AUTHORS:
Thandazile Moyo[1]
Zaynab Sadan[1]
Aysha Lötter[1,2]
Jochen Petersen[1]

AFFILIATIONS:
[1]Minerals to Metals Research Initiative, Department of Chemical Engineering, University of Cape Town, Cape Town, South Africa
[2]Mineral Law in Africa, Department of Private Law, University of Cape Town, Cape Town, South Africa

CORRESPONDENCE TO:
Jochen Petersen

EMAIL:
jochen.petersen@uct.ac.za

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Barriers to recycling e-waste within a changing legal environment in South Africa

Electronic waste (e-waste) recycling presents an opportunity to reclaim materials from a secondary resource and to create jobs and other economic opportunities. E-waste consists of various materials such as metals, plastics, glass, and other chemical substances. Some of these materials are hazardous if processed or disposed of improperly. Therefore, e-waste is classified as hazardous in South African law up until the hazardous components are removed. With the appropriate infrastructure and technology, a large portion of materials contained in e-waste can be reclaimed, and any adverse impacts of irresponsible management prevented. The private sector has played a proactive role in shaping the South African waste economy, and the government is taking strides to draw up enabling regulatory frameworks. Through a literature review and stakeholder engagements, this paper unpacks the organisation of the South African e-waste recycling industry. We consider whether the legal environment drives a common vision for a circular e-waste economy and probe the barriers to e-waste recycling across the value chain. The findings indicate that the development of the e-waste recycling sector in South Africa is dependent on a robust collection network and the enabling of local end-processing, refining, and manufacturing capacity. The availability and quality of input material and the development of local refining and manufacturing capacity are co-dependent and should be addressed simultaneously.

Significance:

- E-waste recycling is an emerging industry in South Africa and the enablers and constraints for the development of this industry are still being explored.
- The legislative environment with regard to e-waste recycling is evolving and needs to be continuously reviewed to assess its ability to enable/activate the development of the sector.
- Local end-processing is currently limited to very small volumes of selected fractions of e-waste. The potential to activate upper levels of the e-waste value chain, such as end-processing, is important to the development of the sector.

Introduction

Electronic waste (e-waste) refers to discarded end-of-life and end-of-use electrical and electronic equipment (EEE). The e-waste stream is the fastest growing waste stream in the world, with 53.6 million tonnes generated globally in 2019 alone, and this figure is expected to increase to 74.4 million tonnes by 2030.[1] The growth of this waste stream is fuelled by higher consumption rates, shorter product life spans and limited options for repair of EEE. Technology is important in the modern world, and its role in the energy transition cannot be overstated. However, the growing demand for EEE and its disposal at end-of-life or end-of-use demand increased extraction of the primary resources used in the manufacture and create environmental and social challenges.

In 2019, South Africa generated an estimated 416 kt of e-waste, and this should be regarded as a conservative estimate as data collection in the waste sector is generally poor.[1] E-waste streams contain various materials which include metals, plastics, glass and ceramics. High-value components, such as gold and copper, can be economically recovered through well-established recovery technologies, while low-value materials, including some plastics, cannot. Those components that can be economically recovered locally could drive the growth of a secondary resource economy. The recovery of metals reduces reliance on the extraction of virgin metals and avoids the potential negative social and environmental effects of traditional mining practices. E-waste recycling, although not a solution to these ills, provides an alternative source for the development of further technologies.

In South Africa, e-waste is classified as a hazardous waste stream and its toxic components, including certain metals, pose a threat to health, well-being and the environment if poorly managed. As such, the *National Environmental Management Waste Act 2008* (NEMWA) requires various environmental authorisations and licences when carrying out certain waste management activities to manage the potential harm.[2] The South African Department of Environmental Affairs, now known as the Department of Forestry, Fisheries and Environment (DFFE), is the national regulatory department that issues these authorisations and licences. However, these regulatory measures may promote or inhibit e-waste recycling in South Africa, and frequent regulatory changes create legislative uncertainty, which adversely impacts the fledgling e-waste recycling sector.

The National Waste Management Strategy (NWMS) has driven a shift in legislation towards promoting the circular economy and the waste management hierarchy.[3,4] Extended producer Responsibility (EPR) has contributed to the shift towards circularity. NEMWA defines EPR measures as '[an extension of] a person's financial or physical responsibility for a product to the post-consumer stage of the product'[2]. The shift is in line with the global shift to recognising waste as a resource, not only from an energy recovery perspective but also for the reduction, reuse, recovery, and recycling of materials. In a circular economy, products, parts and materials are used and cared for, repaired, reused and recycled as much as possible with the aim to avoid producing waste or pollution.[5] The waste management hierarchy provides a framework for preferential consideration of sustainable waste management options from most to least preferred. This hierarchy is accepted locally and internationally as a guide for prioritising waste management practices. It is made up of five ranked options in order of desirability, namely prevention, reuse, recycle, recovery, and disposal.[3,4,6]

