings include:

- The primary geographic markets for sourcing WEEE in South Africa are Gauteng, Western Cape, Eastern Cape and KZN. Firms maintain that these provinces (either individually or combined) account for 50-90% of their inputs. The Free State, Northern Cape, Limpopo and Mpumalanga, together with the SADC region, are regarded as secondary (or supplementary) sourcing markets (Figure 8).



Note: While all firms indicated the main provinces/regons in which they source inputs, only 15 provided actual percentages and/volumes. This figure reflects the results of these 15 firms.

Figure 8: Geographic markets for WEEE inputs

- The large integrated waste companies, pre-processors and processors have national footprints, while dismantlers tend to focus on one or two provinces and, in some instances, select SADC countries.

- Respondents maintain that Gauteng will maintain its lead position as the main source and consolidator of WEEE in South Africa in the short- to medium-term, resulting in an intensification of competition for supply/ collections amongst smaller and medium-sized companies. Firms are responding to this by broadening their focus to other provinces (Western Cape, Eastern Cape and Northern Cape), establishing partnerships and alliances in neighbouring countries, and diversifying their product and service offerings to include other recyclables and industries (e.g. automotive and mining).

- Competition for WEEE sources in the Western Cape and KZN has led to a number of the smaller firms consolidating their activities to achieve the necessary economies of scale. They channel their inputs to larger, more established dismantlers, such as Cape eWaste and Indalo Resources Ltd, who in turn pass them on to companies such Desco. This level of selective specialisation and optimisation of resources is similar to what happens in developed WEEE markets, where firms need to achieve a certain threshold of 300t before commencing with dismantling activities[54].

- The SADC contribution ranges from 3-20% amongst firms and is considered a highly variable market.
  - Eight firms have a regional presence in countries such as Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Botswana, Swaziland, Tanzania, Zambia and Zimbabwe. Only one firm, Sims Recycling, has a presence beyond SADC (into sub-Saharan Africa) due to the global focus of the parent company.
  - Three firms indicated that while they have received interest from neighbouring countries, they have not yet acted on it.
  - Firms enter into partnerships with firms based in neighbouring countries to do the dismantling and sorting onsite before importing it into South Africa for further processing in order to minimise associated operational and logistics costs.

3.1.6.3 Input Sources

Firms source their inputs from a wide array of different organisations, businesses, industries and institutions in the private and public sector, government and academia (including schools), and private households. The preferred marketing channels used are highlighted in Table 11.

- All firms interviewed have designated staff responsible for the management, sales, marketing and administration of their firm. While firms make use of different channels to source their inputs, they attest to the importance of reliability and loyalty in the procurement process.
- Small firms rely on active marketing, walk-in clients, direct drop-offs by businesses and households, and tenders for most of their inputs.
- Larger firms tend to have formal, long-term relationships with large corporates (usually 5-10), manufacturing firms and banks; tender for contracts from government; have an established network of smaller firms collecting and dismantling for them (ranging from 50- 100+ firms); and designated collection and drop-off sites in main urban centres. Desco, for example, estimates that national and provincial government departments and large corporates accounted for around 70% of the WEEE material it collects for processing, while the remaining 30% comes from over 100 small- to medium-sized recyclers across the country.

Table 11: Marketing channels used by sampled firms

Marketing Channel	Large Firm (Pre-processor Processor)	Small- to Medium-Sized Firm (Dismantlers)
Active marketing (cold calling, corporate website and social media platform)	●	●
On-line bookings for collections	●	●
Walk-in clients		●
Direct drop-off at plant	●	●
e-Waste storage audit tenders (SOCs, government departments, municipalities, schools/learning centres, hospitals, etc.)	●	●
Partnerships with smaller recycling firms	●	●
Long-term supply agreements (with leading private sector companies, banks, ICT firms, OEMs, mines etc.)	●	
Designated collection programmes and sites	●	
Partnerships with retailers for WEEE drop-off (e.g. Makro, Incredible Connection, HiFi Corporation, Builders Warehouse, Woolworths, Pick 'n Pay)	●	●
Households	●	●

- Some firms are very selective with whom they procure from and will only source from large corporates as it guarantees a steady and stable source of supply. While small dismantling firms will accept waste from informal vendors, medium- and large-scale firms prefer to operate a closed-door policy and only use accredited suppliers[55].
- For many firms, particularly dismantlers, collection is the most expensive stage in the WEEE recycling value chain due to the high transportation and logistics costs involved (e.g. petrol, e-tolls, distances between urban centres, wages for drivers and casual staff, etc.).

[54] Based on interview feedback

[55] Largely due to the reputational risks associated with the informal trade of fractions (such as copper).

- Respondents indicated that volumes received vary from month to month, with December, January and April the worst months in the year from a collection point of view[56].

- Firms also attested to the high level of interdependence in the industry, with smaller recycling companies selling their WEEE fractions to the large-scale recycling companies.

- Many firms have invested in specially designed vehicles, trucks and collection bins to facilitate the collection and transportation of WEEE between suppliers/collection sites and their recycling facilities. Reclam, for example, runs a fleet of 800 trucks to assist in the collection of scrap metal from across the country. RecLite supplies reinforced, high quality collection bins for all lamp types and sizes. The fluorescent tube bin has a capacity of up to 500 tubes, and the larger bin has a capacity of ±350 kg of CFLs and other lamps. The bins pack flat for ease of delivery and can be reused many times. The purchase of the bin is a once-off cost, until replaced. The bins are compliant with ISPM Certification.

- While some companies (generators) expect payment for their electronic waste, others make it available to recycling companies for free.

    - One integrated waste collector maintains it gets around R40/kg for raw WEEE, while a small dismantler receives R1-R8/kg for separated computer scrap and R12/kg for cables. A medium-sized dismantler gets R3.30/kg of glass from a glass recycler. Other prices are shown in Table 12.

    - In the case of lamps, the large recyclers do not pay for the lamps that they receive due to the high costs involved in recycling/processing them. Lamps also constitute a hazardous waste stream and by law need to be disposed of in a formalised and environmentally acceptable manner.

    - According to one respondent, prices paid for WEEE tend to be higher in Gauteng than in other provinces and neighbouring countries. This has prompted them to expand their supplier and collection network outside of the established markets and contract in individuals and SMMEs on an ad hoc basis to dismantle and sort WEEE before transporting it back to Gauteng.

[56] Due to the extensive holidays over these months and the associated closure of businesses.

Table 12: Typical prices for select types of WEEE, 2015

Item of WEEE	Description	Price
Memory (RAM)	High grade	R50/kg
PC Boards	High grade	R30/kg
PC Boards	Medium grade	R20/kg
PC Boards	Low grade	R5/kg
PC Boards	Cell phones	R35/kg
PVC Cables		R7/kg
Monitors	CRTs	R10 each
Scrap WEEE	CPUs, printers, photocopiers, etc.	R1.20/kg
Scrap WEEE	Keyboards, mouses, scanners, kettles, etc.	R0.50/kg
X-ray Film		R10/kg
Scrap Electrical Waste	Fridges, freezers, stoves, washing machines, etc.	R1.50/kg
Televisions	CRT TV	R5 each

3.2 WEEE technologies and processes used

The objective of this sub-section was to gain an understanding of the types and sources of technologies used to handle the different WEEE streams and fractions; current processing capacities and gaps; and any opportunities for waste technology (product and process) innovation and investment.

3.2.1 Scope of technologies currently in use

Firms were asked to elaborate on the types of technology in use in their company, across the three identified waste streams, and across the different stages in the value chain.

3.2.1.1 Dismantling Stage

Small- to medium-firms engaged in the dismantling stage of the WEEE value chain maintain that the separation and liberation of components held together by screws is most effective when performed manually. As such, manual labour, using rudimentary tools such as electric screwdrivers, pliers, drills, hammers, chisels and grinders, are deemed sufficient to meet the volumes and operational needs of dismantling companies (Table 13, Figure 9):

- In the case of ICT and consumer electronics, WEEE is put on metallic sorting tables and PCBs, CPUs, other components, cables and plastics are removed using screwdrivers, pliers, drills, hammers, chisels and grinders.
- For large and small household goods (including temperature exchange equipment), plastics and glass shelving are stripped manually with screwdrivers and pliers, and the grill and motors cut off using grinders. Some respondents indicated that this dismantling step is sometimes not included in their processes and items are sent directly to scrap metal recyclers in their original form. Only one large WEEE recycler has a fridge de-gassing pump.
- Lamps require no prior dismantling.
- In the case of 'other' WEEE (LIBs and cables), batteries and cables are manually removed from WEEE using basic handheld tools. In most cases, cables are sent directly to pre-processors/scrap metal merchants for treatment, but there is one firm that has established a manual fibre optic stripping project in the Eastern Cape. Typical tools used include cable jacket strippers and 'Kevlar' scissors to cut strength members.

Table 13: Tools used by firms in the dismantling stage

WEEE Stream	Dismantling Tools Used
ICT and consumer electronics	• Pneumatic or electric screwdrivers, pliers, hammers, drills, and grinders
Large and small household goods (including temperature exchange equipment)	• Pneumatic or electric screwdrivers, drills, hammers and chisels, pliers and grinders • De-gassing pumps
Lamps	• No dismantling required
Other (e.g. cables)	• Pneumatic or electric screwdrivers, pliers, cable jacket strippers, 'Kevlar' scissors

Apart from the lamp recyclers, there is currently only one pre-processor who does not use manual labour to dismantle WEEE prior to pre-processing, given the size and nature of operations. Obsolete WEEE is sent straight to a shredder where it is cut into smaller pieces, typically 1 cm^2 or smaller, and then through a battery of separation steps.

According to respondents, manual dismantling offers the following benefits:

- **Contribution to employment** – While time-consuming, firms maintain that it requires a very low skills base and is labour-intensive and thus contributes to the government's national development objectives of job creation and socio-economic upliftment.
- **Better output fractions** – Manual disassembly yields a much higher quality or 'cleaner' fraction than if it were performed using automated methods permitting different markets to be found for each WEEE fraction or separated component. In the case of PCBs, minimising contamination and the loss of valuable precious metals and other materials from the boards through manual removal is necessary in distinguishing whether it is of a high, medium, or low value.
- **Lower capital investment and operational costs** – According to one firm, a 100t plant with a staff complement of 6 people requires a start-up investment of R300,000. Manual dismantling is a dry process requiring no expensive chemical inputs, energy intensity is low, and labour can be easily sourced.

  Unlike in developed WEEE markets in Europe (which requires a minimum threshold of 300t per annum), the South African WEEE recycling industry does not observe any minimum quantities for companies to start dismantling, since labour costs are low, and the business opportunity and value addition in their activities lies in separating components, accumulating the volumes and selling the fractions produced to the domestic and export markets for further processing.

Industry participants do not see the need to set up sophisticated automated disassembly plants in South Africa without a significant improvement in collection volumes (supply).

Accessing appropriate dismantling technology, if required, is not regarded as a problem, as they are available from Italy or China at capital costs of around R15 million.

Figure 9: Manual dismantling production process in South Africa

3.2.1.2 Pre-processing Stage

According to firms engaged in the pre-processing stage of the WEEE value chain, reducing the size of incoming components and units to fractions that can be easily sorted and separated requires the use of large, mechanised equipment and technologies that are often purpose-built or customised to suit their particular requirements.

Typical equipment used in pre-processing includes balers, shears, shredders, granulators, pulverisers and separators, used separately or in combination with each other. Plants can be modular or fixed in design. The type, scale and sophistication of equipment used and the number of process stages included in plants is firm specific and influenced by the nature of the input feed material, specification requirements of end-user processors for fractions produced, and the corporate resources available for investment (Table 14).

- In the case of ICT and consumer electronics, WEEE is processed and separated into ferrous, non-ferrous, precious and base metals, and metallic and non-metallic fractions using equipment such as shredders, grinders, pulverisers, cyclones, scrubbers, rotatory magnets, eddy current separators, and water separation tables (Figure 10).

- For large and small household goods (and other ferrous and non-ferrous scrap waste) equipment used includes mechanical shredders, pulverisers, granulators, shears and balers, croppers, rotatory magnets, eddy current separators, and cyclones. The resultant outputs include ferrous, non-ferrous, and non-metallic fractions (Figure 10).

- In the case of lamps, the technology and equipment used by the two recyclers comprises of a series of crushers, screens, sieves, agitators, separators and cleaners. Resultant outputs include glass, aluminium end caps, ferrous metal components, distilled mercury and phosphor powder. Both plants are automated and one of the plants is of a modular design.

- In the case of 'other' WEEE, both cables and plastics are processed by means of super croppers, rippers, grinders, granulators and water tables to separate the metallic fractions from the inorganics and contaminants. CRTs, LIBs and other batteries are currently not processed by any of the pre-processors surveyed[57].

Table 14: Equipment and technologies used by firms in the pre-processing stage

WEEE Stream	Pre-processing Equipment and Technologies Used
ICT and consumer electronics	• Shredders, mills, hammers, grinders and pulverisers – To reduce and densify waste to small fragments • Dense media separators, rotatory magnets and eddy current separators – To separate metallic from non-metallic fraction • Scrubbers – To purify air streams • Water separation tables – To separate organics from non-organic fractions
Large and small household goods (including temperature exchange equipment and other ferrous and non-ferrous waste)	• Static and mobile shears – For cutting large pieces of sheet and other raw materials • Mobile balers – For compacting light metal raw materials prior to transportation (particularly where stockpiles exist in remote areas); • High density ferrous and non-ferrous balers – Used for the compression of light scrap pieces into high density bales; • Briquetting machines – For compressing metal shavings and turnings into cylindrical briquettes • Shredders – For reducing waste to small fragments. • Croppers and grinders – For further densifying shredded scrap • Super choppers, gas cutting equipment, raspers and granulators – For high speed processing and separating metal from non-metal fraction • Rotatory magnets and eddy current separators – To separate metallic from non-metallic fraction • Scrubbers – To purify air streams • Cyclones – To separate metallic from non-metallic fraction, • Water separation tables – To separate organics from non-organic fractions
Lamps	• Mechanised lamp crushing, separating and cleaning systems (MRT or Balkan)
Other (e.g. LIBs, cables)	• Granulators for selective fractions

Pre-processors handling ICT and consumer electronics, and large and small household goods can be classified into two groups of companies:

- **First-stage (elementary) pre-processors** – These are pre-processors who are only involved in the first stage of pre-processing – *liberation* (or size reduction). Firms such as Desco Electronic Recyclers Ltd, E-waste Technologies Africa, Sibanye Recyclers Ltd, shred, grind or cut a homogeneous WEEE input fraction (such as PCBs or plastics) into smaller pieces in order to meet the specification requirements of their clients.

