Towards a Circular Economy: E-waste Management in Africa

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Abstract

Africa generates approximately 2.5 million tonnes of e-waste annually—a growing challenge with serious environmental, health, and economic implications if not effectively managed. This study offers a first step towards sustainable e-waste management in Africa by providing an understanding of the e-waste stream. It explores interactions with governance structures and assesses alignment with global, regional, and national policies. Using desk research, interviews, country case studies, focused stakeholder group discussions, and site visits, the study identifies best practices, evaluates regulatory frameworks, and highlights systemic challenges. The observation and findings suggest that Africa plays a dual role as both a generator and recipient of e-waste, with much of it arriving as near-end-of-life electronics. The informal sector dominates e-waste recycling, often using unsafe methods that pose serious health and environmental risks. Weak enforcement, inadequate infrastructure, and limited formal recycling further hinder progress. However, opportunities exist in resource recovery, innovation, and digital tracking solutions. The study calls for integrating informal and formal e-waste actors, strengthening regulations, enforcing extended producer responsibility schemes, and increasing investment in recycling infrastructure.

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Abbreviations

AI	Artificial intelligence
DFFE	Department of Forestry, Fisheries, and the Environment
EEE	Electrical and electronic equipment
e-Gov	Gauteng Department of e-Government
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
EPRON	The E-waste Producer Responsibility Organization Nigeria
ERA	E-Waste Recycling Authority
EVs	Electric vehicles
eWASA	EPR Waste Association of South Africa
E-waste	Electrical and electronic equipment waste
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
ILO	International Labour Organization
MDBs	Multilateral development banks
MESTI	Ministry of Environment, Science, Technology, and Innovation
MSMEs	Micro, small, and medium-sized enterprises
NEMA	National Environmental Management Act
NEMWA	National Environmental Management: Waste Act
NGOs	Non-governmental organizations
NWMS	National Waste Management Strategy
OECD	Organization for Economic Cooperation and Development
PCBs	Printed circuit boards
PRO	Producer Responsibility Organization
SADC	Southern African Development Community
SDGs	Sustainable Development Goals
UEEE	Used Electrical and Electronic Equipment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WEEE	Waste Electrical and Electronic Equipment

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Executive Summary

Introduction

Innovation has increased the production of electrical gadgets and appliances to help humans cope with the challenges of this global age. The reliance on electrical and electronic equipment (EEE) and its increased production have also caused a significant surge in electronic waste (e-waste). E-waste is now one of the fastest-growing waste streams globally, and Africa is experiencing a sharp rise. Globally, e-waste is projected to reach 82 million tonnes by 2030. According to Baldé et al. (2017) and Forti et al. (2020), Africa generates an average annual 2.5 kg per capita of e-waste, well below the European average of 16.2 kg and the Americas' 13.3 kg. In 2019, about 2.9 tonnes of e-waste were generated in Africa, with Egypt, South Africa, and Nigeria leading the surge. Notwithstanding local e-waste generation, the increase in transboundary movement of e-waste, especially from Western countries to Africa, could pose significant risks for the continent if not adequately controlled. While recoverable materials from e-waste also hold economic value, only a small fraction is appropriately processed. Africa has not been able to take advantage of the growth opportunities of this waste stream to develop sustainably.

Leveraging the growing e-waste stream as a development tool will not come easy. It will require a comprehensive understanding of the sector and the development of comprehensive regulatory frameworks and targeted strategies. Unfortunately, little has been documented about the e-waste management sector and its value chain actors, as well as the ability of the sector to promote waste recovery within a broader circular economy context in African countries. The diverse value chain actors need to be identified, and their roles, responsibilities, and significance in various stages of e-waste disposal need to be documented for targeted policy intervention.

This study fills this void by conducting a baseline study to understand the sector and pinpoint developmental gaps and needs. It will also make recommendations tailored to the principal stakeholders in the region's electronics value chain. The study will thoroughly analyze exemplary cases, identifying best practices and offering actionable recommendations for policymakers, industry stakeholders, and African communities. While African countries are incorporating elements of the circular economy into their national legislation (AMCEN, 2019), they are also identifying key priority actions to develop a comprehensive framework for sustainable e-waste management. This framework aims to be scalable and implementable across the continent, ultimately improving environmental outcomes and public health.

Justification for studying e-waste in Africa

- **Environmental and health risks:** Toxic chemicals from informal recycling pollute air, water, and soil.
- **Economic potential:** Efficient recycling unlocks valuable resources and holds the key to creating decent and sustained jobs.
- **Regulatory gaps:** Weak policies allow illegal dumping and unregulated cross-border trade.
- **Alignment with SDGs:** Circular economy strategies support SDG 12 (responsible consumption) and SDG 13 (climate action).

Study objectives and methodology

The study identifies best practices, maps stakeholders, assesses regulatory frameworks, and documents e-waste management approaches. Using Ghana and South Africa as case studies, it employs mixed methods, including desk research, case studies, and stakeholder interviews, to develop actionable recommendations.

Key findings and observations

Environmental, social, and economic impact

- E-waste has profound environmental, health, social, and economic effects, with significant challenges and opportunities depending on how it is managed.
- The beneficial impact is higher for the formal e-waste sector than for the informal, though it varies depending on the stage of the e-waste value chain.
- Most e-waste recycling in Africa is handled by the informal sector, where workers dismantle electronics without protective equipment, exposing them to toxic chemicals.
- The informal recycling sector's dominance should be strategically leveraged to promote the capital-intensive formal recycling sector to maximize the potential of e-waste recycling in Africa.
- Overall, transitioning to the formal sector would be desirable. Thus, African countries need to develop hybrid e-waste management models that combine the strengths of informal e-waste collection networks with the more advanced processing capabilities of formal recycling systems.