In the South African context, there is a gradual shift away from the age of the landfill, which was focused on disposal as the least preferred strategy in the hierarchy, towards the local recycling of e-waste. Through this paper, we aim to provide insights that can support South Africa to fully participate in higher tiers of the waste hierarchy while also providing opportunity for economic development and local job creation. Furthermore, we draw on insights gained through site visits and interviews to map out e-waste recycling networks and identify barriers to full participation in e-waste value chains in South Africa. However, while the aim of South Africa's legislation on e-waste management is shifting, the existing waste infrastructure remains weak. Limited fractions of recyclable e-waste are collected and much of it is exported for processing elsewhere[6-9], thus limiting the development of the e-waste recycling sector locally. It is therefore crucial to understand what is currently inhibiting this development. We outline how the e-waste sector is organised and identify the current barriers to an effective e-waste recycling sector. We also consider developments in legislation and the potential impact on the growth of the sector in South Africa.

Methods

All data and information gathering in this study were of a qualitative format, based on research done by Sadan[6]. The data were obtained through a literature review, formal interviews, informal conversations with stakeholders and observations made during site visits to local e-waste processing operations.

Desktop study

The literature review provided insight into the global and South African contexts of e-waste legislation, value chain activities and stakeholder information. Most of the studies on the status quo of the sector were done more than 10 years ago.[10-13] However, the sector has undergone significant developments since then, which is highlighted in the technology landscape report by Mintek in partnership with the Council for Scientific and Industrial Research (CSIR), published in March 2017.[14] This particular report provided a comprehensive study on the sector and is used as the foundation upon which this research has been built.[14]

Interviews and site visits

The literature review was complemented with primary data collected through interviews and site visits.[6] The initial interaction with the e-waste industry was via the Southern African E-waste Alliance (SAEWA), which is an e-waste industry network and voluntary industrial association. SAEWA was contracted to organise and facilitate site visits to e-waste recyclers in the Gauteng (February 2017) and Western Cape (April 2017) regions. The sites were chosen based on the company profile, size of operation, e-waste activities, location as well as availability and willingness to participate in the research. Interview questions were drawn based on themes and knowledge gaps identified during a preliminary literature survey. The questions used are provided in the Appendix and the detailed approach taken to draw up the questions is reported by Sadan[6]. Interviews and site visits provided insights on health and safety practices in the industry, material flows of feedstock and products, agenda and motivations of the recycler, perspectives on waste legislation, technology and operations, and other peripheral information that may have implications on the e-waste recycling operations. Ethical approval for the study was granted by the University of Cape Town.

Table 1 gives information on the interviews and site visits conducted; further details can be found in Sadan[6]. The data collected during site visits and interviews were coded manually using thematic analysis.[15,16] Figure 1 shows images from the data unpacking process.

Table 1: Interviews and site visits conducted

Interviewee descriptor	Location	Description of role and organisation	Description of information gathered
Susanne Karcher	Cape Town	Environmental consultant and coordinator of the Southern African E-waste Alliance (SAEWA)	High-level overview of the e-waste recycling sector; environmental legal compliance; product market and trade information
Environmental Risk Officer	Cape Town	Environmental Risk Officer at a higher education institution	Organisational perspective on e-waste management; waste information registration and requirements
Business owner – NC Electronix	Western Cape	Owner and manager – small-scale e-waste business operating outside of Cape Town Central Business District	Insights into small-scale e-waste recycling operations, flows, product markets, value chain and stakeholder interactions
Business owner – Square Mobile	Western Cape	Owner and manager – small-scale start-up focusing on mobile phone collection and recycling	Insights into e-waste collection logistics; e-waste awareness campaigning and community-based mobilisation; perspectives on the legislative procedure for a start-up e-waste recycler
Business owner – Cape E-waste	Western Cape	Owner and manager – medium-scale e-waste recycler and collection agent to Desco	Perspective on barriers in obtaining full legal compliance; comparison of regional differences in the e-waste business
Business owner – Smiley's Electronics	Western Cape	Owner of an informal refurbisher and reseller	Informal sector perspective
Mark Dittke	Cape Town	Managing Attorney, Dittke Attorneys – specialising in Health, Safety and Environment	Insights into policy and legislative framework in South Africa; auditing services
Manager – TraX Interconnect	Cape Town	TraX Interconnect (Pty) Ltd – manufacturer of PCBs	Insights into nature of raw materials, offcuts, scrap and effluent streams
Owner and manager	Gauteng	One of two lighting recycling companies in South Africa, with growing capacity	Insights into specialised stream recycling, the processes and challenges in establishing the business
Divisional manager	Randburg, Gauteng	Mintek – Government-funded research institution	
Anonymous 1	Gauteng	Sindawonye – Large-scale e-waste recycling company	Insights on large-scale recycling dealing with tenders from a telecommunication company
Anonymous 2	Gauteng	Desco Electronic Recyclers cc – Large-scale e-waste recycling company	Insights on the e-waste value chain, collection and pre-processing; export of value fractions and disposal of residuals
Anonymous 3	Bangalore, India	Government funded e-waste recycler and researcher	Insights on innovation and technology development in a developing country