- **Second stage (advanced) pre-processors** – These are firms that are involved in both *liberation and separation* activities. Integrated scrap metal recycling companies such as Reclam Ltd, Sindawonye Granulators and Processors Ltd, and URC Ltd, have diversified into WEEE recycling and are leveraging internal metal recycling technologies and capacities to shred, pulverise and separate WEEE into distinct 'cleaner' streams such as ferrous, non-ferrous, precious and base metal fractions.

Ancillary equipment used across all waste streams and companies include forklift trucks, conveyancing systems, shears and baling machines, and metallic storage bins.

Given the complex, multi-material nature of WEEE, the use of mechanised processes offer the following benefits:

- **Greater efficiency** – Plants can handle large volumes of WEEE of varying material complexity and size on a continuous basis;

- **Automation** – Plants can run continuously and be remotely managed;

- **Better management of hazardous by-products and waste** – Processes are enclosed and can contain and treat fumes, fines and waste; and

- **Higher valued output** – Outputs produced can meet end-user specifications.

[57] As the volumes are too low and technologies are not locally available

Figure 10: Type of equipment used in ICT & household equipment pre-processing

3.2.1.3 Processing Stage

It is at the processing stage of the WEEE value chain that considerable investments in advanced metallurgical processing technologies are required in order to achieve high metal recovery and low environmental impacts.

While the final processing of ferrous and non-ferrous metal fractions is well developed in South Africa, the final processing of PCBs and other complex fractions such as phosphor powder to recover REEs is either limited or does not yet exist in South Africa (Table 15).

Technologies currently in use for processing PCB fraction

There is no single processing technique capable of processing all types of waste PCB material, due to their heterogeneous nature; significant differences in volumes of PCBs collected; and different levels of economic development among countries. While South African companies have made significant in-roads in investigating the economic feasibility of treating PCBs produced in the country using both hydrometallurgical and pyrometallurgical techniques, many of the projects have not taken off, due to lack of waste quantities (sufficient economies of scale) and financing. Some of these initiatives under each processing technique are briefly discussed below.

- **Pyrometallurgical processing** – Although 70% of the world's PCB production is processed using pyrometallurgical techniques, it is not a viable processing route for South Africa. Mintek and the Rand Refinery Ltd, in two separate projects, investigated the feasibility of using high temperature smelting and processing technology to chemically convert PCBs into different phases so that valuable metals can be recovered. However, both projects were discontinued owing to insufficient PCB volumes available to achieve the necessary economies of scale, and environmental concerns relating to the toxic and carcinogenic compounds emitted in the off-gases following incineration. Rand Refinery's smelter has a fluidised bed incinerator capable of treating approximately 1,500t per annum of material, including by-products from the mining industry, e-waste, carbon fibres and sludge. At the time of its investigation into the viability of reconfiguring its precious metal refinery to include PCBs (2000-2007), it envisaged developing a plant with the capacity of 4t per day.

Gauteng Refinery specialises in the recovery and refining of precious metals, and accepts a wide range of feedstock, including – but not limited to – PGM residues, mining concentrates, jewellery scrap, coins, autocatalyst scrap, PCBs and electronic scrap. All metals supplied are purified and sold as either as sponge, granules, bars or intermediate salts, depending on customer requirements. Its precious metal refinery offers a comprehensive range of refining techniques to recover all six PGMs, together with gold and silver. However, when consulted as to the possibility of recovering valuables from a polymetallic product produced pyrometallurgically from PCBs (containing 80% Cu 100g/t PGMs+Au and 450g/t Ag) they maintained that is currently not feasible as the precious metal concentrations are far too low to be economic.

Anglo Platinum, South Africa's primary precious metal producer, indicated that the full process flowsheets of their smelting and refining operations are based around the premise that the company is, first and foremost, a primary PGM producer. Nevertheless, should there be feed streams available that naturally fit into their flowsheets, they would always consider them. Anglo Platinum has investigated various options with regard to recycling, but has found that the business cases are not competitive, mainly because of excessive initial capital cost requirements for receiving, analysing and introducing the stream into their processes. The issue around analysis is particularly problematic when considering the processing of PCBs – more so than, for example, the recycling of spent autocatalysts.

- **Hydrometallurgical processing** – SA Precious Metals Ltd has developed a hydrometallurgical PCB refining solution with the capacity to process approximately 2t per day of PCB materials. The plant's PCB refining capacity is small when compared to the current PCB production volumes in the country (estimated at around 7,000 – 10,000t), but it can be scaled up to 4t per day once a consistent supply of PCB materials is secured. As it is modular, it can also be established across the country, in proximity to established PCB consolidation points.

  The Centre for Bioprocess Engineering Research (CeBER), at the University of Cape Town, is currently investigating bioleaching as an alternative/additional technology for metal extraction and recovery from WEEE. However, the research is still in the very early stages of enquiry[58].

The costs involved in establishing a PCB refining plant are driven by a range of factors including the nature of the feed material, processing route adopted, processing capacity, and metal refining capabilities.

Integrated smelting and refining facilities such as those found in Belgium, Canada, Germany and Sweden use very advanced technology and sophisticated flowsheets to recover all the metals found in PCBs including precious and base metals. The initial capital investment and ongoing operational costs are therefore very high. Given local parameters, establishing an integrated smelting and refining plant is not considered to be a viable option for South Africa at present. A much more viable option is to establish smaller plants, focused on the recovery of e.g. gold and silver, with potential for future scale up. Such a plant could cost anywhere between R20 and R40 million.

[58] CeBER, 2016

Technologies currently in use for processing ferrous and non-ferrous metal fractions

South Africa has a well-developed downstream ferrous and non-ferrous metals recycling industry. There are approximately 200 foundries that are engaged in the recycling and recovery of iron, steel, aluminium, copper and zinc fractions as well as large integrated steel manufacturers such as ArcelorMittal, Columbus Stainless and Scaw Metals.

- Steel manufacturing companies in South Africa use argon-oxygen decarburisation technology to recover steel from scrap.
- The technology used in foundries is dependent on the type of foundry but the majority of them use argon-oxygen decarburisation technology to recover valuable metals from scrap material.

Copper and aluminium fractions are the key non-ferrous fractions produced in South Africa's WEEE recycling industry.

- South Africa has a large copper smelter – Palaborwa Mining Company – which treats clean copper ore. However, its flowsheet does not provide for the presence of contaminants and adapting its flowsheet to accommodate copper-containing WEEE scrap or copper byproducts would be too expensive given the low volumes available. As such, the preferred option amongst recyclers is to send their copper fractions to foundries for further treatment.
- In the case of aluminium, Hulamin, an aluminium processing company based in Pietermaritzburg, receives baled and shredded inputs from companies across the country, which it converts into various semi-fabricated products for sale in the export or local market.

While capital expenditure estimates of setting up a foundry and aluminium recycling plant in South Africa were difficult to establish, in Europe an aluminium processing plant with capacity to refine 50,000t per annum of aluminium scrap would cost around R425 million (€25 million).

Technologies currently in use for processing electronic plastic fraction

Some plastics manufacturing companies are taking advantage of the availability of WEEE plastics scrap in South Africa to optimise their production costs. They blend WEEE plastics scrap with virgin ABS material and produce plastics products such as household chairs, benches, utensils, plumbing pipes and building tools. Plastics extrusion and injection moulding machines are two key types of equipment used in such enterprises.

The sorting/separation of plastic types into categories before shredding is done manually using workers' experience and properties of the plastics such as type, colour, grade and its smell after burning it. There is an opportunity to introduce the use of automated technologies to separate WEEE plastics after dismantling as well as in designing and strengthening the properties of new plastics products manufactured from scrap material.

However, the lack of consistency in the quality of WEEE plastics scrap material and low internal processing capacities is resulting in only a small percentage (±20%) of total electronic plastic waste being recycled and converted into manufactured products.

There are a number of issues impacting on the South African recycling industry's ability to recycle and re-use WEEE plastics in the manufacturing of new products. These include:

- Difficulties in manually separating (on basis of type, colour, grade) the wide range of plastics found in WEEE – hence the need for automated technologies.
- Presence of hazardous substances including cadmium, lead, antimony and flame retardants. Flame retardants are additives that reduce the risk of flammability in EEE.
- Plastics with a high concentration of flame retardants, particularly from large and small household goods, cannot be recycled and are landfilled. In Europe, they are incinerated to produce energy in cement kilns.
- The degradation of polymers over time affects

the quality of new products produced from plastics scrap – hence the need for R&D in new plastics product design.

- Existing WEEE product design is not conducive to the recycling of electronic plastics. A printer, for instance, contains over 30 different types of plastics each with its own chemical properties, thereby making recycling and re-use difficult[59].

The capital expenditure requirements for an entry level plastics extrusion and injection moulding machines, with capacity to process approximately 100kgs/hr, range from R1-R5 million if they are sourced from China and R2-R10 million if they are sourced from Europe (France, German and Italy).

Technologies currently in use for processing phosphor powders

Currently South Africa does not have the technological capabilities to recover REEs from phosphor powder recovered during the lamp recycling process. All powders are either exported to processing plants in Europe where they are subsequently treated, or stockpiled.

Technologies currently in use for processing glass fractions

Consol Glass Ltd and a few other companies use glass recovered by lamp recycling companies in the manufacturing of glass products. Consol Glass Ltd uses high temperature smelting and processing technology to chemically convert sand, soda ash, limestone and recycled glass material (cullet) into manufactured glass products including building blocks, household products and packaging materials for beverages, medicines and personal care products. The company invested approximately R240 million in its processing infrastructure, which includes around 11 furnaces and 29 production lines in Gauteng, Western Cape and Kenya.

[59] Goodship & Stevels, 2012

Table 15: Technologies used by firms in the processing stage

WEEE Stream	Processing Routes/Technologies Used
PCBs	• Completed automated, modular hydrometallurgical process • Pyrometallurgical processing in a gold refinery
Ferrous and non-ferrous metal	• Pyro- and hydrometallurgical processing in foundries, smelters and refineries
Phosphor powders	• No processing undertaken locally
Plastics	• Incinerated or processed further by means of pyrolysis
Glass	• High temperature smelting

3.2.2 Sources, costs and capacity of installed technologies in pre-processing and processing firms

Firms engaged in pre-processing and processing activities were asked to elaborate on the sources of technologies in operation, their approximate cost and installed processing capacity. The findings for 8 firms (7 pre-processors and 1 processor), are presented in Table 16.

- As can be seen, most pre-processors have integrated plants comprising various steps and pieces of equipment. While some firms have developed their own in-house proprietary solutions (Desco, SA Precious Metals, URC), others have sourced necessary plant and equipment from local agents and distributors for international brands, or directly from abroad.

- Firms are increasing their investment in WEEE technology and equipment to improve efficiency and capacity for when WEEE volumes take off (3-5 years).

- It is important to note that in the case of processing, while technology solutions are available off-shore, local firms have successfully developed their own uniquely South African processing technologies for treating complex fractions such as PCBs. However, such a process required a considerable amount of prior R&D, high levels of capital investment and long lead times (5-10 years) to reach full-scale demonstration and commercialisation.

Table 16: Scope of technologies used by select pre-processors and processors in South Africa

Description of Technology	Country of Origin	Cost (±ZAR)	Installed Capacity
Africa E-Waste			
The plant is fully-mechanised and of modular design. The MP8000 system was sourced from Balcan, a world-leader in lamp innovation and recycling. The Balcan lamp and bulb recycling system is able to recycle all types of waste mercury-bearing lamps and is designed to accept both whole and pre-crushed lamps of all sizes. It also requires less than 15 KW of power and no water to operate (Box A – Appendix H.	UK	R1.5 – R7 million	The Balcan MP8000 has a capacity to handle 5,000 linear tubes (4ft) and other lamps per hour (around 200kg/hr) and operates 4-5 days a week
Desco			
Desco's range of pre-processing equipment includes *inter alia* 4 shredders with a combined capacity of 15,000t per annum and 2 baling machines that bales all WEEE plastics before selling them to the domestic and export markets (Box B – Appendix H)	Germany & China	New shredder from Europe and China is approximately R3 million and R1.5 million respectively. A local second-hand one = R250,000.	The company's shredder has capacity for 10t per day of PCBs. The company is planning to upgrade its facilities to handle 20,000t per annum of PCBs in 5 years' time.
Reclam			
A wide range of state-of-the-art mechanised heavy machinery and equipment is used to process the full range of recyclable ferrous and non-ferrous raw materials in large volumes. Equipment range includes four 1,000 to 3,000 horsepower shredding or fragmentising machines (each with a processing capacity of up to 50t/hr) as well as static and mobile balers, croppers and gas cutting machines, briquetting machines, choppers, raspers, granulators and grinders.	Local and international – Reclam endorses Hamma Equipment (offers complete shredding plant solutions as well as training, maintenance, servicing and upgrades).	Not provided	The capacity of the plant at Reclam is 200 t/hr.
RecLite			
The company's Lamp Processor system was sourced from MRT. Neither the standard LP200, nor LP600 were ideal for RecLite's production requirements so MRT custom-designed a new one – the LP400. The plant permits the crushing, screening, separation and cleaning of all types of lamps/lighting equipment. The life of plant is 20 years before a major overhaul is required. Certain components will have to be replaced after 12 years. Plant maintenance is done locally and annually and is not expensive (Box C – Appendix H).	Sweden	R6 - R10 million depending on the desired configuration	The MRT LP400 system has the capacity to handle 6,000 tubes per hour. The separation plant was sized according to the potential future market size (800 kg/hr).
Sims Recycling			
Plastic, ferrous and non-ferrous components are sorted and sent for further pre-processing by means of shredding to produce an intermediate input for onward sale.	International	Not disclosed	Not disclosed
Sindawonye			
Sindawonye possesses the most sophisticated granulation and non-ferrous shredding plant in the Southern Hemisphere. Basic raw materials are then separated by means of magnetic as well as air separation techniques. The processing completely destroys all data stored in WEEE materials and non-ferrous components are also completely destroyed from their original form. The company has also invested in specialised equipment to handle hazardous WEEE to the value of around R5 million.	Local and international	Not disclosed	The plant includes a shredder with the capacity to shred approximately 8t of WEEE per hour.
SA Precious Metals			
The PCB refining plant is highly automated, modular plant, which uses a batch production system. The company prefers to buy un-shredded PCBs which then milled on-site and fed into the plant. This enables the company to avoid losses of valuable secondary materials. SA Precious Ltd's PCB refining plant has capacity to extract 100% of the metals contained in PCBs and it produces zero waste.	Developed by SA Precious Ltd	Not disclosed	Capacity to treat 2t per day of high, medium and low grade PCBs. The plant's capacity can easily be expanded to 4t per day provided there is enough feedstock material and of consistent quality.
URC			
The operation is fully mechanised and uses a multitude of processing equipment, including 1,200 hp shredders, heavy media, magnetic and eddy current separation equipment, shearers and balers, granulators, a Liquicell multi-stage in-line scrubbing system, and conveyors. They also use some CAT machinery like front end loaders. They have forklifts, cranes, and 5 x 30t trucks (See Box D – Appendix H)	Some of the equipment sourced from the USA, the rest was developed in-house	Not disclosed	Not disclosed.