Regulatory and policy frameworks

- Regulatory frameworks and industry standards must be developed to ensure the responsible and ethical use of AI in waste management.
- Existing EPR frameworks fail to address the multi-use cycles and cross-border trade of EEE. African countries must establish an ultimate producer responsibility scheme to address this gap, compelling international producers to manage e-waste under the polluter-pays principle.
- Government structures are often organized along sectoral lines, limiting the cross-sectoral integration necessary for advancing circular economy initiatives.
- Effective implementation of EPR schemes throughout Africa will require collaboration between governments and companies, with the government playing a key role in driving this initiative.
- Policymakers must incentivize sustainable production by offering tax breaks, funding research, and enforcing product standards.
- It is important to balance regulation with incentives. While strict enforcement ensures compliance, subsidies for recyclers and tax incentives for businesses encourage investment. For Africa, hybrid financing mechanisms—such as eco-levies on new EEE, public-private partnerships, and recycling credits—can support the sector without displacing informal workers.
- Only 13 African countries have dedicated e-waste policies, and many lack enforcement capacity.
- Even where policies exist, implementation is weak, and many countries lack monitoring systems for tracking e-waste flows.
- Illegal e-waste imports continue despite the Basel Convention and the Bamako Convention, which regulate the hazardous waste trade.

Cross-border and international considerations

- Cross-border collaboration needs to grow through regional frameworks, knowledge-sharing platforms, and joint infrastructure projects to build the sector's efficiency and resilience.
- Most imported UEEE in Africa arrives near or at the very end of its end-of-life stage, highlighting the need for sustainable management to avert adverse environmental and social impacts.
- The international and continental conventions are insufficient and lack robust mechanisms to curb illegal activities.

Financing and investment gaps

- The high costs associated with formal e-waste recycling systems further exacerbate Africa's development challenges, leaving industries and cities driving circular economy initiatives in dire need of financing to support the transition.
- Non-existent proper local municipal financing frameworks in Africa mean that cities will seek this investment from central governments, which are already hard-pressed by their thin domestic resource mobilization revenue.
- Multilateral development banks (MDBs) face significant hurdles in scaling up funding for circular economic activities. Traditional project-based finance provided by MDBs is not well suited to the systemic and multi-stakeholder approaches often inherent to circular economy solutions.

Infrastructure needs for formal recycling

- Few countries have functional e-waste recycling plants due to high setup costs and a lack of investment incentives.
- South Africa, Rwanda, and Egypt have started developing formal e-waste collection systems, but progress is slow.
- Most e-waste is dumped in open landfills, leading to toxic contamination of soil and water.

Untapped economic potential of e-waste recovery

- E-waste contains valuable metals such as gold, silver, copper, and palladium, estimated to be worth $55 billion globally.
- The formal recycling sector remains underdeveloped, missing opportunities to create jobs and generate revenue.
- Circular economy approaches, such as refurbishment and remanufacturing, are gaining traction but require stronger policy support.
- MSMEs could help bridge the gap between informal and formal recycling systems, but there are no clear incentives for MSMEs to engage in e-waste collection, repair, or recycling.

Emerging digital solutions for e-waste tracking

- Blockchain and AI-powered tracking systems could improve e-waste monitoring and prevent illegal dumping.
- Some African countries, including Nigeria and Rwanda, are exploring digital compliance tools to track e-waste from import to disposal.
- Mobile e-waste collection platforms could connect consumers with recyclers and encourage responsible disposal.

Resource accessbility and efficiency challenges

- A paradox exists where cities accumulate excess e-waste while formal recyclers struggle to secure sufficient raw materials.
- Weak collection systems, inadequate aggregation centers, and lack of regulatory support create inefficiencies in the value chain.
- Models exist on a lower scale for formalizing collection and aggregation; government policy must support such models.

Best practices beyond recycling

- Countries could promote circular economic activities through repair, refurbishment, and innovative product design strategies. Addressing the energy efficiency concerns associated with refurbished products will be essential for some of these practices to succeed.
- Eco-design principles in product manufacturing can potentially reduce e-waste generation.
- Strategic policy interventions, capacity building for informal recyclers, and stakeholder engagement are critical steps towards building circularity around e-waste and creating sustainable solutions for the continent.

Policy recommendations

Despite the challenges, e-waste presents opportunities for resource recovery and economic development. Circular economy initiatives such as advanced recycling technologies, refurbishment, and eco-design strategies can drive sustainability. However, fragmented policies, weak enforcement, and inadequate infrastructure hinder widespread adoption.

1. Integrate formal and informal sectors

- Governments should establish frameworks for collaboration between informal collectors and formal recyclers.
- Extended producer responsibility (EPR) schemes should include financial incentives for informal actors.
- Engagement platforms should be created to ensure fair pricing and transparent interactions.

2. Strengthen legislation and regulatory enforcement

- Governments must establish clear e-waste regulations aligned with global conventions (e.g., Basel Convention and Bamako Convention).
- Stronger monitoring systems should be implemented to track e-waste flows and ensure compliance.
- Dedicated regulatory agencies should be empowered to oversee e-waste policies.

3. Enhance local government involvement

- Unauthorized e-waste dumps must be properly managed or cleared.
- City authorities should enforce regulations to prevent illegal dumping.
- Investments in accessible collection infrastructure and end-use markets should be prioritized.

Conclusion

Despite the burgeoning challenges, e-waste must not be seen solely as a regulatory burden but as a strategic tool that can be leveraged for sustainable development in Africa. E-waste can be a critical sustainable growth pole when the right policies are in place. E-waste can contribute to decent job creation, technological innovation, and circular economy growth. African governments must work closely with private sector actors, international partners, and local communities to establish sustainable collection and processing networks. Cross-border collaboration needs to grow through regional frameworks, knowledge-sharing platforms, and joint infrastructure projects to build the sector's efficiency and resilience.

The next phase of e-waste management in Africa depends on proactive policy interventions integrating environmental protection, economic development, and social inclusion. If African countries can do this, they can turn e-waste from an unwanted environmental problem into an opportunity for sustainable industrialization and environmental stewardship.