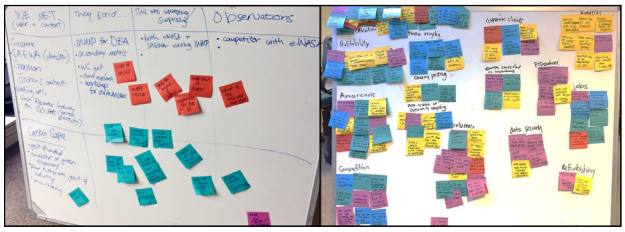

Figure 1: Interview matrix unpacking and theme grouping.

Research limitations

A constraint on this research was that the stakeholder engagement took place during a dynamic and transient time in the legislative context of the South African e-waste industry. The transient nature called for regular check-ins with newly published literature and follow-ups with interviewees. Examples of such changes are the call, and subsequent withdrawal of the call, for Industry Waste Management Plans (IndWMP) and the import ban of foreign recyclables to China (2018) during the study.[17,18] Changes after the study include the consultation process for, and subsequent publication of, regulations regarding EPR.[19,20] The 2020 NWMS was also published after the researchers' stakeholder engagement took place.

Also, only a limited number of site visits and interviewees could be consulted, with a bias towards Cape Town due to relative ease of access to the participants. Furthermore, the diversity of the types of businesses, i.e. large, small or medium scale and the formal, semiformal or informal nature, also led to disparity in responses to interview questions as each type experienced the industry differently.

Results and discussion

E-waste legislation and governance in South Africa provides historical markers of a shift in perspective on e-waste as a potential source of value. Shifting away from disposal towards recycling, reuse and reduction, the intention of legal developments looks towards moving up the waste management hierarchy. As the law develops, these changes may have unintended consequences and a common vision acts as a guide. Understanding the barriers to recycling e-waste in South Africa from an industry perspective can assist in guiding the implementation of the law in achieving circular economy initiatives.

In the following sections, we discuss the results by outlining the legislative and governance of EEE and the resultant e-waste in South Africa and the recent inclusion of the circular economy concept within the law. The inclusion of the concept is unpacked in relation to the EPR Regulations and the product-specific notice for EEE, as well as the impact of the e-waste landfill ban. The changes to the law address some of the barriers identified; however, the barriers to the common vision to recycling is only one aspect of the waste management hierarchy and barriers at other points within the EEE value chain are beyond the scope of this paper.

E-waste legislation and governance in South Africa

South Africa has three spheres of governance – national, provincial and municipal. There are policies and legislation on waste regulation and management set by all three spheres. In this paper, we only look at national waste policies and legislation, which are established by DFFE. There is not much specific waste legislation set by the provincial sphere, whereas the municipal sphere has several items of relevant municipality-specific waste legislation in the form of by-laws.[6] However, municipal by-laws are guided by, and must align with, national legislation.

Four key stages in the development of the waste economy were identified through the mapping of waste legislation and policy in South Africa: (1) the age of landfill, (2) the emergence of recycling, (3) the flood of regulation and (4) the drive of EPR. Before 1999, South Africa's waste economy was firmly rooted in the 'Age of the landfill', meaning disposal using a landfill remained the dominant choice for both general and hazardous waste.[21] Recycling, as an alternative to landfill, was first formally presented in the first NWMS document in 1999, and then in the White Paper on Integrated Pollution and Waste Management (IP&WM) in 2000. However, commitment towards recycling was only made by the government in the Polokwane Declaration, published in 2001, which marked the beginning of the second stage of waste management legislation in South Africa, 'the emergence of recycling'. The Declaration set targets for government, business and civil society: 50% reduction in waste generated, a 25% reduction in landfill volumes, and a zero-waste plan by 2022. Although there was no legislation enforcing these targets at the time, there has been growth in the recycling industry, primarily through the efforts of the private sector.[21]

In 2008, the promulgation of the NEMWA marked an important milestone for the waste management sector in South Africa. The Act was followed by a 'flood' of related regulations and norms and standards to control and minimise the negative environmental and health impacts of the waste sector. These include regulations on waste management activities, waste information and waste classification, as well as norms and standards regarding waste storage and assessment of waste for landfill disposal, among others. South Africa's waste recycling economy is largely driven by the informal sector of 'waste pickers' and the private sector. The new and continuously evolving legislative environment has placed, and continues to place, a significant burden on businesses who, among other things, face growing costs of compliance administration. This places substantial administrative and legislative burden on businesses operating outside the disposal stage in the waste management hierarchy, and there is no clarity on whether the materials they handle continue to be regarded as waste once they have been processed.