3.2.2.1 Equipment expenditure analysis

Overseas, a fully automated shredding and sorting plant for a standard line with an incoming flow rate of 3,000-6,000t of WEEE per year requires an investment of around EUR 2-4 million (±R27-55 million). Respondents indicated that it is hard to approximate costs for particular solutions and equipment as it is strongly influenced by factors such as the nature of the WEEE stream being managed, the specifications of the resultant end products, installed capacity and configuration (capabilities) requirements, and the availability of capital investment.

- Respondents maintain that around R3 million is required to establish a small pre-processing operation for first-stage (elementary) treatment. This encompasses the purchase of a truck to facilitate collections, a manual bailing machine (for ungranulated plastics), shredder/ granulator, premises and basic operating costs.
- One recycler stated that a large, mechanised pre-processing operation handling mixed WEEE (ICT and consumer electronics and small and large household goods) and involved in both liberation and separation activities could cost between R5 and R8 million.
- A medium-sized state-of-the-art lamp crushing and separating plant would require a capital investment of R5 – R12 million. By contrast, a second-hand reconditioned plant (either Balkan or MRT) can be purchased for between R2.5 and R4 million.
- In the case of individual items, such as shredders, a similar variation in costs is apparent. Imported new shredders cost anywhere between R1.5 – R3 million each, while second-hand ones, available locally, are significantly cheaper at around R250,000. Based on the experience of various recyclers, each option has its own set of advantages and disadvantages (Table 17).

Table 17: Shredder options and approximate costs

Country of Origin	Approximate Cost	Features
Europe (mainly Germany, France and Italy)	R3 million	• Higher capital outlay required, but machine is of higher quality • High levels of durability • Higher shredding capacity • Maintenance and repair services available locally through appointed agents and distributors
China	R1.5 million	• Lower capital outlay required, but quality/durability is a concern • Lower shredding capacity • Maintenance and repair an issue since local agents not always available
South Africa (pre-owned or second-hand)	R250,000	• Mostly owned by small- to medium-sized recyclers pellitising WEEE plastics to meet client size specifications • Equipment purchased at auctions, second-hand industrial equipment suppliers, and distributors and agents for international brands • Lower shredding capacity • Issues with reliability and performance.

3.2.2.2 Current capacity utilisation assessment

A key issue of interest in the study was to assess the current recycling capacities of firms in South Africa and potential for expansion. Table 18 captures the typical tonnages handled across 25 of the firms in sample.

- It is evident that there is considerable variation in the recycling capacities across firms. While small, newly established dismantlers handle as little as 2t per month medium-sized dismantlers handle volumes of 12-20t. Large-scale pre-processors handle between 125-420t of WEEE per month.

The majority of pre-processing firms maintain that while their operations are not running at a loss, they are currently operating well-below their full capacity (Table 19).

- One pre-processor of mixed WEEE asserts that his four shredders are currently operating at 50-60% capacity.
- In the case of lamps, one recycler's plant has an installed processing capacity of 800kg/hr of lamps but is currently operating at between 300-400kg/hr and with a single shift. The other recycler can process up to 500kg/hr of lamp

material, but is currently operating at approximately 200kg/hr and with a three-day working week.

Table 18: Total volumes of WEEE handled by participants, 2015

Company	Volume of WEEE Handled in 2015 (t)
Desco Electronic Recyclers	5,000
Sindawonye Granulators & Processors	3,000
Universal Recycling Company	3,000
New Reclamation Group	1,500
Sims Recycling	1,500
SA Precious Metals	728
Cape E-Waste	500
RecLite	400
Africa E-Waste	383
E-Waste Africa	300
Sibanye Recycling Ltd	300
Computer Scrap Recycling	240
Tshwane Electronic Waste Company	240
Bolunga Electronic Waste Ltd	200
Waste Plan	200
Inca Metals	60
SmartMatta (Re-Ethical)	60
Electronic Cemetery	44
Virgin Earth	24
Effortless Computer Recycling	20
E-waste Technologies Africa	20
Metrex	12
Javco	2

Table 19: Current capacity utilisation estimates across select pre-processing firms

Pre-processor	Approximate Number of Shredders	Current Utilisation Capacity (%)
Respondent 1	4	10-15
Respondent 2	1	10-20
Respondent 3	4	30-40
Respondent 4	Integrated plant	30-40
Respondent 5	Integrated plant	38-50
Respondent 6	1	40-50
Respondent 7	4	45-60
Respondent 8	4	50-60

75% of respondents attribute their capacity issues to low volumes of WEEE being released into the system. They maintain that the amount of WEEE currently treated in South Africa is strongly influenced by both **the 'stock' released** by households and corporates for disposal as well as the **efficiency of the collection** process:

- In the case of ICT and consumer electronics, low WEEE volumes are linked to issues around data security and asset disposal and the perceived value (economic and sentimental) of holding onto goods such as mobile phones, tablets and personal computers rather than releasing them for destruction and recycling.
- Respondents indicated that the low volumes of household appliances such as fridges and stoves entering the WEEE stream can be attributed to the tendency to refurbish such equipment for resale or to pass them on successively to less fortunate members of the community. Such items often reach recycling companies completely obsolete, i.e. they cannot be refurbished and do not contain any hazardous gases. Respondents were of the opinion that the current low volumes of fridges available for recycling do not warrant the establishment of a stand-alone fridge recycling plant in South Africa.
- In the lamp recycling industry, although there has been a noticeable increase in the number of lamps released for recycling since the banning of landfilling in August 2016, much greater volumes are required in order to expand the industry beyond the current two large players.

According to one respondent, another factor influencing their ability to fully optimise available installed capacity relates to the nature of the market for particular intermediate fractions and related off-take agreements with end-user customers.

- In the case of electronic plastics, for example, there are only a very small number of firms in South Africa who require pelletised WEEE plastic scrap as feed in their processes. The volumes they require are also low and highly variable, dictated on a weekly or monthly basis. One pre-processor in KZN maintains that the company they supply requires less than 2t per month, while another in Gauteng only accepts 500kg per month. The absence of a large end-user market has resulted in pre-processors stockpiling their pelletised WEEE plastic and delaying internal expansion plans.
- In the processing stage, only SA Precious Metals Ltd is actively involved in the final recovery of metals from PCBs. The company's annual PCB refining capacity is approximately 728t per annum (assuming it operates on a 24 hours a day and 7 days a week cycle). This is significantly lower than the country's estimated PCB production of between 7,000-10,000t per annum (±10%). However, the company has been able to secure consistent supply of PCBs from

within South Africa and neighbouring countries and it is adequately utilising its available refining capacity.

Despite the current low volumes received, a number of firms are optimistic about the future of the industry and have plans to expand and integrate further along the value chain. One scrap metal trader aspires to build its own foundry/ies in future, another is seeking investment to expand its fleet of collection trucks to enable it to source from other provinces, and purchase a trailer and a small press and shredder for plastics.

One firm in the Eastern Cape, however, is a bit more cautious about the industry's short-term prospects. They maintain that the existing recycling capacity in the main centres of Gauteng, Western Cape and KZN will not be able to absorb the potential volumes of WEEE should they suddenly be released into the system. A period of scale-up would be required to ensure the optimum growth and take-up by the industry.

3.2.3 Skills for manual activities

Firms engaged in manual dismantling activities were asked to comment on the type of skills required, number of staff involved in key activities, and the types of training provided for specific tasks. Notable findings include:

- In terms of basic qualifications required, the entry level requirement is generally a Matric Certificate (Grade 12). However, one firm mentioned that they accept workers with a Grade 10, while another only accepts someone with a National Diploma and basic artisanal training.
- Respondents indicated that the type of skills required is largely dependent on the job function and purpose. The main skills required are washing, stripping, inspection and recording, collection and management of waste, sales, waste handling, transport (forklifts, cranes, weighbridge operators, truck drivers), dismantling, and around aspects of health and safety.
- Most training is provided in-house and on-the-job on the dismantling process and procedures, site inspections and fraction recognition. In one firm, staff are trained using online videos and by means of work-shadowing. In another, supervisors are stationed at each part of the treatment chain and are responsible for imparting skills directly to employees while ensuring compliance to the company's Standard Operating Procedures and occupational health and safety and environmental requirements.

3.2.4 Constraints relating to sourcing, introducing and operating WEEE technologies

Firms were asked to indicate from a list of nine criteria[60] what type of constraints had been experienced in terms of sourcing, introducing and operating WEEE dismantling, pre-processing and processing technologies.

3.2.4.1 Constraints experienced in sourcing technologies

For 80% of the firms surveyed the biggest constraint with regard to sourcing and introducing new technologies relates to legislation/policy/ authorisations. Other constraints highlighted pertain to economic/financial issues, lack of off-the-shelf technologies locally, and infrastructure challenges.

Each is discussed in turn below:

- **Legislation/policy/authorisations** – The time taken to get a hazardous waste license and the associated costs for consultants to do the necessary Environmental Impact Assessments and other investigations is a major constraint experienced by firms across all stages of the value chain. One company pointed out that it took 4 years to secure their waste license as they first had to prove/demonstrate the technology. The long time delays resulted in them having to forfeit an international

[60] Criteria included: Legislation/Policy/Authorisations; Skills/Personnel; Lack of off-the-shelf technology locally; Lack of off-the-shelf technologies abroad; Economic/Financial; Technology Information; Institutional; Infrastructure; Other.

investment grant enabling them to purchase their (foreign) technology.

- **Economic/financial issues** – While medium- and large-sized recycling firms have not experienced difficulties in securing development funding to undertake plant expansions and procure necessary equipment, a number of smaller dismantlers highlighted the lack of incentives and investment to enable them to expand and grow. They also maintain that there are insufficient WEEE volumes to justify investment in technology.

- **Lack of off-the-shelf technologies locally** – Firms pointed out that accessing technologies for recycling are readily available from countries such as China, France, Germany and Italy. The challenge is operating them profitably given the high capital expenditure outlay required, import duties, and current low WEEE collection volumes. One firm imported equipment from abroad and assembled it themselves in order to reduce costs.

- **Infrastructure challenges** – According to one dismantler, there are a number of infrastructural constraints preventing the transition from manual to mechanised processes. In addition to requiring new premises to accommodate a larger working area and warehousing for WEEE stock, noise, utility availability (water and electricity), and acquiring a larger transport fleet become key operational issues.

- **Other** – One respondent pointed out that the decision to invest in a particular technology, particularly at the pre-processing stage, is strongly dependent on market factors rather than the availability of technologies, i.e. whether there is sufficient demand for the outputs/fractions generated from a technology, or the input requirements of firms further down the value chain. End-users usually specify the required form of fraction, which in turn influences where and what type of processing solutions pre-processors adopt.

    - SA Precious Metals, for example, prefers whole PCBs as their input fraction, while Rand Refinery (if it had to restart its operations) would want it in ash form, which requires an additional incineration step after granulation. Shredded PCBs are a preferred form in integrated global co-processing plants such as Umicore.

    - In the case of plastics, end-users generally require fractions to be shredded. As such, a number of dismantlers have had to invest in a shredder to accommodate this requirement.

    - In another instance, one pre-processor considered the regulation requirements in South Africa before evaluating technology options. The choice of technology was also influenced by the particular specifications of the equipment available on the market.

    - One firm mentioned that their choice of technology was also influenced by government requirements relating to minimising the environmental footprint (i.e. preference for a dry rather than a wet process).

3.2.4.2 Constraints experienced in introducing and operating technologies

In the case of introducing and operating new technologies, the biggest constraints experienced relate to:

- **Skills/personnel** – One firm pointed out that entrepreneurs in the recycling industry concentrate on hiring staff with basic schooling, but that industry actually requires National Diploma holders in Electronics and Electronic Engineers in order to expand the base of companies involved. In only one firm were staff sent overseas to receive training on how to operate their plant given the highly specialised nature of the technology used.

- **Lack of off-the-shelf equipment abroad** – Three dismantling firms alluded to the fact that current mechanised processing solutions available abroad are incompatible with the business model and skills set of many smaller recyclers currently engaged in manual dismantling.

Automated technologies will require significant customisation before they can be introduced locally. Similarly, staff will also have to be retrained.

- **Other** – The most significant industry-wide constraint currently experienced with regards to introducing and operating technologies, relates to inputs – insufficient volumes being made available (or collected) to process, and the variable nature of the type and quality of WEEE received.
  - WEEE volumes released to the market are highly variable and fluctuate from month-to-month, resulting in many small- to medium-firms operating below capacity.
  - Meeting downstream client specifications has also proven to be a problem for some smaller firms who maintain that the variable nature of the type of WEEE received results in an inconsistent quality of fraction and thus lower revenues. A number of firms also alluded to the lack of local processing facilities for complex WEEE fractions (notably CRTs and LIBs), and the high costs involved in landfilling and disposing of them in an environmentally-sustainable way.

3.3 WEEE outputs and end-user markets

Given the strong emphasis on retaining resources, including high-value secondary minerals, in South Africa to advance downstream industry development, a key research question was to establish the type and volumes of WEEE fractions produced by recycling firms and the degree to which they are consumed directly by local pre-processors and processors or exported.

3.3.1.1 Type and volume of outputs produced by firms

The main output fractions produced by firms are ferrous and non-ferrous metals, base metals, PCBs, electronic plastic, glass, and other (including LIBs, cables, packaging etc.). While 23 firms were willing to disclose the main fractions produced in their operations (Table 20), only 15 were willing to indicate volumes (but only as percentages of total operations) and main markets for outputs. Firms indicated that market is very concentrated and very competitive and hence were very reluctant to impart detailed information.

- From the information provided, ferrous metal accounts for the largest percentage of outputs, followed by non-ferrous metal, PCBs (whole and shredded), glass and plastics (Figure 11).