1. Background and Context

1.1 Introduction

Life in the 21st century has gradually become dependent on electronic and electrical equipment (EEE), with tools and gadgets an essential part of daily life. Achieving many Sustainable Development Goals (SDGs) depends on a digitally connected world and there has been a steady rise in the demand for EEE globally over the years (Omondi et al., 2022). This growing demand reflects broader trends in technological advancement, price changes, population growth, and digital transformation of work, communication, and entertainment, which thrives on digital and electronic devices (Needhidasan et al., 2014). Electronic and electrical equipment has become deeply integrated into daily lives, bringing positive and negative consequences. Although the proliferation of electronic equipment improves innovation and productivity, its significant consequence is the generation and management of electronic waste (e-waste) (Mohammed, 2022).

E-waste is one of the biggest challenges to global development and achieving the SDGs. Driven by technological innovation, global reliance on electronics, and high product obsolescence, e-waste produces vast volumes of waste yearly as electronic equipment reaches its end-of-life cycle. This waste stream grows annually by 3-5 percent (European Parliament Briefing, 2015) or by 2.6 million tonnes annually, and it is on track to reach 82 million tonnes by 2030.[1] Huang et al. (2009, 2014) have indicated that one of the reasons for the rapid growth of e-waste is the decreasing lifespan and accelerated replacement cycles of electronic products. Indeed, studies by Yazici and Deveci (2013) and Shamim et al. (2015) found that the replacement interval for personal computers and their central processing units significantly decreased from about 4-6 years in 1997 to just 2-3 years by 2015. The result is that e-waste in this stream accumulates faster as consumers upgrade to newer models. The World Health Organization reports that in 2022 alone, about 62 million tonnes of e-waste were generated globally, with only 22.3 percent formally documented as collected and recycled.[2] This leaves about $62 billion worth of recoverable waste unaccounted for, heightening pollution risks to communities worldwide. Without proper management, e-waste could pose significant environmental and health risks (Lu et al., 2015; Rucevska et al., 2015).

1.2 Definition of e-waste

The surge in e-waste has brought complex definitional and practical challenges requiring specialized and creative economic approaches to handling and disposal policies to mitigate the harmful effects. Definitional intricacy arises because electrical devices continually evolve and diversify, complicating efforts to consistently classify and manage this waste stream. The 2024 E-waste Monitor defines EEE as “all products with circuitry or electrical components and a power or battery supply.” It is important to note that EEE becomes E-waste generally when it is unusable to the owner. The United Nations Environment Programme (UNEP) provides the most widely accepted definition. According to UNEP, Waste Electrical and Electronic Equipment (WEEE), commonly known as electronic waste or e-waste, can be defined as any end-of-life or end-of-use piece of “equipment which is dependent on electrical currents or

[1] https://unitar.org/about/news-stories/press/global-e-waste-monitor-2024-electronic-waste-rising-five-times-faster-documented-e-waste-recycling

[2] https://www.who.int/news-room/fact-sheets/detail/electronic-waste-(e-waste)

electromagnetic fields in order to work properly” (UNEP, 2007a; UNEP, 2007b). E-waste presents a pressing issue within the solid waste sector, with interconnected impacts across developed, transitional, and developing countries. According to Li et al. (2007), e-waste covers a broad spectrum of electronic objects, including household appliances, medical devices, control and monitoring instruments, lighting devices, automated dispensing units, consumer electronics such as recreational devices, sports equipment, mobile phones, and computers. According to Chen et al. (2015), and Lambert et al. (2015), it includes EEE components from electrical cables taken out of end-of-life vehicles, plastic housing, cathode-ray tubes, activated glass, lead-based capacitors, batteries, and printed circuit boards (PCBs).

The rising tide of e-waste brings with it both challenges and opportunities. Thus, while it is acknowledged that e-waste streams have clearly adverse socio-economic and environmental repercussions due to their hazardous components, they also offer substantial opportunities for resource recovery and sustainable economic growth. Thus, even though the accumulation of e-waste presents challenges globally, a circular economy approach opens pathways for resource reuse and improved economic outcomes, potentially reducing production costs and prices through recycling and repurposing e-waste. This model alleviates environmental burdens and contributes to a more sustainable economic framework by emphasizing the recapture of valuable materials. Conversations on e-waste must capture these realities.

1.3 Why study e-waste in Africa: justification and motivation

E-waste is one of the fastest-growing waste streams globally, driven by rising electronic and electrical equipment consumption and high replacement rates. The United Nations estimates that global e-waste generation reached 53.6 million tonnes in 2019, with Africa accounting for a small but rapidly increasing share. Unlike other regions, Africa faces a dual challenge: it generates increasing volumes of domestic e-waste while also serving as a major recipient of discarded electronics from developed countries. The continent's e-waste is growing at an estimated annual rate of 3-5 percent, yet infrastructure for collection, recycling, and proper disposal remains severely underdeveloped.

This surge in e-waste presents critical health and environmental risks. Informal recycling practices, including open burning and acid leaching, expose workers—often women and children—to hazardous substances like lead, mercury, and cadmium, increasing risks of respiratory diseases, neurological disorders, and cancer. These toxic pollutants also contaminate soil and water, threatening ecosystems and food chains. Additionally, while meeting consumer demand, the widespread import of second-hand electronics exacerbates Africa’s e-waste burden by introducing large quantities of soon-to-be-obsolete devices with limited recycling pathways.

Despite these challenges, Africa has a significant opportunity to harness the economic potential of e-waste. Proper recycling can recover valuable materials such as gold, silver, and palladium, creating revenue streams and employment opportunities for marginalized communities. Formalizing the sector could drive sustainable business models, attract investment, and integrate informal workers into safer, regulated recycling networks. However, weak policy and regulatory frameworks continue to hinder progress. While international agreements like the Basel Convention aim to prevent hazardous waste dumping, enforcement remains weak, and the transboundary movement of e-waste persists. Strengthening local policies tailored to Africa’s unique context—while balancing economic, environmental, and social priorities—is essential. The transition toward a circular economy offers a transformative solution, aligning with global sustainability efforts, particularly SDG 12 (responsible consumption and production) and SDG 13 (climate action).