Prior to the EPR Regulations, voluntary EPR initiatives in South Africa were largely driven by private industry and non-profit organisations (NGOs). In 2012, a government-led mandatory model for EPR started with the promulgation of the Waste Tyre Plan. The scheme, referred to as the Recycling and Economic Development Initiative of South Africa (REDISA), was funded through a levy charged to the producer on tyres sold. REDISA managed to make some contributions to the establishment of depots and waste tyre processing facilities, and invested in research and development in the waste tyre sector.[22] However, REDISA was eventually liquidated following allegations of mismanagement and misappropriation of funding. Subsequent legal battles have highlighted various governance issues within organs of the state. As a consequence, there appears to be a continuous lack of trust from recycling industries regarding the South African government in allocating and distributing funds towards industry development and this impacts the e-waste sector.[6]

To address some of the waste management challenges, the national government published the National Pricing Strategy for Waste Management (NPSWM) in 2016.[23] The NPSWM introduced a suite of economic instruments to action the polluter pays principle, reduce waste and its resultant environmental and social impacts, and grow a secondary resource economy. EPR is considered one of the upstream economic instruments.[23] The NPSWM provides guidance on the two streams for implementing EPR schemes in South Africa: an EPR fee managed by industry or an EPR tax managed by government.[24] Regardless of the stream, the implementation of effective EPR will require cooperation between the public and private sectors.

In 2020, the DFFE published the EPR Regulations under the authority of section 18 of NWMWA. The Regulations were accompanied by product-specific notices for EEE, lighting and paper, packaging, and some single-use products. The Regulations require an EPR fee to be established and applied proportionally to all members by the producer responsibility organisations, or by an individual producer that establishes their own fee. The Minister of Forestry, Fisheries and the Environment must concur with the Minister of Finance on the motivation and justification of the fee submitted by producer responsibility organisations or producers.[25] Therefore industry will be required to play a leading role in implementing EPR alongside government as the regulating authority.

The ever-changing legislative environment through the enactment, and subsequent superseding, of various regulations, continues to cause instability in the waste sector, thus becoming a hindrance for technology development and innovative recycling initiatives.[8]

Changes towards a common vision – a circular economy of e-waste

South Africa must redefine waste as a valuable resource.[26] This will not only help implement the upper rankings of the waste management hierarchy, i.e. prevention and re-use, but also ensure the development of the recycling industry, and the growth of a secondary resource economy. The Department of Environmental Affairs indicated its aim to drive the agenda of waste diversion from landfill, including but not limited to:

- diverting more waste from landfills towards other waste management options,
- increasing institutional capacity for managing waste streams,
- supporting the implementation of EPR schemes,
- encouraging the integrations of the informal sector, and
- developing small and medium enterprises in the alternative waste management technology solutions space and driving 'radical socio-economic transformation'.[27]

Thus, the drivers for waste diversion from landfill are not only from an environmental stewardship perspective but are also to promote socio-economic opportunities such as job creation and economic opportunities. Although the view of waste from an environmental liability perspective remains unresolved, waste is increasingly seen as a potential resource and economic contributor.[6,27]

Insights from the interviews conducted in the study suggest that this can be considered a common view among private industry, NGOs, and researchers, who have seen the potential economic opportunities associated with a circular economy for e-waste.[6] However, a legislative environment that supports it is required. Notably, South Africa is taking strides to update its legislation in this regard, although questions remain as to whether these changes adequately reflect and align with concepts of e-waste as a resource.

Redefining waste in a circular economy

The definition of waste according to the *National Environmental Management: Waste Amendment Act* (NEMWAA) is:

> *any substance, material or object that is unwanted, rejected, abandoned, discarded or disposed of, or that is intended or required to be discarded or disposed of, by the holder of that substance, material or object, whether or not such substance, material or object can be re-used, recycled or recovered… .*[28]

Within NEMWAA, there are priority waste streams that can be declared so by the Minister of Environmental Affairs. This has not been expressly done to date. Thus, the priority status of e-waste has been inferred by the way the stream is regulated, and this 'inferred priority' status is confirmed in the NWMS 2020 and the Waste Research, Development, and Innovation Roadmap (the Waste RDI Roadmap is a South African government initiative aimed at supporting South Africa's transition to a circular economy) which both explicitly refer to e-waste as 'priority waste streams'.[4,29]

In 2018, waste exclusion regulations were established to guide what waste streams or portions of waste did not fall within the ambit of the Waste Act to encourage diversion from landfills. Further clarity on what constitutes waste was provided in 2020. The Supreme Court of Appeal, in the case of *Minister of Environmental Affairs and Another v ArcelorMittal South Africa Limited*, held that basic oxygen furnace (BOF) slag does not fall within the definition of waste because it is not unwanted, rejected, or abandoned and therefore no waste management licence was required.[30] The purpose was to sell the crushed and screened BOF slag which constitutes recycling under the Act. Therefore, there are legal movements to exclude economically viable by-products from the definition of waste, moving from waste to an economic resource. What constitutes waste, and consequently what requires a waste management licence to handle, is changing in the law. Therefore, there is scope to have e-waste redefined as a resource worth 'mining' for its various mineral value fractions. If e-waste is redefined and managed as a resource, the circular economy is more likely to be implemented.