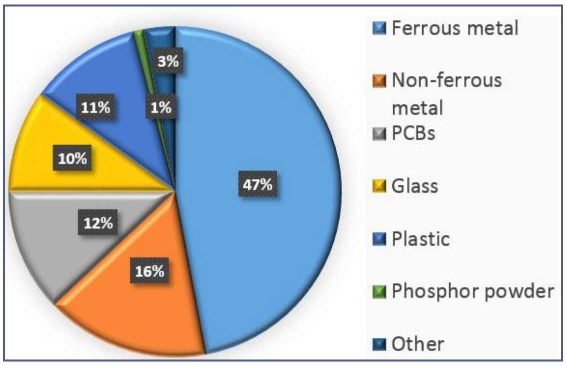


Figure 11: Main output fractions produced across select firms as a percentage of total outputs, 2015

3.3.1.2 Factors influencing the decision to export or sell onwards to a local firm

There is a considerable degree of interconnection and overlap between firms in the South African WEEE industry; with outputs from one stage (and firm) providing the inputs to another. Collectors feed into dismantlers and pre-processors, small dismantlers feed into larger dismantlers, dismantlers feed into pre-processors and processors; pre-processors feed into per-processors, pre-processors feed into processors, and local processors into foreign processors.

During the interview process it became apparent that the majority of firms (across all stages of the value chain) are committed to reducing the environmental impact of WEEE and volumes landfilled annually, support community upliftment, the growth of small businesses, and endeavour to process WEEE to a point that it cannot be consumed internally (in South Africa) before exporting. Table 21 maps out the approximate split between foreign and local end-user markets for fractions across firms reviewed.

- As can be seen, only one firm does not send any of its output to local manufacturers as the prices received are too low. The company exports its scrap metal and sorted components to China and Germany. Local prices paid for pre-processed WEEE ranges from R0.50/kg to R50/kg, depending on the type of WEEE and the metal value contained within it.

However, firms did point out that market factors play an important role in determining how much WEEE output is processed locally and how much is exported. Firms will go to the customer who offers the best price; who is easily accessible; with whom they have a good/well-established relationship; and whose specifications they meet.

- End-user markets for fractions are determined by the grade and quality of the end product. Most customers require some form of quality assurance in this regard.

- Firms acknowledge that there are some complex fractions for which there is no local processing solution or presence, necessitating exporting or landfill. In other instances, the volume produced is so negligible that it does not warrant further processing and thus it is stockpiled, exported or landfilled.

Table 20: Composition of main output fractions across select firms

Company	PCBs	Ferrous Metals	Non-ferrous Metals	Glass	Phosphor Powders	Plastic	Other
Africa E-Waste	●	●	●	●		●	
Bolunga Electronic Waste	●	●	●			●	
Cape E-Waste	●	●		●		●	
Computer Scrap Recycling	●	●	●			●	
Desco Electronic Recyclers	●	●	●	●		●	●
Effortless Computer Recycling	●	●	●			●	
Electronic Cemetery	●	●		●		●	●
eWaste Africa	●	●	●	●	●	●	●
E-waste Technologies Africa	●	●	●			●	
Inca Metals		●	●				
Indalo Resources	●	●	●	●		●	
Javco						●	
Metrex	●	●	●			●	
Reclam	●	●	●	●		●	●
RecLite	●	●	●	●	●	●	●
SA Metals Group	●	●	●			●	●
Sibanye Recycling	●	●	●	●		●	●
Sims Recycling	●	●	●	●		●	
Sindawonye	●	●	●			●	●
SmartMatta	●	●	●			●	
Tshwane Electronic Waste	●	●	●	●		●	
URC	●	●	●			●	
Virgin Earth	●	●	●	●		●	●

Table 21: Local and foreign end-user market split for outputs

Company	PCBs	Ferrous Metals	Non-ferrous Metals	Glass	Phosphor Powders	Plastic	Other
Africa E-Waste	PP	PP	PP	▲		PP	
Bolunga Electronic Waste	PP	PP	PP			PP	
Cape E-Waste	PP	PP		PP		PP	
Computer Scrap Recycling	FP	FP	FP			FP	
Desco Electronic Recyclers	FP	PP	PP	PP		FP	▲ FP
Effortless Computer Recycling	PP	PP	PP			PP	
Electronic Cemetery	PP	PP		▲ PP		PP	▲
eWaste Africa	PP	PP	PP	PP	△	△	▲
E-waste Technologies Africa	FP	PP	PP			PP	
Inca Metals		PP	PP				
Indalo Resources	PP	PP	PP	▲		PP	
Javco						PP	
Metrex	PP	PP	PP			PP	
New Reclamation Group	FP	PP FP	PP FP	PP		PP	▲ FP
RecLite	PP	PP	PP	PP	FP	PP	FP
SA Metals Group	PP	PP	PP			PP	PP
Sibanye Recycling	PP	PP	PP	▲		PP	FP
Sims Recycling	FP	PP	PP FP	▲		PP FP	
Sindawonye	FP	PP FP	PP FP			PP	▲
SmartMatta (Re-Ethical)	PP	PP	PP			PP	
Tshwane Electronic Waste	PP	PP	PP	PP		PP	
Universal Recycling Company	FP	PP FP	PP FP			▲	
Virgin Earth	PP	PP	PP	▲		FP	▲

Key: PP = Local pre-processor/Processor FP = Foreign Processor ▲ = Landfilled △ = Stockpiled

Note: Most recyclers of ICT/consumer electronics equipment produce small amounts of glass from screens, which is generally landfilled. In some cases, firms reflected this under "Other", while others under "Glass". Glass that can be recycled is sold onto approved pre-processors.

3.3.1.3 Main markets for WEEE fractions produced in South Africa

The downstream markets for WEEE fractions produced in South Africa range from domestic semi-fabricators and manufacturers of plastics, glass, steel and aluminium to integrated precious smelters and refineries based overseas in Asia, Europe and North America. Each of the markets is at various stages of development and have got unique underlying drivers. In general, ferrous, non-ferrous and base metals are largely consumed locally, while PCBs are exported.

Market for ferrous and non-ferrous fraction

Ferrous and non-ferrous metal fractions are a major revenue driver for firms in the WEEE recycling industry, accounting for 60-65% of total production output (Figure 13). Success in this market can largely be attributed to the developed nature of the local steel manufacturing sector and the fact that it serves both the local and regional (SADC) market. Another factor is that ferrous and non-ferrous metals tend to be sold immediately after dismantling thereby helping to minimise processing costs.

Respondents noted that metal recovery rates from pre-processing ICT & consumer electronics and household equipment varies considerably depending on the type of metal being extracted. The recovery of ferrous metal can be as high as 50%, while aluminium and zinc is much lower at 10% and 5%, respectively.

- **Aluminium and copper** – These are the main non-ferrous metal fractions produced in South Africa. A few firms produce small amounts of nickel, lead and zinc. In most cases, the non-ferrous fraction produced by dismantlers and first-stage pre-processors is sold onto more advanced pre-processors such as Salvage Recycling, SA Metals Group, Sindawonye Granulators & Processors, and URC, before ending up in foundries or large processing plants.

  Aluminium ingots, bales, granules, shreddings and cuttings produced are used by aluminium foundries in the manufacture of various cast, rolled and extruded aluminium products. The aluminium is processed domestically by companies such as Hulamin to manufacture food packaging material such as beverage cans. Some aluminium fractions are also exported to processors in Europe and Asia.

Copper fractions are mainly sold to domestic foundries where they are recycled and recovered. In pre-processors, such as Reclam, recycled copper products include copper alloy materials such as brass and bronze and tend to be smaller in size than many of the company's other non-ferrous products. These products are sold to various manufacturers of a variety of copper and alloyed castings and rolled, drawn and further processed into extruded products. Reclam has also built a chemical plant in Rustenburg for the manufacture of copper sulphate from the company's copper product, which is used as a reactant in the platinum refining industry[61]. Some copper fractions are also exported to processors in Europe and Asia.

- **Nickel** – Is generally extracted from stainless steel and other raw materials that have a high nickel content. These are sold on to local and international processors for use in the production of specialised high alloy steel.

- **Recycled lead and zinc materials** – These consist mainly of loose cuttings that have been sorted and separated by quality and chemical composition. Lead products are primarily used by lead melting facilities that produce products used in the manufacturing of various kinds of batteries, while the zinc products are primarily used in a variety of zinc melting and die casting operations.

The dynamics within the local ferrous and non-ferrous metal recycling industry, and specifically the prices received from processors, are directly influenced by broader global market developments and local industry trends. In this regard, the following issues were raised by WEEE recycling firms:

- Global over-capacity in steel production, the slowing Chinese economy (the single largest consumer of steel in recent years), and the influx of Chinese steel products on the local market, have impacted both the volumes of scrap steel exported as well as the prices received for processed WEEE scrap.

- The financial and economic performance of WEEE recycling companies' ferrous and non-ferrous metal business has also been adversely impacted by **the dti's** steel pricing preference system and government interventions around the issuing of export permits, particularly for copper and aluminium fractions. In the case of the former, in 2010 ferrous metal scrap was reportedly selling at between R3-R4/kg but declined to between R1-R2/kg in 2015. Many recycling companies have not been able to secure export permits, resulting in them having to sell their copper and aluminium fractions into the domestic market at prices 70% below the international price.

Table 22 summarises the current market prices and main end-user markets for ferrous and non-ferrous metals produced in South Africa.

Table 22: Ferrous and non-ferrous metal prices and markets

Metal Type	Indicative Price (R/Kg)	End-User Markets
Ferrous (light steel – sub and medium grade)	1-2	• Advanced local pre-processors and foundries such as Reclam, SA Metals, Ferrous Metal Processors, Buffalo Steel Ltd, Wayne's Scrap, etc. • Local steel manufacturers such as Arcelor Mittal, Columbus Stainless, and Scaw Metals
Aluminium	15-30	• Advanced local pre-processors such as Reclam and Universal Recycling Company • Local aluminium semi-fabricators such as Hulamin • Processors in Europe and Asia
Copper	55-70	• Local foundries and steel fabricators • Processors in Europe and Asia

Market for electronic plastic fraction

Various types of plastics are found in EEE including in the casing, PCBs and cables. Dismantlers and pre-processing firms (such as Desco, Indalo, New Earth Technologies, Sibanye, Sindawonye and Ubisi Metals) sort plastic waste according to chemical composition and colour.

Firms maintain that there is a notable difference in the prices received for the pelletised plastic fraction compared to electronic plastic in its raw

61 www.reclam.co.za

(component) form (Table 23).

The main buyers of electronic plastic fraction are the domestic plastics manufacturing industry where shredded/granulated WEEE plastic scrap is blended with virgin material to produce various extruded plastics products, such as building tools, roofing tiles and plumbing pipes. It also finds application as a raw material in petrochemical processes, as a reductant in metal smelters, and as an additive in the manufacture of wheels in wheelbarrows.

Table 23: WEEE plastic types, prices and markets

Plastic Form	Indicative Price (R/kg)	End-user Market
Raw	1-4 (depending on type and sorting)	• Domestic plastic manufacturers such as JCL Plastics Ltd, Javco Ltd • Various agents for plants based in Asia (China and Thailand)
Pelletised	7-12 (depending on type and sorting)	

While a number of dismantlers and pre-processors indicated that they wish to sell their plastic fraction to local firms, they are of the opinion that the end-user market is currently too small, uncertain, cyclical and specialised to fully absorb all the output produced[62]. They also maintain that the SABS quality certification required is onerous given the highly variable/inconsistent nature of WEEE received.

- One company has no end-user for its plastic scrap and has an on-site stockpile of 1.5-2t.
- Another firm, sells its output to a Chinese firm whose price is substantially higher than that of local buyers.

Market for PCB fraction

South Africa produces PCBs mainly from the recycling of ICT and consumer electronics equipment. PCBs are the most valuable components in EEE given their higher concentration of precious and base metals in componentry and circuitry. The concentration of gold and palladium found in PCBs recovered from a personal computer can be as high as 250 g/t and 110 g/t, respectively[63]. This has led to considerable 'cherry-picking', particularly amongst informal collectors and dismantlers, where PCBs (and sometimes individual components) are removed and the remaining materials of low economic importance (including plastics, wires and glass), are discarded in an environmentally-unsustainable manner.

In South Africa, the grading of PCBs is not standardised; it is based largely on visual inspection and the composition of the board itself. Highly populated boards are viewed as richer in precious metals than the less populated ones and generally receive a higher price in both the local and international market. In light of this, there is a preference amongst recyclers to sell PCBs in raw form to ensure the maximum price possible. In the cases of large pre-processors, PCBS are usually granulated prior to export and are given a batch price by the receiving global processor.

In South Africa, PCBs are commonly classified as high, medium or low grade (Table 24):

- **High grade PCBs** – These are highly populated boards recovered from computer integrated circuits, hard drives, laptops and display screen equipment. Processors, semi-conductors and connectors in high grade PCBs contain precious metals which can be recovered. PCBs recovered from older computers (produced between 1980 and 2000) are widely regarded as having higher grade PCBs than the ones recovered from computers produced after 2000.
- **Medium grade PCBs** – These comprise mainly of pins, edge connectors and capacitors recovered from computers, display screen equipment and mixed WEEE.
- **Low Grade PCBs** – These are PCBs recovered from large household appliances and temperature exchange equipment and TVs. They contain little precious metals but are mostly valuable for their copper content.

[62] Based on feedback, there are only around 10 plastics manufacturing companies (Gauteng 4, KZN 2, Eastern Cape 2) that are blending WEEE plastics scrap within virgin ABS material to produce plastics products like chairs, benches, plumbing pipes, gutters, building tools, beds stands and roofing tiles for toilets (RDP houses only)

[63] Hagelüken, 2009

Table 24: Average local price for PCBs and main end markets

Grade	Indicative Price (R/Kg)	End-User Markets
High	40 - 85	• Domestic pre-processors such as AST Recycling, Desco, Sibanye, Sims Recycling, Sindawonye Granulators and Processors Ltd, and Ubisi Metals
Medium	20 - 30	• Domestic processors such as SA Precious Metals • Global co-processors based in Belgium, Sweden and Canada • Sale to agents and merchants for metal recovery in Asia & Europe
Low	1 - 15	

During interviews a number of challenges were raised by respondents with respect to the sale of PCBs:

- According to a large pre-processor, the PCB business in South Africa is currently overtraded and margins are small. Consequently, it exports all PCBs it receives through its various networks in unprocessed form. This decision is purely an economic one; the prices received abroad are significantly higher than those in the domestic market.
- Another pre-processor highlighted that it is a significant overhead cost to transport PCBs to European and Asian refineries. A locally-based refinery would go some way to lessen the high logistics costs involved in recycling and disposing of PCBs.
- One medium-sized dismantler pointed out that that there is a substantial price difference between what they get paid for unprocessed PCBs by a local pre-processor (R40-50/kg), compared to what the local pre-processor receives (R60-R85/kg) from the onward sale of its shredded PCBs to an international processor.
- A small dismantler pointed out that they experience long lead periods between the delivery of PCBs to local pre-processors and the receipt of payment. This adversely impacts on their cash-flow cycle and financial performance.