E-waste in Africa—the research problem

Addressing the challenges and opportunities of Africa's EEE importation and informal recycling practices requires policymakers to develop effective regulatory frameworks and intervention strategies. However, this requires a comprehensive analysis of the e-waste management sector, including its value chain actors, in order to identify sustainable waste recovery solutions within a broader circular economy context—an area that remains largely unexamined in African countries. The diverse value chain actors need to be identified, and their roles, responsibilities, and significance in various stages of e-waste disposal need to be documented for targeted policy intervention.

Moreover, despite the challenges with e-waste, some countries[3] have made significant strides in mitigating the harmful effects of electronic waste to certain extent through effective policies, legislation, and practices. These pioneering efforts have led to notable reductions of environmental pollution and increased safeguarding of public health. However, a research gap still exists in documenting these success stories, including identifying the key factors in their success. Additionally, there is a need to explore how these practical strategies can be adapted and replicated across the African continent to establish a cohesive and sustainable e-waste management approach.

This study aims to fill this void through baseline assessment to understand the sector in Africa, with a focus on Ghana and South Africa as comparative case studies. The study analyzes the current state of the EEE sector in Africa, pinpointing developmental gaps and needs. It also seeks timely recommendations tailored to the principal stakeholders in the African EEE value chain. The study will thoroughly analyze exemplary cases, identifying best practices and offering actionable recommendations for policymakers, industry stakeholders, and African communities. While African countries are incorporating elements of the circular economy into their national legislation (AMCEN, 2019), they are also identifying key priority actions to develop a comprehensive framework for sustainable e-waste management.

1.4 Objectives of the study

Africa is committed to becoming a global leader in the "just transition to a circular economy", a crucial step towards sustainable development. The transition to a circular economy promises to stimulate economic growth, create new jobs in various economic sectors, and support innovation and digitalization while at the same time improving the state of the environment. The study will analyze the e-waste management and recycling chain activities, exploring their interactions with institutional and governance structures and assessing their alignment with the existing global, regional, and national policy and regulatory frameworks.

[3] According to the Global E-waste Monitor 2020, 13 countries in Africa have implemented policies, legislation, or regulations addressing e-waste.

The study aims to:

- Identify best practices in e-waste management through a comprehensive review of policies, regulations, and institutional setups related to e-waste management in Africa.
- Provide an overview of the stakeholder ecosystem and processes involved in e-waste management and the global recycling value chain.
- Identify relevant development, institutional, policy, and regulatory frameworks linked to the e-waste value chain.
- Comprehensively document the current systems and practices associated with e-waste generation, collection, disposal, and recycling in different countries across the African continent.
- Pinpoint policy gaps that hinder recycling and the adoption of a circular economy in the e-waste space.

1.5 Approach and scope

This study adopts a mixed-methods approach comprising desk reviews, interviews, case studies, and focus group discussions to investigate and understand Africa's e-waste stream, value chain and potential for leveraging it for a circular economy. The initial phase involves a systematic desk review to analyze (1) documented trends in second-hand electronic and electrical equipment importation and e-waste generation in Africa, and (2) initiatives leveraging e-waste to foster a circular economy. This review identifies context-specific challenges, including gaps in implementation and regulation, providing a foundation for case studies and stakeholder engagement. Primary data collection included interviews and focus group discussions with key stakeholders such as government institutions, private sector actors, and industry experts from both the demand and supply sides. Country-specific case studies enriched the qualitative analysis, while reviewing diverse documentary sources offered in-depth insights into the e-waste ecosystem. Complementary desk research, spanning academic and news publications, strengthened the evidence base.

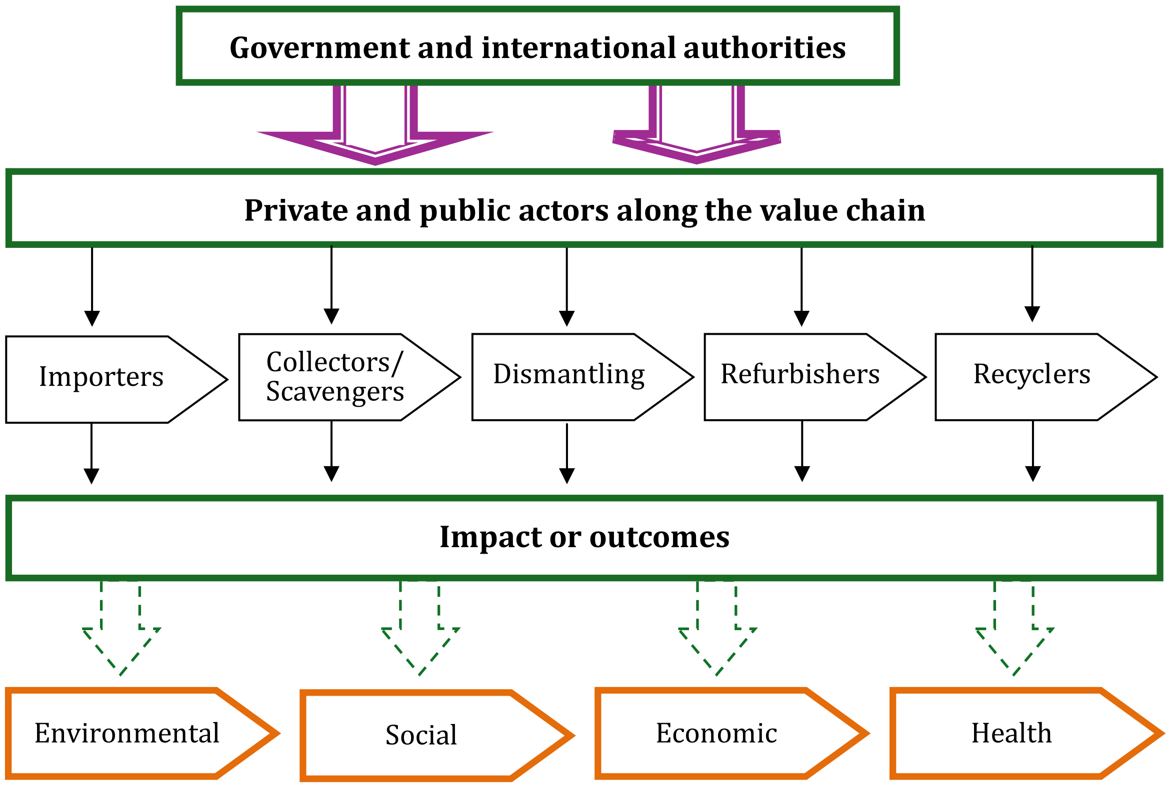
Ghana and South Africa were selected as case studies for their contrasting e-waste management systems, providing a comparative view of Africa's e-waste landscape. Despite clearing the Agbogbloshie dumpsite, Ghana continues to struggle with informal e-waste handling, where imported second-hand electronics quickly become waste, and recyclers rely on the usual hazardous methods like open burning. While Ghana has an extended producer responsibility (EPR) law, weak enforcement allows informal recycling to persist. In contrast, South Africa has a structured system supported by the National Environmental Management: Waste Act 59 (NEMWA) of 2008, formal recycling facilities, and financial incentives for processors. This contrast offers insights into informal versus formal recycling models, highlighting policy gaps, economic opportunities, and pathways toward a circular e-waste economy.