Legal developments towards circularity

South Africa has aligned its policies and strategy with the circular economy concept. South Africa is a founding member of the African Circular Economy Alliance whose ambition is to spur Africa's transformation to a circular economy that delivers economic growth, jobs and positive environmental outcomes at the national, regional and continental levels.[31] The Chemical and Waste Economy Phakisa, a presidential programme aimed at addressing environmental damage and unlocking the economic potential within the hazardous waste, identified e-waste as a key waste stream to valorise. The NWMS emphasised the programme as a commitment to the implementation of the circular economy as a municipal waste management sphere initiative.[4]

The circular economy concept has also been adopted as a systemic approach to combat environmental degradation and climate change by the White Paper on Science, Technology and Innovation.[32] The concept also appears in the EPR Regulations. The purpose of EPR Regulations is to 'encourage and enable the implementation of the circular economy initiatives'.[25] The EPR Regulations have a specific product notice for EEE, connecting the law with e-waste circularity.[2] These legal developments reflect a common vision of e-waste circularity adopted by South African legislators.

The EPR Regulations define the circular economy as a 'a regenerative system in which resource inputs and waste, emissions, and energy leakage are minimised by slowing, closing, and narrowing energy and material loops which can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling and which is in contrast to a linear economy which is a 'take, make, dispose' model of production.'[25] The definition emphasises long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling, thereby aligning with the waste management hierarchy. The specific product notice for EEE requires producers to take responsibility for the post-consumer stage of the product.[33] The definition of the circular economy and the purpose of the EPR align. However, measures put in place by producers should focus on designing long-lasting EEE with maintenance and repair options available, rather than focusing on e-waste management and recycling, if the circular economy is to be implemented.

An example of downstream management of e-waste external to the EPR Regulations is the e-waste landfill ban.[34] The ban came into effect on 23 August 2021. However, a ban on EEE going to landfill does not require the reclaiming of existing e-waste present in the landfill or in the environment. It encourages an increase in discarded EEE stock to be managed through alternative waste management measures, such as refurbishment, remanufacturing, and recycling.

The EPR Regulation, the EEE product-specific notice, and the e-waste landfill ban further the ambitions of the circular economy to minimise resource inputs and waste. However, the common vision might result in a blind spot regarding environmental and social externalities. If the cost of waste management is externalised to the product cost, and therefore placed on consumers, the incentive to innovative product and process design is lost. Therefore, the vision towards a circular economy must account for consumer protection.

The legislative landscape is progressive and responsive to global trends; however, this has not effectively trickled through to practice yet. In 2017, only 6.3% of the collected hazardous waste was recycled, with the remaining 93.7% sent to landfil.[35] As previously mentioned, e-waste falls under the hazardous waste category; only 9.7% of e-waste was recycled in 2017, with the balance (90.3%) being landfilled.[35] This suggests that South Africa is still in the age of the landfill. However, there appears to be some concerted efforts towards realising a circular economy within the e-waste industry in South Africa, but its emergence has been slow. In the following section, we identify the current e-waste recycling network in the South African context and highlight the challenges faced by different actors within this network which may explain further why this progress has been slow.

Identifying the barriers to recycling e-waste in South Africa

The spheres of operation of the South African e-waste collection network have been mapped as shown in Figure 2. The large-scale recyclers are aggregators and distributors of bulk e-waste, whereas the small- and medium-scale recyclers, whose operations can be informal, semi-formal or formal, are collection and dismantling agents; they are cut off from international markets. It was noted from the interviews that small-scale recyclers provide a free collection service for small volumes of e-waste to ensure feedstock for their recycling activities. Furthermore, it is very common for recyclers to buy e-waste from waste generators directly. This can be done through purchasing of obsolete equipment or via a recycling rebate, as done, for example, by GreenOffice, a printing equipment recycler. Transport costs remain the highest expense for many small- to medium-sized recyclers due to their necessarily large collection radius (NC Electronix, Cape E-waste interviews).[6] On the other hand, larger e-waste generators, such as Telkom, would pay for the recycling service and would offer long-term contracts to e-waste recyclers through a tender system. But such contracts generally exclude small-scale actors, especially if they are operating informally or semi-formally. Semi-formal in this case refers to actors that have not met the full legal requirements but whose activities follow the formal rules. These operations were found to have registered with voluntary industry associations such as SAEWA who use a tier system to rank their members, with semi-formal operations being of a low tier and benefiting from receiving mentorship towards formalisation.

Overall, the e-waste chain converges on the large recyclers who aggregate collected material and send it to end-processing (metal extraction), mostly to copper smelters overseas where the key metal fractions (principally copper and gold) are recovered and refined for resale, and non-value fractions are incinerated or stabilised in inert residues such as smelter slag.