Market for glass fraction

Glass accounts for approximately 10% of the WEEE fraction produced by the recyclers reviewed. Most of the glass is produced by the lamp recyclers, with very small amounts produced by recyclers of ICT & consumer electronics and large and small household goods.

- Glass fraction comprises around 90% of lamp recyclers' production outputs. Respondents indicated that they generally sell this onto local glass manufacturing companies such as Consol. Smaller quantities are also sold to the block (brick) manufacturing industry. Industry participants indicated that the end-user market for glass is currently small and specialised.
- Small volumes of crushed glass, or cullet, are produced during the recycling of ICT & consumer electronics and large and small household equipment. Some smaller dismantlers and pre-processors sell the glass onto companies such as Salvage Recyclers for around R3.30 /kg.
- Cullet is graded according to colour (amber, green and flint) and type (bottle glass, plate and mirror glass, armoured and laminated glass) and distributed to glass manufacturers in South Africa, who then use it to manufacture bottles and other glass products. According to one large pre-processor, there is no real local market for glass cullet fraction in South Africa.

Markets for Complex Fraction

Complex fractions include LIBs, CRTs, and mercury and phosphor powders.

- **Lithium Ion Batteries (LIBs**) – In developed countries, batteries from the EEE devices are sent to dedicated facilities for the recovery of cobalt, nickel and copper. In South Africa, approximately 5t of LIBs are received annually by recyclers and separated out during the dismantling stage. This negligible contribution of LIBs (less than 3%) to their total fraction output has not warranted firms investing in technology to process them further. As such, the majority of firms store them separately to accumulate sufficient volumes before exporting them to Europe and Asia.
- **Mercury and phosphor powders** – Since the passing of legislation prohibiting the landfilling of waste lamps in South Africa, most recyclers

pass any lamps received onto the two established lamp pre-processors – E-Waste Africa and RecLite. Given the lack of local processing facilities, all phosphor powders, as well as purified mercury, are exported to end-users in Europe.

- **CRTs** – CRTs are highly hazardous components and require appropriate handling and management prior to disposal. CRTs remain a big problem in South Africa and no current technology exists for their adequate treatment. According to one respondent, the costs involved in purchasing the required technology to recycle the lead are high, at around R30 million. As such, the preferred method of management amongst the larger firms is to store them in special bins on site and use an integrated waste management company such as EnviroServe to dispose of them at designated hazardous waste sites. The costs to do this, however, are very high. One recycler indicated that they pay R500 - R550/t for the collection of hazardous WEEE. Some of the smaller firms opt to sell them onto larger pre-processors at a cost of approximately R12/kg.

Conclusions & Way Forward

A key finding from this technology landscape mapping assessment is that the future growth and dynamism of the WEEE recycling industry in South Africa is not determined by technology *per se*, but by the availability and flow of consistent volumes of WEEE into the local recycling value chain. In this regard, government, businesses and households as the main generators of WEEE, together with recyclers and other stakeholders, have a shared responsibility in working together to develop appropriate strategies and interventions to resolve this challenge, and unlock this resource, going forward.

4.1 Summary of key findings

The objective of this research was to assess the technology solutions and treatment capacity levels currently underpinning the formal WEEE recycling industry in South Africa, identify research, development and innovation (including technological innovation) opportunities, and to identify any constraints/gaps to unlocking future business, socio-economic development and innovation opportunities in the sector. As such key findings from the study are:

- Although still in its infancy, relative to the established WEEE recycling industries in Europe and Asia, the South African WEEE recycling industry has become a lot more integrated, formalised and diversified over the past decade. The sector remains dominated by a few large, well-established 'consolidators' offering services across the collection, dismantling and pre-processing stages of the value chain (85% of volumes handled by 27 sampled recycling companies in 2015). Importantly, there has been considerable expansion in the number of small to medium-sized firms offering location-specific collection and basic dismantling services over the past five years.

- Gauteng remains the central 'hub' for the collection, consolidation, pre-processing and processing of WEEE in South Africa. This can be attributed to the dominance of economic activities in the province, history of industrial and processing activities (particularly in Ekurhuleni), higher income earning and spending patterns, and established infrastructure and logistics network connecting the province to the rest of South Africa and sub-region.

  The Western Cape, KZN and, more recently the Eastern Cape, act as important provincial nodes for the consolidation and aggregation of WEEE across the country. Mpumalanga is currently not an important geographical market for WEEE collection and dismantling activities. As in the case of the North-West and Limpopo, Mpumalanga tends to be served directly from Gauteng given its close proximity.

- A noticeable finding from the study is that firms are actively diversifying and expanding their geographic footprint (nationally and regionally), and procurement channels, in order to boost WEEE collection volumes and increase their industry competitiveness. While the SADC market is an important supplementary source of WEEE inputs for large scale pre-processing and processing firms, a number of medium-sized dismantlers are in the process of establishing strategic partnerships to source raw and dismantled WEEE fractions for import back into South Africa. This includes entering into long-term supplier agreements with larger recycling firms, metal traders and retailers, broadening the scope and number of collection sites, and investing in logistics infrastructure and fleet equipment to better manage the collection and transportation of WEEE. Smaller dismantlers, however, highlight rising logistics, transportation and warehousing costs (tolls, fuel prices, rental space) as a constraint to the effective implementation and operation of their activities.

- Barriers to entry are considered to be relatively high at the pre-processing and processing stages of the value chain and in specialised waste streams such as lamps and temperature exchange equipment. The key determinants for success for WEEE recycling companies are high and consistent volumes of WEEE inputs, established markets and networks for WEEE fractions, and capital for investing in warehousing, logistics, plant and processing equipment. The availability of skills and technology are not regarded as major obstacles for firms wishing to participate in the sector. Most firms interviewed have in-house training and skills development programmes for staff at all operational levels.

- The barriers to entry are comparatively lower at the collection and dismantling stages. Firms assert that anyone with a Grade 12 can be trained to manually dismantle WEEE and that staff can be employed relatively easily despite the variable nature of WEEE supply. While respondents indicated that there are opportunities for more small firms to enter the collection and dismantling space, they did emphasised that it is not a major sectoral employer. A total of 677 people were employed across 18 firms sampled, with an average of 2-10 people employed per firm at the dismantling stage depending on the size of the company and volumes of incoming WEEE materials. However, at 25 jobs/1,000t, the sector has the potential to increase this number as more WEEE is unlocked into the value chain.

  Furthermore, while the majority of small- to medium-sized businesses interviewed regard WEEE as a logical diversification opportunity and complementary activity, it is not profitable as a standalone activity. Analogous to this, is the fact that refurbishment is a key revenue driver for small- to medium-sized recycling companies, accounting for up to 60% of their annual revenues. Recycling constitutes the remaining 40%. Respondents indicated that the government can bolster the continued growth of the EEE refurbishment sector by developing and assisting with the provision of requisite infrastructure (warehousing, dismantling premises, office space, etc.) and assist in the training of refurbishment technicians[64].

- In 2015, approximately 17,733t of WEEE was collected and recycled across the 27 recycling companies sampled in the study. Of this, 79% comprised of ICT & consumer electronics, and 15% small and large household goods. Firms assert that national, provincial and local government departments, and large corporates currently account for the bulk of ICT equipment received. They also maintain that the volume of household equipment, particularly temperature exchange equipment such as fridges, is lower than expected due to the established second-hand market for such items, the culture of passing on to relatives and workers, and their long lifespans (10-20 years). Lamps accounted for 4% of volumes processed. Respondents indicated that there has been a noticeable increase in obsolete lamp collection volumes handled since the banning of landfilling in August 2016. The remaining 2% comprised of cables and other industrial equipment containing PCBs including automation and base station (telecommunications) equipment.

- The main output fractions produced by firms in 2015 were ferrous metals (47%), non-ferrous metals (16%) and PCBs (12%). Ferrous and non-ferrous metals, the main output from household equipment and scrap metal pre-processing, is predominately treated further by local smelters and foundries. PCBs are the most valuable output fraction produced from ICT and consumer electronics recycling owing to the high precious and base metal content contained in componentry. The majority of PCBs from pre-processors are either shredded or exported whole to processors in Europe, Asia or North America. A few small- and medium-sized firms

[64] In other developing countries including China, Ghana and Nigeria, an entirely new economic sub-sector involving the repair and trading of refurbished EEE has emerged, creating a source of livelihoods for urban and rural poor. In the case of Nigeria this has been assisted by the development of numerous 'computer refurbishment industrial parks'.

sell their PCBs, in un-shredded form to SA Precious Metals Ltd for further, local metal extraction. While other outputs, such as WEEE plastics and glass, are also processed locally to varying extents, CRTs remain problematic and are currently landfilled. LIB volumes collected in South Africa are too small resulting in recycling companies stockpiling them before export to Europe and Asia.

Plastics are generally sold in shredded form to local plastics manufacturing companies though in smaller volumes. Respondents indicated that the take-up of WEEE plastics by end processors is very low in South Africa resulting in stockpiles accumulating on firm sites. There is thus an opportunity to develop new industries using WEEE plastics in products designed for lower-scale markets such as plumbing pipes and gutters for low-cost housing.

- According to respondents, the markets for some WEEE fractions (electronic plastics, glass, ferrous and non-ferrous metals) are unstable and unpredictable which makes it difficult for recycling companies to forecast their revenues and approach banks for funding to finance upgrades and expansions[65]. Compounding this situation are export restrictions and duties levied on ferrous and non-ferrous metal fractions. The resultant prices secured by local firms in domestic markets are significantly lower than those in export markets. As such, prices, particularly for non-ferrous metals fractions in the domestic market are 70% lower than in export markets. It is recommended that an enquiry of current trade restrictions and duties on specific WEEE fractions be undertaken in the short-to medium-term, to critically evaluate the benefits and limitations of such restrictions.

- There was general consensus amongst the firms interviewed that sourcing appropriate recycling technologies is not a major challenge in the industry. The technologies that are widely used in South Africa's WEEE recycling industry are as follows:

  - WEEE is predominantly disassembled manually using easily available hand-held tools such as pneumatic and electric screwdrivers, grinders, hammers, chisels, drills and grinders. Despite the rudimentary nature of such equipment, they meet the operational needs of most recycling companies. A relatively small number of firms (mostly in scrap metal recycling) run mechanised dismantling and pre-processing operations. A number of firms indicated that they would like to invest in automated equipment in future, but would require a significant increase in WEEE collection volumes and the establishment of concessionary funding windows to achieve this.

  - Although the pre-processing of WEEE is still limited in South Africa, with only 9 (33%) of the firms sampled actively involved in this stage, the technologies and processes used are aligned with current international best-practice.

  - It is evident that WEEE pre-processing technology is available from countries such as Germany, Italy and France, while cheaper options are available from China. In most cases, the technology selected needs to be modified before being implemented. There is also an established second-hand equipment market in South Africa for equipment such as shredders. In some cases, firms have modified or built their own systems and equipment (e.g. URC). The two large lamp recyclers imported their respective technologies from established global leaders, which were adapted to suite the particular capacity requirements. Some firms also highlighted that future scale-up is also not a problem since they own modular plants that can flexibly be adjusted to any future changes in WEEE input volumes.

  - South Africa has a well-developed downstream metal recycling sector that is

[65] In 2010 ferrous metal (sub grade and medium grade) was selling at between R3 – R4/kg but the price declined to between R1 – R2/kg in 2015. One plastics manufacturing company was buying pelletised WEEE plastics scrap for R7/kg in 2015, but significantly cut back the price to R2/kg in 2016 citing broader market challenges

successfully beneficiating ferrous and non-ferrous metal fractions received from recycling companies. One processor asserted that South Africa's smelting and refining technologies are world-class and on par with that in established WEEE recycling markets. The challenge is not technology per se but ensuring sufficient input materials and of consistent quality in order to achieve the necessary economies of scale and be commercially viable over the long-term.

- Although there is currently no short-term opportunity to establish an integrated smelting and refining plant such as those in Belgium (Umicore), Sweden (Boliden) and Canada (Gencore) in South Africa given the low volumes of WEEE available, there is scope to increase the percentage of PCBs processed locally before export. SA Precious Metals Ltd's technology is in the commercial demonstration stage and has the capacity to be scaled up from 2t per day to 4t per day. The modular design of the plant, its hydrometallurgical flowsheet, and small footprint (±2,000 m^2) means that it can be located at sites where PCBs are available.

- While Rand Refinery has developed a pyrometallurgical approach to process PCBs before export, they require PCBs to be shredded and incinerated beforehand to ensure a clean input fraction.

- In the case of lamp phosphor powders, volumes produced in South Africa are small in comparison with other output fractions (1% of total output volumes produced in 2015) and thus are stockpiled and exported. Research institutions such as Mintek, Stellenbosch University and the University of KwaZulu-Natal are currently undertaking R&D around the recovery of REE materials. This includes research by Mintek into establishing a refinery in South Africa to process primary and secondary REE materials. This presents an opportunity to evaluate whether lamp powders could be used as an alternative input source should such a refinery be established in future.

- A key finding from the study is that while firms are committed to diverting WEEE from landfill and have invested in recycling infrastructure, technologies, equipment and people to do so, many operations are currently operating at 30-50% capacity. Most notable constraints affecting the implementation and operation of technologies include:

  - **Low WEEE collection volumes** – The low WEEE collection volumes in South Africa, and the resultant inability to achieve economies of scale and remain profitable, is the single biggest challenge facing respondent firms. While firms have responded to this by diversifying the channels used to source inputs; establishing collection consolidation spots/firms in outlying provinces; and investing in logistics equipment; they argue that the tendency of holding onto redundant equipment and assets by government, business and households, is a major deterrent to the overall efficiency and performance of the system. To maximise the recovery of WEEE, there is an urgent need for the establishment of a data management and auditing system to manage and track the flows and types of WEEE generated, collected, processed and stored (*link to planned Industry Waste Management Plan*).