Beyond these primary case studies, the analysis includes insights from Nigeria, Kenya, and Rwanda through a desk review. Nigeria, a major importer of second-hand electronics, faces challenges similar to Ghana's but it runs Africa's first industry-led initiative, the E-waste Producer Responsibility Organisation Nigeria (EPRON). Kenya has advanced regulatory frameworks, while Rwanda has a government-led e-waste strategy with a formal dismantling facility. Lessons from these countries provide a broader perspective on policy approaches and best practices for sustainable e-waste management across Africa. Questionnaires were distributed to government institutions, NGOs, educational institutions, and businesses in the value chain to solicit their inputs, views, and comments (Appendix 2).

1.6 Analytical framework

The study's analytical framework (Figure 1) builds on the work of Maes and Preston-Whyte (2022), focusing on the flow of policies and regulations and their resulting impacts on stakeholders and society. It integrates these identified impacts while tracing their origins to government and international policies. The framework examines how these policies shape the actions and decisions of actors and stakeholders within Africa's e-waste sector.

Figure 1. Analytical framework



Source: Authors' construct, adapted from Maes and Preston-Whyte (2022).

The framework is qualitative in nature and primarily examines relationships among key actors, enabling in-depth exploration of phenomena through descriptive questions like "What is happening?" and explanatory questions such as "How or why does it happen?" This approach facilitated the analysis of empirical evidence using theoretical frameworks, secondary data, and observations. The research process included a thorough review of policy documents, legislation, reports, and literature on e-waste management, with a strong emphasis on recent publications for accuracy and relevance. The selected countries, identified as major destinations and pioneers in African formal and informal e-waste management, serve as case studies to foster policy learning and support the development of informed regional initiatives.

2. E-Waste Impacts in Africa

This section of the study examines the multifaceted impact of e-waste, drawing insights from Africa and other continents. It begins by exploring environmental impact, followed by health and social implications, and concludes with an analysis of economic effects.

2.1 Environmental impact

The environmental impact of e-waste is profound, extending far beyond mere societal inconvenience and the deterioration of community aesthetics. Electronic waste significantly threatens critical environmental elements, including air, water, and soil. Its toxic and non-biodegradable nature leads to the leaching of heavy metals into the soil and groundwater, contaminating drinking water, depleting soil nutrients, degrading air quality, and causing harm to living organisms.[4] End-of-life electronic devices such as smartphones, laptops, and televisions are particularly hazardous, containing a mix of toxic substances that can severely harm ecosystems and living organisms.

Efforts to treat or manage e-waste do not always mitigate its environmental impact, as improper methods can exacerbate harm. Informal e-waste recovery techniques, such as open-air burning and acid baths used to extract valuable materials, often release toxic chemicals and vapor into the environment, contributing to ecological degradation. Even in formal e-waste management settings, the environmental impact can be undesirable if not strictly managed. For instance, during recycling and recovery, three main categories of toxic substances are typically released: *original equipment constituents* like lead and mercury; *substances introduced during recovery processes* such as cyanide; and *byproducts* like dioxins. These substances can be found in various emissions from e-waste processing, including leachates that contaminate soil and water, particulate matter from dismantling, ashes from burning, toxic fumes from mercury amalgamation, and wastewater and cyanide leachates.