The formal e-waste recycling sector is currently not a significant employer and also not a significant contributor to South Africa's waste economy (estimated to be worth ZAR24.3 billion annually).[14,35] This is attributed to the low volumes of e-waste currently processed and to most of the high-value metal processing happening overseas. However, there is recognition that at an estimated 25 jobs/1 000 t of e-waste handled, the sector has significant employment potential when more e-waste is reprocessed.[14]

Figure 3 summarises the barriers to local end-processing. The lack of adequate end-processing and refining capacity in South Africa is principally attributed to insufficient e-waste volumes available to operate technologies that have proven to be successful internationally at the necessary economies of scale. This brings to attention the key challenge of supply. South Africa's e-waste collection network and infrastructure are currently built on the large population of informal waste pickers and small-scale recyclers who provide diverse collection strategies and a wide network of e-waste sources. Estimated numbers of informal waste pickers in South Africa range between 60 000 and 90 000 and even up to 215 000.[21] However, as individually processed volumes remain low and supply is unreliable, the activity is overshadowed by financial insecurity.

The EPR Regulations require measures to integrate the informal collection networks and to compensate those who register with the National Registration Database. The landfill ban can also assist the required economies of scale to achieve a more circular approach to EEE and e-waste management. However, one cause of the low supply volumes is that most e-waste generated is not thrown away but stored in national and provincial government departments, business entities and households.[14] Lydall et al.[14] attribute this to issues to do with data security, the perceived value of EEE (economic and sentimental) and a culture of refurbishing and passing down EEE to members of the family or less privileged communities. Besides e-waste being inaccessible, there is an inability to predict volumes due to incomplete waste data and non-compliance regarding waste information systems.[36]

The lack of adequate local end-processing and refining capacity may also originate from an inherent local culture of exporting unrefined value fractions for final product refining and manufacturing elsewhere.

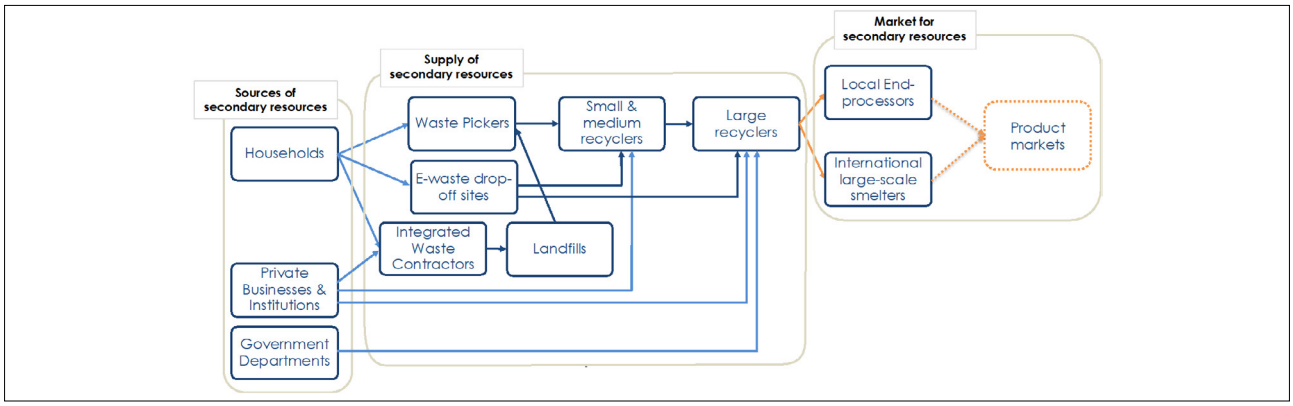

Figure 2: E-waste collection and recycling network in South Africa.[6]