  - **Regulatory uncertainty and high costs of compliance** – The implementation of the WEEE Industry Waste Management Plan and creation of the Waste Management Bureau are still pending thereby making it difficult for the recycling industry to invest in capital equipment. The WEEE industry is keen to know the impacts of the proposed Extended Producer Responsibility (EPR) scheme on their operations. Some remain skeptical over its long-term viability and effectiveness. The system requires a proper institutional and administrative framework to monitor or govern the funds. According to one respondent, the South African government does not have a culture of ring-fencing fiscal revenues for special purposes.

    The majority of respondents highlighted the high costs involved (R80,000 - R200,000) and time taken (2-4 years) to secure a hazardous waste license as a major constraint to business, and a deterrent to expanding operations. The challenge is particularly severe for small- and medium-sized recycling companies in securing funding for their projects from banks or investors. The establishment of a 'one stop shop' for WEEE licensing and other compliance requirements will go some way to improving the overall efficiency and effectiveness of the regulatory system.

4.2 Recommendations

The major recommendations and interventions arising from the study are summarised in Table 25.

Table 25: Suggested recommendations and interventions

Recommendation	Potential Impact/s	Responsible Department/ Organisation
Expediting the implementation of the Extended Producer Responsibility (EPR) scheme in WEEE Industry Waste Management Plan	• Regulatory certainty • Establishment of a nation-wide, properly financed WEEE collection scheme and increased WEEE collection volumes • Financing the development of WEEE collection infrastructure to reduce costs and the recycling of negative value products	• Department of Environmental Affairs
Establishment of concessionary funding windows for the mechanisation of the WEEE sector	• Given the low margin nature of the recycling business, government funding support will help to lessen the financial burden/costs associated with mechanising operations	• Department of Trade & Industry, IDC
Removal of restrictions on access to export markets	• Enable recyclers to get full value for WEEE fractions from export markets, rather than compel them to sell to domestic markets where the prices they receive are lower than prevailing international market price • While incentivising the establishment of local markets to attract recyclers to sell locally instead of exporting	• Department of Trade & Industry
Promoting the use of non-hazardous WEEE plastics in plastics products designed for markets such as plumbing pipes and gutters for low cost houses	• Preferential certification of WEEE plastics products with South African Bureau Standards (SABS)	• Department of Trade & Industry
Incentivising the development of EEE refurbishment infrastructure	• Encouraging the re-use of WEEE, particularly PCs and fridges, which ranks higher than recycling in the waste hierarchy and has the potential to create more jobs than recycling • Capacitating small and medium recycling companies that currently derive 60% of their revenues from refurbishment compared to the 40% from recycling activities	• Department of Environmental Affairs • Department of Trade & Industry
Embarking on greater public awareness campaigns aimed at communicating the benefits of recycling WEEE in order to grow collection volumes	• Reduce the perception of high residual value of WEEE (R1/kg in South Africa) but is free in developed countries	• All stakeholders (government, industry, associations, academia, public) • DEA to champion the clarification of PFMA & MFMA provisions on WEEE
Business and government consider changing business model with respect to EEE ownership, e.g. moving from purchasing to leasing to support greater return of end-of-life products to the value chain	• Reduce the high storage rates of obsolete WEEE in government departments due to issues around assets, security and the PFMA and MFMA provisions	• All stakeholders (government, industry, associations, academia, public)
Creation of a 'one stop shop' for hazardous waste licensing and other compliance requirements for WEEE recyclers	• Regulatory certainty by providing support to the WEEE recycling industry (from a single department or entity) • Issuance of hazardous waste licenses, transport and WEEE export permits under one roof • Timeous finalisation of hazardous waste licenses (currently taking between 2-4 years to be concluded) • Convenience to recycling companies and investors	• Department of Environmental Affairs
Establishment of EEE data management system	• Establish the quantities of EEE put on the market per annum: o Imports and exports of WEEE o Installed capacity of EEE in government, business and household o Average useful lives of EEE o Storage & recycling rates of WEEE	• Statistics South Africa
Capacitate and strengthen collaborative R&D work on the processing of complex WEEE fractions, e.g. phosphor powders containing REE, PCBs, plastics and CRTs	• Through uptake of R&D and technologies, unlock resources (and value) back into the economy • Mintek and the universities have already done some exploratory work on the establishment of a refinery for REE in South Africa • Future R&D activities should determine the feasibility of using lamp phosphor powders as one of the alternative secondary source of REE materials in South Africa.	• Department of Science and Technology • Universities • Science Councils • Recycling companies

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Appendix A: Questionnaire

SOUTH AFRICAN WEEE DISMANTLING, PRE-PROCESSING AND PROCESSING TECHNOLOGY LANDSCAPE – QUESTIONNAIRE

MINTEK
A global leader in mineral and metallurgical innovation

☐ I have been informed about the purposes of this study (cover letter) and I/my organisation participates voluntarily

If this questionnaire has been incorrectly sent to your organisation and you do not deal in the dismantling, pre-processing or processing of waste electronic and electrical equipment (WEEE) in any way, please tick the adjacent box, complete Questions 1 and 21 and return to Mintek via email (Email: wondern@mintek.co.za)

Please tick ☐

NO COMPANY-SPECIFIC INFORMATION WILL BE RELEASED. ALL INFORMATION PROVIDED IS STRICTLY CONFIDENTIAL AND WILL BE SUMMARISED AND COLLATED TO PROVIDE AN OVERALL PERSPECTIVE OF THE STATE OF THE SOUTH AFRICAN WEEE TCHNOLOGY LANDSCAPE

A. Basic Organisational Information

Note: If your company has regional offices, please answer questions for the total South African operation and not for any single branch

1. Organisation / company name: ☐
2. Physical address (head-office): ☐
3. Tel (head-office): ☐
4. Is WEEE management your organisation's: Core business ☐ Secondary business ☐
5. If WEEE is a secondary business, what is your core business? ☐
6. What year did your organisation first commence its WEEE recycling activities? ☐

7. Number of employees in your organisation: [ ]

8. In which province(s) does your organisation have active WEEE recycling activities *(more than one can be selected with an 'X')*?

Gauteng	[ ]	Western Cape	[ ]	Free State	[ ]
KwaZulu-Natal	[ ]	Limpopo	[ ]	Mpumalanga	[ ]
Eastern Cape	[ ]	Northern Cape	[ ]	North West	[ ]

Please indicate the nature of these activities *(more than one can be selected with an 'X')*?

Branch office	[ ]	Factory/plant	[ ]	Collection site(s)	[ ]

Comments: [ ]

B. WEEE Inputs

Note: The objective of this sub-category of questions is to understand the type and volume of WEEE received and handled by your organisation, the main end-user markets for output fractions, and the scope of your organisation's geographical footprint

9. How many tonnes of WEEE did your company collect or buy for processing in 2015? [ ]

10. Please could you indicate the approximate volumes of the following WEEE streams from the total WEEE tonnage that your company handled and processed in 2015?

Type of WEEE handled		Volumes handled in 2015	
Large and small household goods	[ ]	Large and small household goods	t
ICT and consumer electronics	[ ]	ICT and consumer electronics	t
Lamps	[ ]	Lamps	t
Other (e.g. cables)	[ ]	Other (e.g. cables)	t

11. Which geographical market(s) constitutes the main source of WEEE (as an input) for your organisation *(please indicate as a percentage)*?

Gauteng	[ ]	Western Cape	[ ]	Free State	[ ]
KwaZulu-Natal	[ ]	Limpopo	[ ]	Mpumalanga	[ ]
Eastern Cape	[ ]	Northern Cape	[ ]	North West	[ ]
SADC	[ ]				

If SADC selected, please indicate which countries: [ ]

C. WEEE Technologies and Processes Used

Note: The objective of this sub-category of questions is to understand the types and sources of technologies used to handle the different types of WEEE streams, current processing capacities and gaps, and opportunities for waste technology (product and process) innovation and investment

12. In which stage(s) of the WEEE value chain do you operate:

Dismantling [ ] Pre-processing [ ] Processing [ ]

13. What types of technology are currently used by your organisation? Please provide a list, description and details (capacity) of the technology, where possible. If more space is needed please attach a separate sheet.

WEEE Stream	**Dismantling** (*separating or liberating components*)	**Pre-Processing** (*shredding, granulating or pelletizing*)	**Processing** (*foundries, smelting and refinery facilities for metal recovery or re-manufacturing of secondary products*)
Large and Small Household Goods			
ICT & Consumer Electronics Equipment			
Lamps			

14. Please could you indicate where these technologies were sourced, the approximate cost, installed processing capacity (tonnes/units per annum) and current capacity utilisation (tonnes)?

Exact Description of Technology/ies (Make)	Country of Origin of Technology	Approximate Cost of Technology (R' million)	Installed Processing Capacity	Current Capcity Utilisation

9

15. If your operations include manual activities, please could you comment on the type of skills, number of staff involved in key activities, and types of training received?

Stage in the WEEE Value Chain	Entry Level Academic Qualification Required	Type of Skills Required	Number of Staff Involved	Type of Training Received*
Dismantling stage				

*For example, in-house training, external workshops etc

16. Which of the following constraints has your organisation experienced with regards to <u>sourcing</u> WEEE dismantling/processing technologies:

Legislation / policy / authorisations ☐ Economic / financial ☐
Skills / Personnel ☐ Technology information ☐
Lack of off-the-shelf equipment locally ☐ Institutional ☐
Lack of off-the-shelf equipment abroad ☐ Infrastructure ☐
Other ☐

If selected 'Other', please specify:

17. Which of the following constraints has your organisation experienced with regards to <u>introducing</u> WEEE dismantling/processing technologies:

Legislation / policy / authorisations ☐ Economic / financial ☐ Institutional ☐
Skills / Personnel ☐ Technical support ☐ Infrastructure ☐
Other ☐

If selected 'Other', please specify:

18. Which of the following constraints has your organisation experienced with regards to operating WEEE dismantling/processing technologies:

Legislation / policy / authorisations	☐	Economic / financial	☐	Institutional	☐
Skills / Personnel	☐	Technical support / spares	☐	Infrastructure	☐
Other	☐				

If selected 'Other', please specify:

19. What desirable technological interventions would you require to unlock further growth opportunities in the WEEE recycling space?

D. WEEE Outputs

20. Please list the main type of output fractions produced by your organisation, approximate volumes (tonnes) produced annually per fraction, main end-user customer for each fraction, and geographical location of end-user in 2015.

Output Fraction(s)	Approximate Volumes Produced in 2015 (t)	Main End-user Customer(s) for Fraction(s)	Geographical Location of End-User
Printed circuit boards (PCBs)		RSA – Pre-processor ☐ RSA – Processor ☐ Foreign – Pre-processor ☐ Foreign – Processor ☐	RSA ☐ Europe ☐ Asia ☐ Australasia ☐ North America ☐ South America ☐ Rest of Africa ☐

Output Fraction(s)	Approximate Volumes Produced in 2015 (t)	Main End-user Customer(s) for Fraction(s)	Geographical Location of End-User
Ferrous metal		RSA – Pre-processor RSA – Processor Foreign – Pre-processor Foreign – Processor	RSA Europe Asia Australasia North America South America Rest of Africa
Plastic		RSA – Pre-processor RSA – Processor Foreign – Pre-processor Foreign – Processor	RSA Europe Asia Australasia North America South America Rest of Africa
Glass		RSA – Landfill (e.g CRTs) RSA – Pre-processor RSA – Processor Foreign – Pre-processor Foreign – Processor	RSA Europe Asia Australasia North America South America Rest of Africa
Other (Please specify)		RSA – Pre-processor RSA – Processor Foreign – Pre-processor Foreign – Processor	RSA Europe Asia Australasia North America South America Rest of Africa

I certify that the information contained in this questionnaire survey is correct and complete to the best of my knowledge

21. Date completed (dd/mm/yy): ____ Signature: ____

Name of contact person: ____ Email: ____

Note: Contact person details should be the person completing the questionnaire.

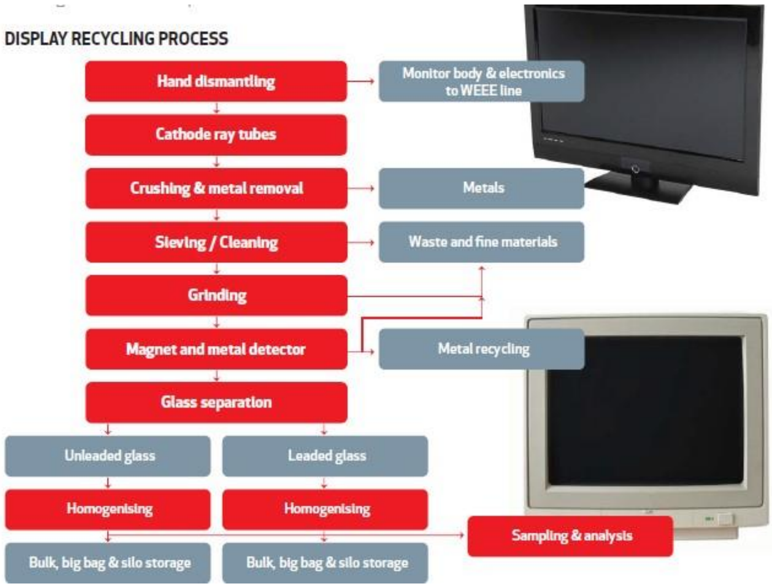
Appendix B: Study Respondents

The input and contributions (directly or indirectly) from the following participating companies are gratefully acknowledged:

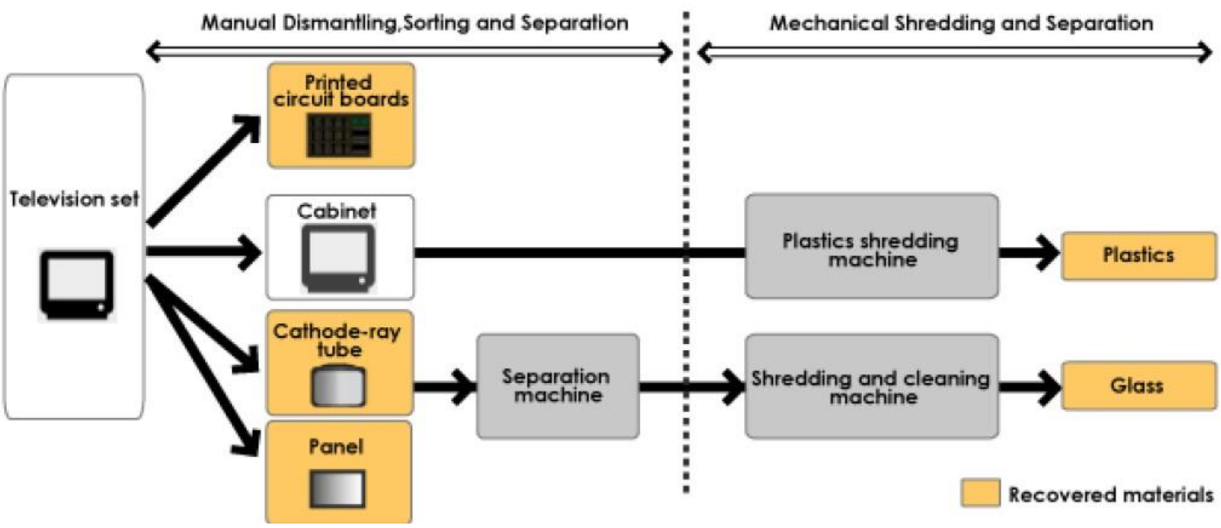
- Anglo American Platinum
- Africa E-Waste Ltd
- Bolunga Enterprise (Pty) Ltd
- Cape E-Waste Recyclers Ltd
- Computer Scrap Recycling
- Desco Electronic Recyclers CC
- Effortless Computer Recycling
- Electronic Cemetery E-Waste Management (Pty) Ltd
- eWaste Africa
- E-waste Technologies Africa
- Gauteng Refinery (Pty) Ltd
- Inca Metals (Pty) Ltd
- Indalo Resources Ltd
- Just PCs Ltd
- Javco Ltd
- Rand Refinery
- Metrex Metal Recovery and Extraction Ltd
- New Reclamation Group (Pty) Ltd
- RecLite (Pty) Ltd
- SA Metal Group (Pty) Ltd
- SA Precious Metals (Pty) Ltd
- Sibanye Recycling Ltd
- Sims Recycling Solutions Ltd
- Sindawonye Granulators and Processors (Pty) Ltd
- SmartMatta (Re-Ethical)
- Tshwane Electronic Waste Ltd
- Umicore NV
- Universal Recycling Company
- Virgin Earth Ltd
- Waste Plan Ltd

Appendix C: Flowsheets for the Recycling of LCD and CRT Screens

LCD screen recycling process[66]:



CRT screen recycling process[67]:



[66] ERP, 2012
[67] AEHA (no date)

Appendix D: Demand Trends for Select ICT & Consumer Electronic Products in South Africa

PC and Laptop Trends

Major global computer OEMs, including Hewlett Packard, Lenovo, IBM, Fijitsu and Dell, have got their national and regional sales, distribution, repair and maintenance centres based in South Africa. Retailers such as HiFi Corporation, Massmart (Macro) and Incredible Connection serve as important sales outlets for such companies and have entered into various take-back agreements with them. collaboration with such firms are major stockists of computers, laptops and tablets from Asia, Europe and the United States of America (USA). A significant amount of second hand computers are said to be imported directly into South Africa from computer refurbishers based in Europe and the USA every year[68].

In 2013, South Africa was estimated to have an installed base of around 8.5 million computers, with the bulk of them installed in national, provincial government departments and business organisations[69]. PCs have an average life span ranging between 3 and 6 years while laptops are much shorter at around 3 years. However, many PCs remain in use for longer than 6 years partly due to tighter infrastructure budgets, higher ZAR/USD exchange rate, longer replacement cycles, the need within corporates to extract maximum value out of their equipment, as well as the difficulties local companies experience in keeping up with changes in global hardware and software trends. Notable ICT market indicators for computer usage in South Africa in 2015 are shown in the Table below.

Table: ICT market indicators, South Africa 2015

Key Performance Indicator (2015)	Description
Computer installed capacity (PCs, laptops)	8,500,000
Average life span of PC	3-6 years
Average life span of Laptop	2-3 years
Average computer imports (units) into SA per annum	500,000

Tablet and Mobile Phone Trends

According to MMASA (2014), approximately 5% of adults or 736,000 households in South Africa owned a tablet. Over the past five years, demand for tablets has been exponential rising from 127,000 in 2011, to 1,840,000 in 2013. Demand is forecast to reach around 6 million devices by 2019[70]. Demand will be driven by new releases and technologies[71]. Tablet usage will remain highest in the LSM 9 (29%) and 10 level (38%)[72]. The average lifespan of a tablet is around 2 years. However, there is a significant second hand market for tablets in

[68] This was based on feedback received during an interview and was not verified by the specific companies concerned.
[69] IDC, 2013
[70] PWC, 2015
[71] Wesgro, 2014
[72] MMASA, 2014

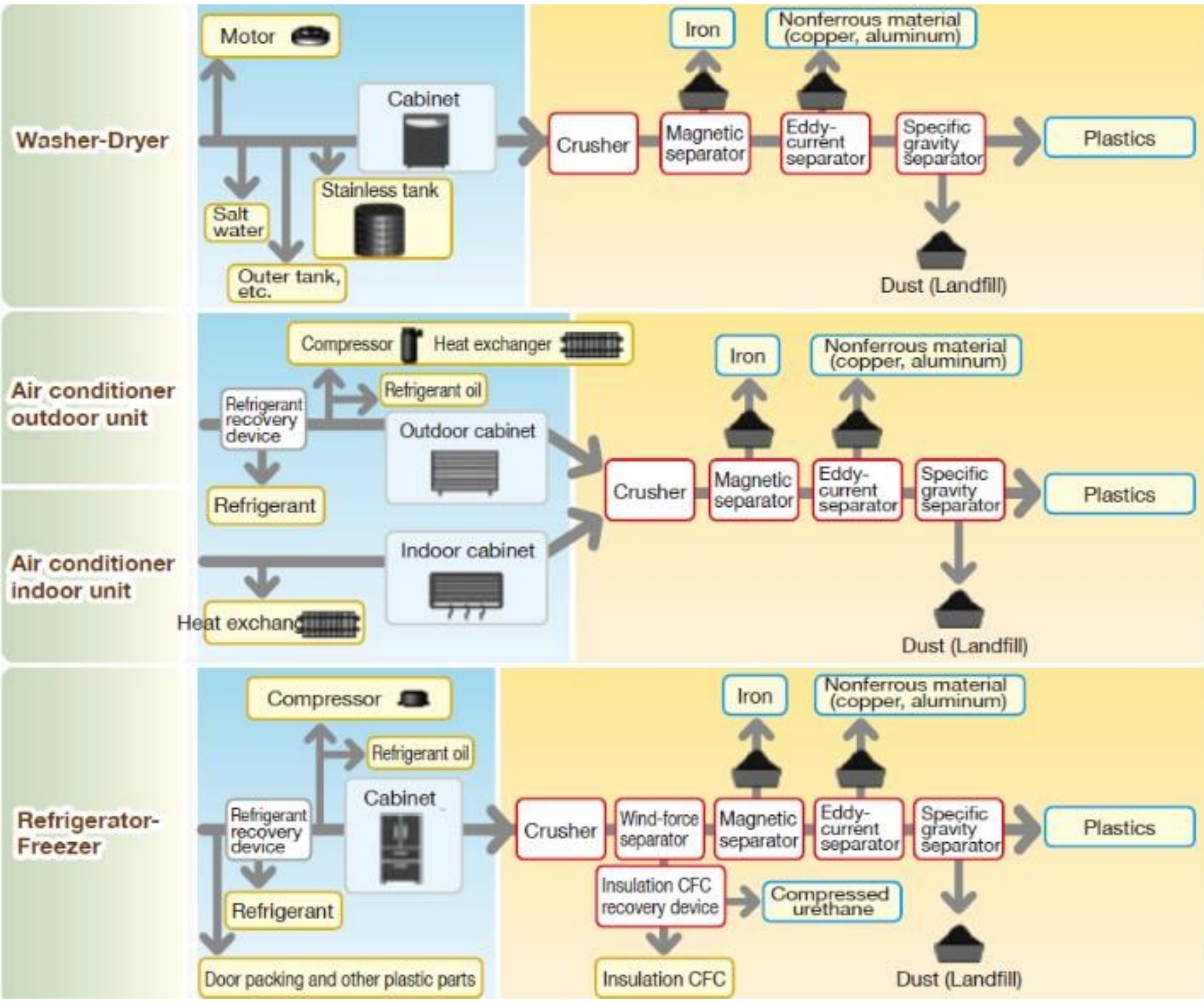
South Africa and a trend of passing on tablets to other people before being released for recycling. The growth forecast for PCs, by contrast, is flat. This reflects both a saturated market, and a trend away from desktop computing to mobile computing, including laptops and handhelds. At the same time, there is strong growth predicted for the second-hand PC sector. Refurbishers report that businesses are opting to refurbish their office IT rather than purchase new, and are also starting to take up leasing schemes with refurbishers. Overall, estimates put the IT sector's value at R30 billion for hardware sales alone, around R100 billion including software, services and consulting.

In terms of mobile phone penetration, 94% of South African working adults use a mobile phone, up from 29% in 2000. In 2013, there was an average of 2.4 mobile phone per household and 14.3 million households with mobile phone in the South Africa (97% penetration). According to PWC (2015), the number of smart phone connections in South Africa is expected to reach around 52.3 million in 2019. Mobile phone ownership ranges from 72% in LSM 2 to 98% in LSM 10. Gauteng reportedly has the highest penetration of mobile phone usage in the country (92%)[73]. As with tablets and ICT equipment, there is a significant second hand market for mobile phones in South Africa and a trend of passing on old phones to family members or other people, or holding onto them, before releasing them for recycling. This makes projecting the current and future installed stock of redundant WEEE problematic.

[73] MMASA, 2014

Appendix E: Flowsheets for Select Small and Large Household Goods

Flowsheets for the recycling of washing machines/dryers, air conditioner units, and freezers/fridges are provided in the figure below:



Appendix F: Recycling Options for Lamps

The different interntional best-practice methods for lamps recycling are discussed below[74]:

End-cut Method

This method is commonly used for linear fluorescent tubes. The main steps are

- **Dismantling** – Lamps are collected whole and then dismantled. During the stripping process, air is fed into the vacuum-sealed tubes. After this the ends of the lamps (metal/lead glass part) are removed and sent for further processing (separation of metal and lead glass).
- **Removal of phosphor powders and mercury** – The hazardous mercury and phosphor are removed by specialised machines. The phosphor is blown out of the remaining glass tube, or sucked out if the tube is broken, and separated into dust-tight containers using a dust precipitator. The phosphor powder may be re-used to make new lamps. When purified to the right level, the mercury collected can also be used to make new lamps or in other industrial processes.
- **Separation of glass and metal fraction processing** – The cleaned tube is reduced in a crusher. The broken glass is fed through a metal separator to ensure it contains no more metal. The crushed glass can be used for furnace linings or, if pure enough, to make new lamps. The remaining material is sorted into different fractions (metals, plastics). The aluminium end caps are sent for smelting and other metals are recycled.

Shredder Method

In the case of lamp types with many different forms and relatively low quantities, automatic dismantling systems are generally not economical due to the variety of materials. In this case, the shredder process, involving the separation of metals and plastics, is not only more economical, there is also no risk to the environment. The shredder method allows all types of lamps to be processed, including broken lamps and production waste. Lamps are processed in three steps:

- **Crushing/Shredding** – Collected lamps are first crushed or shredded to reduce their size.
- Material separation – The broken lamps are separated into three fractions of different particle sizes in a multi-staged separation process. The coarse fraction consists of the lamp caps, which are removed as flat, distorted parts. The medium fraction has a particle size of approximately 5 mm and consists of a mixture of glass and plastic. Plastics can be separated from the glass by being blown out. Sifted phosphor powder and glass dust are removed from the material and form the fine fraction, which is collected separately.
- **Fraction recovery and processing** – Metal parts are sent to a metal recycling plant. Mixed glass is used, either directly or after appropriate pre-treatment, for glass products with lower purity requirements, or as an aggregate material for vitrification, foaming etc. Thermal removal of mercury from phosphor/fine glass by means of distillation.

[74] Sourced from ZVEI (2008), ECLF (2009) and ERP (2012).

Glass Washing Method

This method is used for recycling large volumes of collected fluorescent lamps, regardless of length, diameter or state of the lamp, without the preliminary sorting step. The main steps are:

- **Crushing** – The fluorescent lamps are fed directly from the containers into the plant and crushed. Big-bags containing broken lamps can be input directly into the conveyer unit and emptied.
- **Removal of phosphor powders and mercury** – The broken lamps are cleaned of all phosphor with water in a vibration tank. The rinsing water is pumped out through an inclined filter in which the phosphor powder sludge is sedimented and the water subsequently reused. Mercury is removed from the phosphor powder by means of rotary distillation.
- **Material separation** – The individual material fractions are rinsed and separated by means of sifting. The soda-lime glass separated in this way is dried and sent for quality control via a metal separation unit and an automatic detection system. There the lead glass is separated. The cleaned soda-lime glass is then put into big-bags and delivered to the lamp industry as a secondary material for the production of new lamps.

Centrifugal Separation Method

The centrifugal separation method allows compact fluorescent lamps, energy-saving lamps and other non-tubular discharge lamps to be processed. The process follows the following steps:

- **Stripping and separation of the fractions** – In a centrifugal separation system the discharge lamps are separated into the fractions of glass components and metal/plastic components of the lamp caps, without the lamp caps and electronics components being destroyed. The phosphor is extracted and filtered out.
- **Thermal treatment and magnetic treatment** – The glass of the discharge vessels is then subjected to thermal treatment in heating chambers. The lamp caps, plastic and electronic parts separated in the centrifuge are then fed into a shredder. The shredded material is then passed beneath a separator magnet. This extracts all metal parts
- **Utilisation of recycling** – Metal parts are sent for metal recycling. The glass is fed directly into the processing system for glass products. Plastics are energetically recovered. The phosphor/fine glass is disposed of in an underground landfill.

The unmixed extraction of the metal and glass lamp components permits high quality reuse with a significant level of material utilisation. Fluorescent lamp glass, for example, is used as a raw material for the manufacture of new lamps. Plastics from the processing of compact and energy-saving lamps are mostly used to generate energy. In terms of the phosphor powders, investigations are still at the early stage with regard to developing a cost-effective process for the transformation of the lamp phosphor fraction into a rare-earth concentrate, separate the rare-earth concentrate in the individual rare-earth elements, produce new lamp phosphors from the purified rare-earth oxides, and produced new fluorescent lamps using these lamp phosphors.