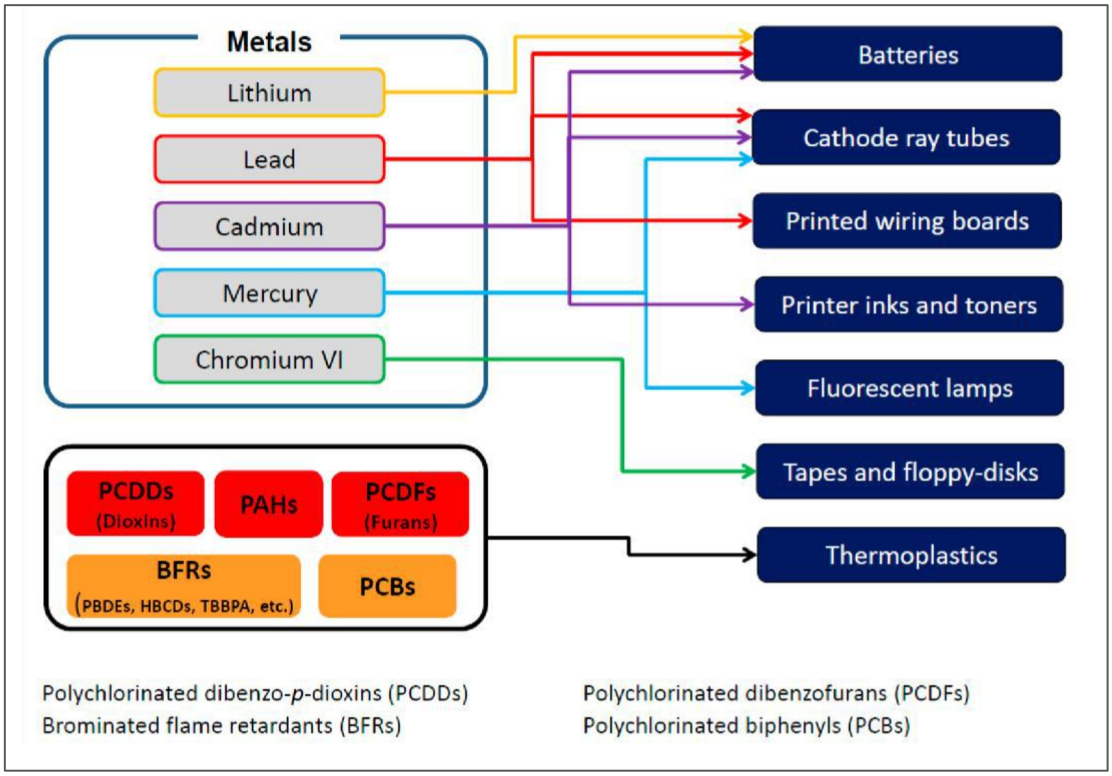
Both informal and formal processing methods pose significant environmental and health risks (Sepúlveda et al., 2010). Observably, even in state-of-the-art facilities in developed countries, elevated levels of heavy metals have been detected in the air and the environment, exposing living organisms to toxic chemicals through various pathways, including inhalation, ingestion of dust, dermal contact, and oral intake (Mundada et al., 2004).

The implications for climate change are also profound. Production of electronic devices is highly energy-intensive (often provided by fossil fuels), contributing significantly to carbon dioxide (CO_2) emissions; e-waste incineration releases CO_2, methane (CH_4), and nitrous oxide (N_2O), all of which are potent greenhouse gases that contribute to global warming. Burning plastics and synthetic materials in e-waste emits dioxins, furans, and other pollutants, contributing to air pollution and climate change. Refrigerators, air conditioners, and other cooling appliances discarded as e-waste release hydrofluorocarbon gases, which are among the most potent climate-warming pollutants, with much higher global warming potential than CO_2.

[4] https://www.genevaenvironmentnetwork.org/resources/updates/the-growing-environmental-risks-of-e-waste/#scroll-nav__2

Beyond releasing greenhouse gases, e-waste has an extended impact on the depletion of natural resources. Many electronic devices contain valuable and finite resources, such as gold, silver, and rare earth metals, often lost when improperly discarded. Unregulated e-waste disposal makes these precious materials inaccessible, necessitating further mining to replace them. This not only depletes natural resources but also drives unsustainable mining practices. Figure 2 shows some toxic elements that are released from e-waste.

Figure 2. Common toxics released from e-waste activities



Source: Lebbie, et al (2021).

2.2 Human health impact

The impact of e-waste on human health is an extension of the environmental consequences. It is multifaceted, stemming from direct exposure to toxic substances affecting the general public, formal workers and informal waste reclaimers. Improper disposal of e-waste substantially increases the risk of infectious diseases (Murad and Siwar, 2007). Open dumping sites release harmful substances into the environment and contaminate the food chain. Exposure to these toxic contaminants occurs through direct contact with the skin, inhalation of polluted air, or ingestion of contaminated food and water (Köhler and Erdmann, 2004). One of the most alarming health effects of e-waste is its contribution to dioxin poisoning. Robinson (2009) reports that human exposure levels to dioxins from e-waste can reach 15 to 56 times the maximum intake recommended by WHO. Evidence of elevated dioxin levels has been detected in human milk, placentas, and hair, posing severe and widespread health risks, including long-term developmental and reproductive consequences for humans.

The root cause of all adverse health outcomes from e-waste stems from the release of hazardous chemicals. According to Balali-Mood et al. (2021), lead, for example, is a potent neurotoxin that impairs child development, while mercury damages the nervous system and contaminates water, threatening aquatic life and, in turn, human health. Cadmium, a carcinogenic heavy metal used in batteries, pollutes soil and water, endangering ecosystems and human well-being. Brominated flame retardants, meanwhile, persist in the environment, accumulate in animal tissue, and disrupt endocrine systems, leading to severe reproductive and developmental issues.

Concerning the illnesses and sicknesses associated with e-waste, Yu, Welford, and Hills (2006) sum them up as including respiratory issues such as breathing difficulties, irritation, coughing, choking, and pneumonitis, as well as neurological and systemic effects like tremors, neuropsychiatric disorders, convulsions, coma, and even death. Informal waste management workers face particularly acute risks, as they are regularly exposed to dangerous levels of contaminants such as lead, mercury, beryllium, thallium, cadmium, arsenic, brominated flame retardants (BFRs), and polychlorinated biphenyls (PCBs). These toxic substances are associated with a range of irreversible health effects, including cancers, miscarriages, neurological damage, and diminished cognitive abilities such as reduced IQ.[5]