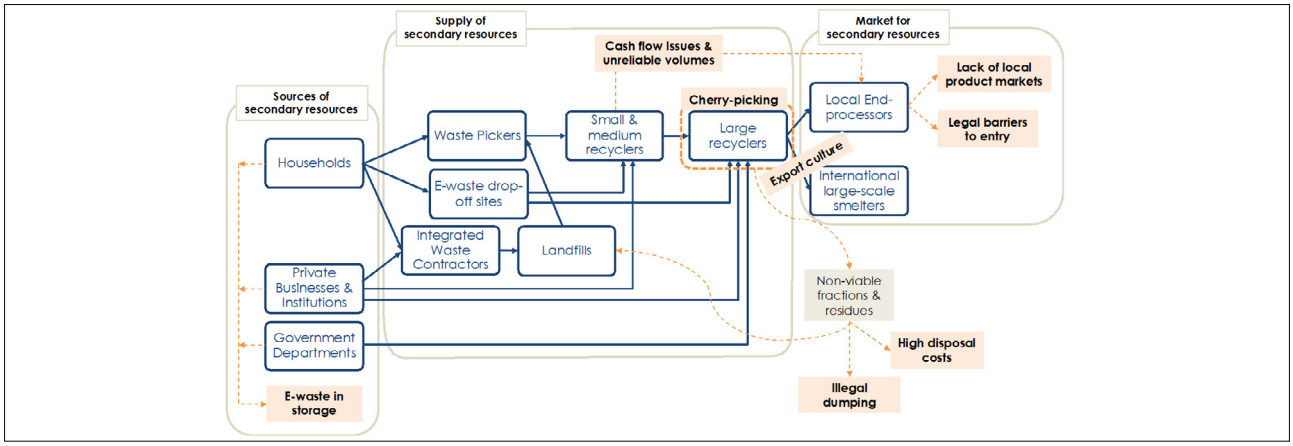

Figure 3: Barriers to local end-processing of e-waste in South Africa.[6]

When assessing metals value chains from the extraction of primary minerals locally, the export-based nature of the local metals industry becomes apparent. High prices in international markets make local end-processing and manufacturing economically unattractive.[37] But there are disadvantages to the current practice of exportation, for example in the context of printed circuit board (PCB). The PCBs are collected, classified into different grades, pre-processed via size reduction then shipped overseas to an importing company that uses their internal assay methods to determine the precious metals content and thus price for the consignment.[6] Consequently, pricing negotiations fall outside the control of South African recyclers. During the interviews, South African recyclers who exported PCBs did not disclose details of the exporting deals, such as the names of the importing companies, or concentration ranges of metal found in the different grades of PCBs. Also, pricing estimates for the different PCB grades were not shared. This was pointed out to be the basis of ensuring competition among recyclers (Anonymous 2 interview) and thus the industry as a whole.[6]

A further barrier includes the impact of China's 'National Sword' policy, which imposed a ban on the import of plastics. The ban impacted South Africa's e-waste recycling industry because most plastics separated from e-waste used to be exported to China (Anonymous 1, Karcher interviews).[6] The ban, and the industry's lack of alternatives, resulted in recyclers either stockpiling plastics or disposing of them in municipal landfills at unprecedented scale. The recycling of plastics from e-waste thus presents an additional value extraction opportunity for South Africa. However, one of the main challenges is the difficulty in the separation of plastic materials, as they are mostly unlabelled and generally composed of mixed grades. Consequently, plastic recyclers in South Africa will not accept these fractions (Anonymous 1 interview).[6] Furthermore, much of the plastics in e-waste contain brominated flame retardants that result in toxic emissions when treated using thermal recycling technologies, which require further treatment.[38] Technological research thus needs to focus on plastic separation techniques, solutions for mixed-grade plastics, as well as treatment of plastics containing brominated flame retardants. Ultimately, of course, the need to recycle and manage the waste stream should be reduced in the first place. To achieve this, waste prevention at the product design stage must be the overarching aim.

In South Africa, most activities in the e-waste value chain are concentrated at the lower end, with most recyclers involved in the collection, dismantling and pre-processing in preparation for export of the value fractions. The volumes generated are insufficient to warrant investment into local end-processing given business models and technologies suitable for the local context. To date, there is only one known operational PCB end-processing plant at SA Precious Metals Ltd which has developed a hydrometallurgical technology for metal extraction from PCBs, with a daily capacity of 2 t. It is unclear whether this technology is financially competitive with international smelters.

Furthermore, to operate economically, a minimum batch volume of 10 t of high-grade PCBs is required by SA Precious Metals. However, this invariably excludes smaller individual aggregators of recycled materials. An example is an unsuccessful collaboration between SA Precious Metals and Square Mobile, a small-scale entrepreneur based in the Western Cape (Square Mobile interview).[6] The challenges that led to the failure of this collaborative effort include:

- Accumulation and storage of the minimum of 10 t of PCBs would usually stretch over several weeks with the associated costs (space, legal compliance) borne by Square Mobile.
- Square Mobile would also need to pay for the shipping of the PCBs from the Western Cape to Gauteng where SA Precious Metals Ltd is located.
- Waiting periods for the profits to be split; profits would be paid only 3 months later.

All these factors resulted in cash-flow problems for a small operator like Square Mobile, forcing them to abandon the venture.

A further limitation faced by the e-waste recyclers is that those who successfully run end-processing operations have the option of choosing only high-grade or high-value materials. This propagates a culture of cherry-picking, leaving the non-viable fractions or residues for disposal elsewhere. This reflects in the local pricing of PCBs by large recyclers, pushing the tendency to cherry-pick to the smaller recyclers and even the waste pickers. A consequence is the informal dismantling/burning of waste EEE, often in public spaces, to liberate these high-value fractions, and illegal dumping of the residue.

Over and above the waste-related licencing costs arising for an end-processor, there are also significant legal barriers and associated licence costs for the trade in precious metals. Also, there is a lack of local markets for products from end-processing, which disincentivises investment in that part of the value chain.[39] An example would be the copper recovered from the copper plating solutions at a local PCB manufacturer which is not of sufficient purity and volume to enable re-sale to any industry using copper as input material (piping, wiring, sheeting) at full market value, and hence it is sold off as scrap at low prices.