Appendix G: Hydrometallurgical and Pyrometallurgical Treatment of WEEE Fractions

Hydrometallurgical Treatment of Metallic Fractions

Hydrometallurgy is the branch of extractive metallurgy that involves reactions in (mainly) aqueous solutions at much lower temperatures for the treatment of base and metallic inputs. With their relatively low capital cost, reduced environmental impact (e.g. no hazardous gases/dusts), potential for high metal recoveries and suitability for small scale applications, hydrometallurgical processes are promising options for the extraction of base and precious metals contained in WEEE, particularly PCBs[75].

The hydrometallurgical treatment of WEEE generally requires a small grain size in the feed material in order to maximise the metal yield. Since the metals are present in native form and/or as alloys, a two-stage process based on oxidative acid leach[76] of base metals (copper in particular) followed by leaching of precious metals using cyanide, thiosulfate, thiourea or halide as lixiviant(s) can be used. This is then followed by purification and concentration using processes such as solvent extraction, precipitation, cementation, ion exchange, filtration and distillation[77]. Metal recovery is the final step in a hydrometallurgical process. Metals suitable for sale as raw materials are often directly produced in the metal recovery step. Sometimes, however, further refining is required if ultra-high purity metals are to be produced. The primary types of metal recovery processes are electrolysis, gaseous reduction, and precipitation.

Pyrometallurgical Treatment of Metallic Fraction

- **Incineration** – A common method of getting rid of plastic material and other organics to further concentrate the metals due to its volume reduction efficiency, sterilisation and energy recycling advantages. The crushed scrap can be burned in a furnace or in a molten bath to remove plastics, leaving a molten metallic residue. The plastic burns and the refractory oxides form a slag phase[78].

- **Pyrolysis** – A thermal process where material is heated up in an inert gas atmosphere. At certain temperatures, organic fractions (plastic, rubber, paper, wood etc.) contained in WEEE decompose and form volatile substances which can be used in the chemical industry or for the generation of energy by combustion of the gases or oils. Metals recovered during pyrolysis (such as gold, copper and palladium) are regenerated in a pure form since no oxygen is present and thus no metal oxides are formed. A major drawback the pyrolysis process is the formation of halogens which arise from fire retardants and plastic mixtures contained in WEEE[79].

- **Smelting** – An established method of extracting metals from ores and a preferred approach in WEEE recycling. Currently more than 70% of PCBs globally are processed by means of smelting rather than by mechanical means. Copper and lead smelters have been used successfully to recover lead, copper and precious metals from pre-processed WEEE scrap and granulated PCBs containing iron (Fe), aluminium (Al),

[75] Tuncuk et al., 2012
[76] According to Judhav & Hocheng (2015) several studies have reported the use of the following acids for the recovery of metals from PCBs – nitric acid (HNO_3), HCl, sulphuric acid (H_2SO_4) and aqua regia.
[77] Gramatyka et al., 2007; Tuncuk et al., 2012
[78] Gramatyka et al., 2007; Ebin & Isik, 2016
[79] Gramatyka et al., 2007; Williams, 2010; Evangelopoulos, 2014; Wang & Xu, 2014; Ebin & Isik, 2016

copper (Cu), lead (Pb), tin (Sn), antimony (Sb), zinc (Zn) and precious metals (PMs) as metallic constituents. In the secondary copper smelting process, Pb, Sn, Sb and PMs are collected in the copper parent phase, which is casted as anode at the end of the process. Anodes are refined by electrolysis, yielding a copper cathode production with purity of up to 99.99%. Dissolved anodes leave a slurry residue (anodic slime) which is rich in valuable metals and is further processed with high recovery rates (over 90%). Modern processes in the copper industry are able to recycle up to 17 metals, however, Fe and Al fractions are not recovered, but instead are oxidised and collected in slag. The anode composition and the quality of the dust and slag fluctuate significantly due to the heterogeneity of the input materials[80]. In the case of lead smelters, reverberatory furnace and blast furnaces are used to recover lead from WEEE scrap.

Leading global processors, such as Boliden (Sweden), Umicore (Belgium), Dowa (Japan), Aurubis (Germany) and Gelncore (Canada), employ smelting in their systems, with high recovery rates. Boliden and Umicore are integrated operations, combining both copper and lead smelting methods in their flowsheets[81].

High-quality steel scrap is usually processed in Basic Oxygen Furnace (BOF) convertors, of which the Electric Arc Furnace is the most flexible. Ultra-High Power Electric Arc Furnaces (with transformer ratings of 250 MVA) are very efficient at producing steel in batches of over 160 t per melt. Stainless steel scrap (Fe-Cr-Ni-C-X alloys) is processed/smelted in similar arc furnaces as for normal steel, though for thermodynamic reasons it is converted in Argon Oxygen Decarburisation (AOD) converters[82].

The aluminium industry is doing much to maximise the recycling of the various aluminium-containing metal alloys and other materials. Different technologies are used for processing different aluminium scrap types. High-quality and pure scrap is remelted to produce wrought aluminium qualities, while refining under a salt (NaCl-KCl) slag is used for poorer scrap qualities. Recovery is rates are affected by the purity and morphology of scrap. Even with simple aluminium scrap, intimate connections to other materials can have a marked effect on recycling efficiencies[83].

[80] See Ebin & Isik, 2016, p. 109, for a simplified flowsheet of secondary copper recovery from WEEE
[81] Ebin & Isik, 2016, p. 110. Flowsheets for the various companies can be found in Khaliq et al., 2014
[82] Worrell & Reuter, 2014
[83] Reuter et al., 2013

Appendix H: Process Descriptions

BOX A: PROCESS DESCRIPTION – E-WASTE AFRICA

The lamp recycling process at E-Waste Africa is a fully-mechanised, modular plant and was installed and commissioned in South Africa in July 2014. The MP8000 system was sourced from Balcan in the UK, a world-leader in lamp innovation and recycling. The Balcan lamp and bulb recycling system is able to recycle all types of waste mercury-bearing lamps and is designed to accept both whole and pre-crushed lamps of all sizes. It also requires less than 15 KW of power and no water to operate. The Balcan MP8000 has a capacity to handle 5,000 linear tubes (4ft) and other lamps per hour (around 200 kg/hour) and operates 4-5 days a week.

Once crushed, the lamp debris is fed via a conveyor fed loading system into an agitator unit that loosens the mercury-bearing phosphor powder adhering to the glass. During this process, the mercury-bearing dusty air generated inside the unit is continually drawn off to a filter unit that removes and collects the powder. Air exhausted from this filter is then further cleaned by passing through another larger and highly sophisticated filter, which removes the last traces of mercury vapour and other impurities. Cleaned recycled glass debris is separated into glass and metal fractions by a powerful magnet. The resultant separated clean fractions include glass, end caps (metal or plastic depending on lamps processed. If lamps are mixed for processing then the end cap will be mixed), and mercury-bearing phosphor powder.

MP8000 specifications

Criterion	Description
Capacity	• Whole lamps – 5,000 fluorescent tubes per hour • Crushed lamps – 4,000-5,000 per hour • Mixed (crushed and whole) – 5,000 per hour • Weight equivalent – 1,800-2,000 kg/hour
Electrical requirements	• Each unit is supplied to customers available electrical supply and country requirements • Consumption – Max 25 kW 3Ph
Compressed air requirements	• 7.2 Nm3/h (4.5CFM)
Supply pressure	• 6 Bar
Connection pipe	• 0,75" thread
Mercury (Hg) emissions from final exhaust	• Typically – 0.001-0.002 mg/m3 • Max permissible – 0.025 mg/m3
Estimated carbon filter life	• 5 years
Output fractions	• Glass • End caps (metal or plastic depending on lamps processed. If lamps are mixed for processing then the end cap will be mixed) • Mercury-bearing phosphor powder
Residual contamination and leachate values	• Analysed as water – max 0.025 mg/l • Analysed as bulk product – typically 1-3 mg/kg

The MP8000 system

BOX B: PROCESS DESCRIPTION – DESCO ELECTRONIC RECYCLERS

Upon arrival at its recycling centre, WEEE is weighed and offloaded. Large and small household goods are separated from ICT and consumer electronics products given their different processing routes:

- ICT and consumer electronics equipment items selected for processing are put on a table where they are manually dismantled into WEEE fractions such as PCBs, plastics, ferrous and non-ferrous metals, glass and PVC cabling using pneumatic screw drivers, drills, grinders and hammers. The dismantled WEEE fractions are placed in different storage bins to accumulate sufficient volumes of each of the fractions before further pre-processing can be done.
- In the case of temperature exchange equipment and large and small household goods, fridges are first de-gassed using a pump and then the glass/plastics shelving and motor (containing copper) is removed. The fridge is then sold to scrap metal dealers in its dismantled state. Obsolete stoves are passed on to scrap metal recycling companies in their original form.

After dismantling, PCBs are shredded in four shredders, with a combined capacity of approximately 15,000 tpa. The main output fractions produced are ferrous and non-ferrous metals, shredded PCBs, plastic and batteries.

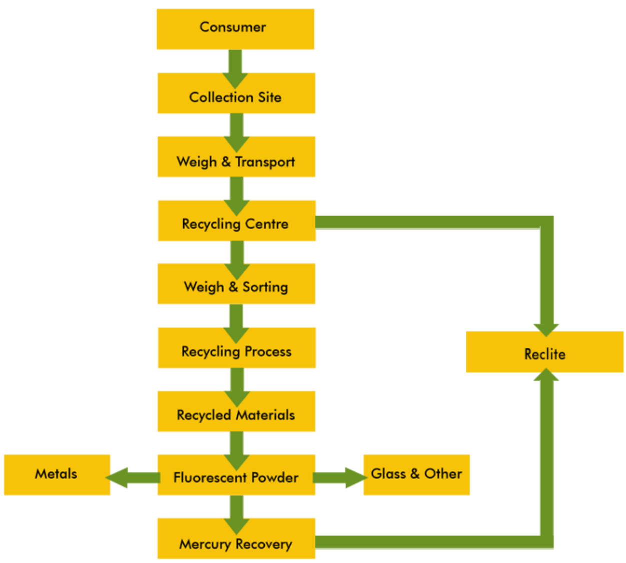
Desco's facilities are ISO 14001 compliant and is a Level 1 BBBEE certified company. The company's recycling processes are structured to meet International Standards 9001, 14001 and OHSAS 18001 compliance and the Second Hand Goods Act (Act 23 of 2009). The company is a Level 1 BBBEE certified company; has a recycling authority permit from Gauteng Department of Agriculture and Environment; all vehicles and drivers are Hazardous Chemicals certified and remain current in this certification; is in possession of Waste Hub Permits for both City of Johannesburg and the City of Tshwane (allowing its vehicles to traverse all areas of Gauteng).

BOX C: PROCESS DESCRIPTION – RECLITE

The company uses the MRT (LP400) system, from Sweden, designed for processing a wide range of mercury bearing products, including fluorescent tubes, CFL's, HID, halogen lamps, batteries, medical and dental waste, and electrical components. The technology comprises of crushing, screening, separation and cleaning steps, producing very clean recycled fractions .ICT and consumer electronics equipment items selected for processing are put on a table where they are manually dismantled into WEEE fractions such as PCBs, plastics, ferrous and non-ferrous metals, glass and PVC cabling using pneumatic screw drivers, drills, grinders and hammers. The dismantled WEEE fractions are placed in different storage bins to accumulate sufficient volumes of each of the fractions before further pre-processing can be done.

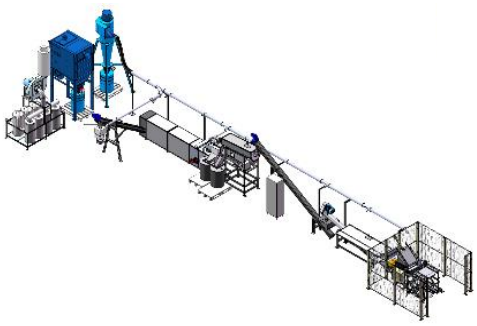
The plant is fully automated, easy to use, is a dry process, requiring no water or chemicals, and has a very low energy consumption requirement (3-4 KWh/day). The crush and sieve plant operates at sub-pressure, preventing mercury from being released into the environment as exhaust air. This is constantly discharged through the internal carbon filters. The plant's capacity is 6,000 tubes per hour. Lamps are fed into the crush and separation plant via a drum turner or manually. The separation plant was designed with a processing capacity of 800 kg/hour to accommodate future market growth. The plant's current capacity is 300-400 kg/hour. The resulting separated fractions are mechanically washed until clean and discharged to their own individual containers for re-use. Fractions include glass, plastic, fluorescent/phosphor powder, aluminium, ferrous metals, and mercury (>99% purity). All lamps that have been destroyed and components recycled are issued with destruction and recycling certificates certifying the mass and the percentage of each recycled component.

Pre-processing flowsheet at RecLite



Key features of the MRT lamp recycling system:

- Operated partly by hand, and partly automatic
- Dry separation technology working at sub-pressure
- Material throughput of 200-1200 kg/h, depending on model
- Variable set-up and can be configured to meet country specific characteristics



The LP400 system installed in South Africa

BOX D: PROCESS DESCRIPTION – UNIVERSAL RECYCLING COMPANY

At URC, the input material is first put through a 1200 HP shredder which breaks up the material into pieces of up to 130mm and less. The shredding process breaks up the electronic scrap so that the various materials can begin to be separated. The dust is suctioned out by air and removed from the system by a cyclone. The waste air is then passed through a Liquicell multi-stage in-line scrubbing system that ensures that only clean air is emitted. A rotary magnet removes the ferrous fraction, which is sold to steel mills and foundries as raw material. The non-magnetic fraction is then screened in three sizes and by heavy media, eddy current magnets and water separation tables is separated into inorganics (plastic, wood, paper), the heavy fraction (copper, brass, zinc lead and stainless steel) and the light fraction (aluminium).

The company's plant operate in an environmentally friendly manner, limiting any air, water, soil or sound contamination and produce a vital metallic raw material for reuse both domestically and for the export market. The processing yard is concreted and all run-off rainwater, which has been diverted into various underground sumps and dams built around the yard, is collected for reuse. All material is scanned with Radcom radiation sensors upon arrival and departure. All material over the legal limit is then reported to the National Nuclear Regulator (NNR) or the Department of Health (DoH) for safe disposal.

URC is a licensed waste processor, with an ISO 9001 accreditation, and adheres to the Occupational Health and Safety Act No. 85 of 1993, which includes the regulation under Machinery and Occupational Safety Act 6 of 1983. The company is a founding member of the Metals Recyclers Association of South Africa (MRA), a member of the Institute of Scrap Recycling Industries (ISRI), based in Washington, DC, and the Aircraft Fleet Recycling Association (AFRA), an international group that regulates the safe recycling of large civilian and military aircraft worldwide.

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