2.3 Emerging gender and social impacts

Beyond the social impact of health concerns, e-waste poses serious social challenges, particularly in developing countries, where the involvement of women and children in e-waste processing is a growing concern.[6] The dismantling, sorting, and recovery of materials are often carried out manually using rudimentary techniques, disproportionately involving vulnerable populations, including women and children. While male adults and children dominate in the refurbishing, repair, collection and recycling, women make up a significant share of the workforce among the waste picker communities at dumpsites, where women and girls are estimated to make up around 30 percent of the workforce in African countries such as Nigeria.[7]

According to Osibanjo (2015), children aged 5 to 12 in Africa are often involved in hazardous metal recovery processes, such as burning plastic coatings from wires or using acid baths to extract precious metals from computer chips, all without adequate safety measures. Women also contribute indirectly by providing ancillary support, such as selling food and water for drinking or cooling burning objects at dumpsites. Workers, including pregnant women and children, are exposed to these unsafe and toxic conditions without protective gear, enduring long hours for minimal wages. Women face heightened risks due to gender-specific vulnerabilities in reproductive health, particularly during pregnancy. According to Frazier and Fromer (2011), exposure to lead and mercury in the first trimester can significantly impact fetal development, leading to neurobehavioral issues, low birth weight, spontaneous abortion, or congenital defects. Children are also highly susceptible to long-term effects, including disruptions in neonatal development, hormonal regulation, and immune system function.

[5] https://www.genevaenvironmentnetwork.org/resources/updates/the-growing-environmental-risks-of-e-waste/#scroll-nav__2

[6] In Nigeria women make up a significant share of the workforce among the waste picker communities on dumpsites, where women and girls are estimated to make up around 30% of the workforce.

[7] https://www.brsmeas.org/Implementation/Gender/GenderHeroes/GenderHeroesinAfrica/tabid/4762/language/en-GB/Default.aspx

The e-waste sector is largely male-dominated, with women's participation often limited by societal norms, systemic biases, and perceptions of required physical strength and technical expertise. Women are underrepresented and typically occupy low-paying, non-specialized roles that lack adequate safety measures tailored to their needs. While some women are employed in formal recycling companies as dismantlers, machinery operators, or administrative roles, they often face gender-specific challenges and biases. However, significant opportunities exist to bridge this gender gap by offering vocational training tailored to women's needs, improving access to financial resources, and providing female-led mentorship programs to unlock their potential across the e-waste value chain.[8]

In general, the social consequences of e-waste are profound for all sexes. Prolonged exposure to toxic substances like lead leads to severe health problems. At the same time, unsafe working environments increase the risk of injuries or fatalities from accidents, such as falling equipment or improperly discarded electronics. These conditions perpetuate cycles of poverty, exacerbate health inequalities, and widen the socio-economic gap.

Addressing these issues requires a shift toward formalized e-waste management systems prioritizing worker safety, equitable compensation, and environmental responsibility. A healthier, safer, and more sustainable world can be created by reducing the adverse effects on communities, including environmental pollution and health hazards. Formalized e-waste management offers substantial social benefits, including job creation, skills development in green technologies, and enhanced employability. It promotes environmental awareness, responsible consumption, and improved waste management practices. Transitioning to formal recycling mitigates health risks by reducing exposure to harmful chemicals while providing vulnerable groups, such as women and children, safer working conditions and training opportunities, fostering gender equality and improved social outcomes.

2.4 Economic impact

The global e-waste economy is a billion-dollar industry with substantial implications for costs and revenues across government and private sectors involved in its value chains.[9] Globally, as of 2022, about $28 billion worth of metals were turned into secondary raw materials from a potential overall gross value of about $91 billion.[10] This means that about $63 billion worth of recoverable metals remains unexploited due to inefficiencies in current recycling systems. According to the 2024 Global e-waste Monitor, most of the potential value in secondary raw materials from e-waste is concentrated in copper ($19 billion), gold ($15 billion), and iron ($16 billion). The generation of e-waste carries significant cost implications for the global economy, with an overall impact resulting in a net cost of approximately $37 billion, primarily driven by externalized health and environmental costs associated with unmanaged hazardous substances and greenhouse gas emissions.[11] This net loss reflects the combined benefits of viable metal recovery as secondary resources ($28 billion) and avoided greenhouse gas emissions ($23 billion), offset by the costs of e-waste treatment ($10 billion) and the externalized costs to human health and the environment ($78 billion).

[8] https://www.unep.org/news-and-stories/story/why-gender-dynamics-matter-waste-management

[9] https://www.precedenceresearch.com/e-waste-management-market

[10] This represents a significant increase from the 2019 figure of about $57 billion.

[11] https://ewastemonitor.info/wp-content/uploads/2024/03/GEM_2024_18-03_web_page_per_page_web.pdf

Beyond these numbers, it is important to note that importing used EEE and repairable EEE has permitted some African individuals and companies to buy inexpensive and vital electronics or IT equipment that would otherwise have been difficult and expensive to acquire (Asante et al., 2019). Tech repair enables affordable tech and reduces generational poverty. Recycling e-waste components like copper, silver, and gold is significantly more cost-efficient than obtaining these materials through mining. Additionally, salvaging e-waste for repairs reduces the carbon footprint by minimizing the need to transport large shipments of valuable materials across the globe.

Osibanjo and Nnorom (2007), and Grant and Oteng-Ababio (2016) have expounded on the critical role played by the informal e-waste recycling sector in supporting livelihoods, serving as a primary source of income for many impoverished urban communities in Africa. As of 2013, the informal sector performed about 25 percent of the e-waste recycling in South Africa, with an estimated workforce of 10,000 and 2,000 regular workers. Adetuyi and Williams (2022) assert that in Nigeria, over 30,000 workers derive their livelihoods from informal e-waste recycling, significantly contributing to the country's GDP. Similarly, the Agbogbloshie e-waste dumpsite in Ghana directly employs more than 15,000 informal workers. Beyond direct employment, the informal e-waste sector generates additional economic opportunities through secondary activities such as repairing and maintaining electrical gadgets, fostering entrepreneurship and supporting local livelihoods.