To address these barriers, the South African government has taken strides towards investing in research and development through various instruments. The Waste RDI Roadmap and the Technology Innovation Agency funded the University of Johannesburg's Process, Energy and Environmental Technology Station (UJ-PEETS). Other examples include the various National Research Foundation funded waste research chairs, such as the South African Research Chair Initiative (SARChI) Chairs in Waste and Society and Waste and Climate Change. The different research instruments address various areas such as understanding the e-waste value chain and its stakeholders, research into technology development for recovering value materials, life-cycle analysis of technology and social aspects of the e-waste sector, and potential for industrial symbiosis in e-waste processing, to name but a few. Although academic researchers have actively been testing out different technologies and process models, these have been largely confined to bench-scale and concept studies. Assessment of the viability of the proposed approaches requires research to move from bench to pilot and to demonstration scale. Similarly, several baseline studies have been conducted on the social aspects to e-waste recycling but there has been no follow-through to establish if proposed solutions can indeed drive the desired change.

Conclusions

The e-waste industry in South Africa, although not a significant contributor to the waste economy, is recognised to have the potential for growth. However, the extent to which the sector will mature is dependent on the organisation of its collection network as well as the development of local refining and manufacturing capacity. The availability and quality of input materials, and the development of local refining and manufacturing capacity are co-dependent. On the one hand, implementation of context-appropriate technologies at appropriate economies of scale is only possible with sufficient e-waste volumes. On the other hand, the expansion of the industry to downstream processing will encourage an improved and robust collection infrastructure to obtain necessary volumes. Therefore, these two factors would need to be dealt with simultaneously to ensure the sustainability of the industry.

The South African waste sector in general is operating in a transient legislative environment. Although new regulatory instruments are being devised to promote the responsible development of a circular e-waste economy, there are concerns about hindering this desired growth and squeezing out the informal and small-scale operations. These operations currently provide much-needed support, especially on the lower end of the value chain. Interventions of the South African government to drive research, development and innovation in the sector are visible; however, some of the outputs are yet to trickle down to the different tiers of e-waste recycling activities.

To overcome the barriers to a circular economy for e-waste in South Africa, further research to explore policy and legislation mechanisms as well as technology transfer and infrastructure development is recommended.

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Competing interests

We have no competing interests to declare.

Authors' contributions

Z.S.: Conceptualisation; methodology; data collection; sample analysis; data analysis; validation; data curation. T.M.: Writing – the initial draft; writing – revisions. A.L.: Writing, referencing, and revisions, restructuring and inclusion of 'Redefining waste in a circular economy', 'Legal developments towards circularity', and 'E-waste legislation and governance in South Africa'. J.P.: Revisions; student supervision; project leadership; project management; and funding acquisition.

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Appendix: Sample interview questions

Materials received and produced

- What types of e-waste do you deal with?
- Do you deal with any hazardous substances? If so, what is it and what type of e-waste devices does it come from?
- What waste streams do you have? How do you manage your waste streams?
- What product streams do you produce?
- Where do you sell your products?
- What/who are your sources of e-waste (e.g. public or private sector, households)?
- What is your average annual volume of e-waste handled?
- What type of device do you receive the largest volumes of?

Technology and operations

- What e-waste management activities do you do?
- Describe your e-waste collection infrastructure and logistics.
- Has/have your business/operations grown over the years you have been operating?
- Elaborate on the possible reasons for this.
- What sources of income do you have?
- How large is your collection radius?
- What technology do you use?
- How many employees do you have and how are they organised?
- Do you have plans for growing your business? If so, what are they? If not, why?
- How do you communicate with your clients (buyers/ sellers)?
- How do you attract new clients (buyers/ sellers)?
- How is your financial/ business model structured?
- If you could have anything to improve your business operations, what would it be and why?
- Describe the initial steps you took to start up your business.
- What skills did you require to start and maintain this business?
- What skills did you develop through running your business?
- What health and safety procedures do you follow?
- Do you have any traceability procedures to keep track of devices from collection to the time it leaves you?

Trade and legislation

- Do you have any issues with the current legislative framework? If so, what are they?
- If you could change any part of the policy and legislative framework regarding e-waste, what would it be and why?
- What trade regulations do you currently deal with?
- What was the first legal step you followed to set up your business? Describe what the experience was like.

The interview structure varied from interview to interview depending on the flow of discussion. The interviewer allowed for the personal experiences of the interviewee to come up and for them to lead the discussion. Therefore, the above questions did not always follow this order and not all of the questions were always asked or answered. Where deemed pertinent, follow-up interviews were scheduled in order to obtain missing information. Face-to-face follow-up interviews were preferred; however, telephonic and email interviews were mostly done depending on the availability and preference of the interviewee/research participant.