The duality of e-waste in Africa cannot be over-emphasized. On one hand, there is evidence of the long-term environmental, social, and economic implications of the informal sector's rudimentary processing methods, which pose significant risks to health and the environment, impacting local populations and ecosystems. On the other hand, e-waste processing offers opportunities for entrepreneurship, job creation, reusing and refurbishing electronics, waste reduction, and recovering valuable metals. The ensuing policies and strategies to combat e-waste outcomes have economic consequences. For instance, according to Daum et al. (2017), the implementation of EPR schemes globally is shifting the cost of recycling and end-of-life management into the price of EEE. While this approach promotes sustainable practices, it has economic implications as it raises costs, potentially exacerbating technological disparities between developed and developing countries. Moreover, unregulated e-waste disposal heavily strains government budgets as municipalities struggle to address its environmental and health impact.

While some economic benefits from e-waste are evident, many opportunities remain untapped, particularly in Africa, where formal recycling systems are still underdeveloped. This neglect results in missed opportunities to create sustainable employment and build a skilled workforce in a growing sector, highlighting the economic potential of responsible e-waste practices. Recognizing this untapped potential, the International Labour Organization (ILO) has noted that 50 million tonnes of e-waste with significant job-creating potential are discarded annually.[12]

[12] https://www.ilo.org/resource/news/50-million-tonnes-potentially-job-creating-e-waste-discarded-annually

3. E-waste Management in Africa

Globally, end-of-life EEE management includes reuse, repair, refurbishment, recycling, and landfilling, with regional variations driven by infrastructure and market factors. Africa is dominated by informal systems that extend the life of these EEE imports. Generally, the waste management record in Africa is poor. Although about 70-80 percent of all municipal waste is recyclable, only about 1 percent of Africa's e-waste is recycled, with proportions varying by country. For instance, South Africa recycles 9.7 percent of its e-waste with a stern focus on dismantling and exporting valuable materials, while Ghana processes 40-60 percent of its domestic e-waste.[13] Countries like Egypt, South Africa, and Rwanda have appreciable formal recycling industries. In contrast, Ghana relies primarily on informal systems.

Informal e-waste management is characterized by hazardous practices that release toxic substances like lead, mercury, beryllium, and cadmium during dismantling (Forti et al., 2020; Abalansa et al., 2021). Despite the significant influx of EEE, efforts along the value chain rely on manual methods, with precious metals reclaimed through acid leaching and open burning. This has led to the accumulation of e-waste in major dumpsites, including Ghana's Agbogbloshie, South Africa's Badplaas, Carolina, and Elukwatini, as well as Nigeria's Alaba (Tetteh and Lengel, 2017; Velis, 2017; Maphosa and Maphosa, 2020). While these crude practices pose environmental and health risks, they also provide employment due to their labor-intensive nature (Amoabeng et al., 2020). Informal sector workers, including minors, often operate in unsafe conditions without protective gear. Common activities include waste picking, scavenging, sorting, dismantling, reselling, and refurbishing old electronics into usable devices, with scrap dealers consolidating materials for resale (Oteng-Ababio, 2010).

Cost constraints have fueled the growth of Africa's informal waste management sector. Informal methods are more affordable, unregulated, and require minimal capital, relying on basic, rudimentary processes. Workers in this sector often obtain e-waste directly from nearby dumpsites, making it an easily accessible means of livelihood. While the informal sector dominates, most African legislation prioritizes formal e-waste management due to its technical expertise and environmentally sustainable recycling practices. However, formal e-waste processors face higher operational costs, including collection fees, undermining their competitiveness. This economic disparity limits the formal sector's scalability and complicates regulatory enforcement. Formal recycling facilities struggle to expand in countries like South Africa and Morocco, where they are competing against informal participants who benefit from lower compliance costs, localized operations, and easier access to affordable e-waste.[14]

Africa's challenges in managing end-of-life e-waste are compounded by several factors, including the absence of dedicated e-waste infrastructure, a framework for end-of-life product take-back, and inadequate public education and awareness of the problems associated with uncontrolled importation of near-end-of-life and end-of-life EEE. Lax legislation, widespread uncontrolled dumping and landfill sites, and inadequate disposal practices compound these challenges. Opportunities to adopt a “waste as a secondary resource” approach remain largely untapped across Africa, while alternative e-waste treatment methods, such as waste-to-energy initiatives, are limited.

[13] https://pmc.ncbi.nlm.nih.gov/articles/PMC8817158/

[14] https://illuminem.com/illuminemvoices/e-waste-management-in-africa-overview-and-policy

3.1 Status of e-waste generation and flows

Developing countries, particularly Africa, have been disproportionately affected by e-waste generation. Gollakota et al. (2020) make this observation and conclude that while Africa does not produce much e-waste, the continent has become the dumping ground for discarded electronics from the developed world. Lim (1987) and Akese and Little (2018) refer to the exportation of hazardous waste from developed countries to impoverished developing countries as “toxic colonialism”. This is reflective of the exploitative dynamics at play. It captures the unfair cross-border transfer of environmental burdens to developing regions saddled with infrastructure challenges for this waste stream's safe disposal or recycling. For instance, according to Merem et al. (2021), Ghana and Nigeria received 77 percent of the e-waste from England and Wales alone in 2019.

Within Africa, West Africa has become the largest dumpsite of e-waste, reflecting a troubling pattern of dumping in countries such as Ghana, Nigeria, and Côte d’Ivoire. This means African countries face the dual challenge of processing imported e-waste alongside their locally generated waste. Transboundary importation of e-waste in Africa introduces additional pressure on waste management systems, potentially undermining their capacity to recycle domestically produced e-waste (Velis, 2015).

According to Baldé et al. (2017) and Forti et al. (2020), Africa generates an average annual 2.5 kg of e-waste per capita, well below the European annual average of 16.2 kg and the Americas’ 13.3 kg. In 2019. Figure 3 shows a regional breakdown of e-waste generation in Africa.

Flows into Africa

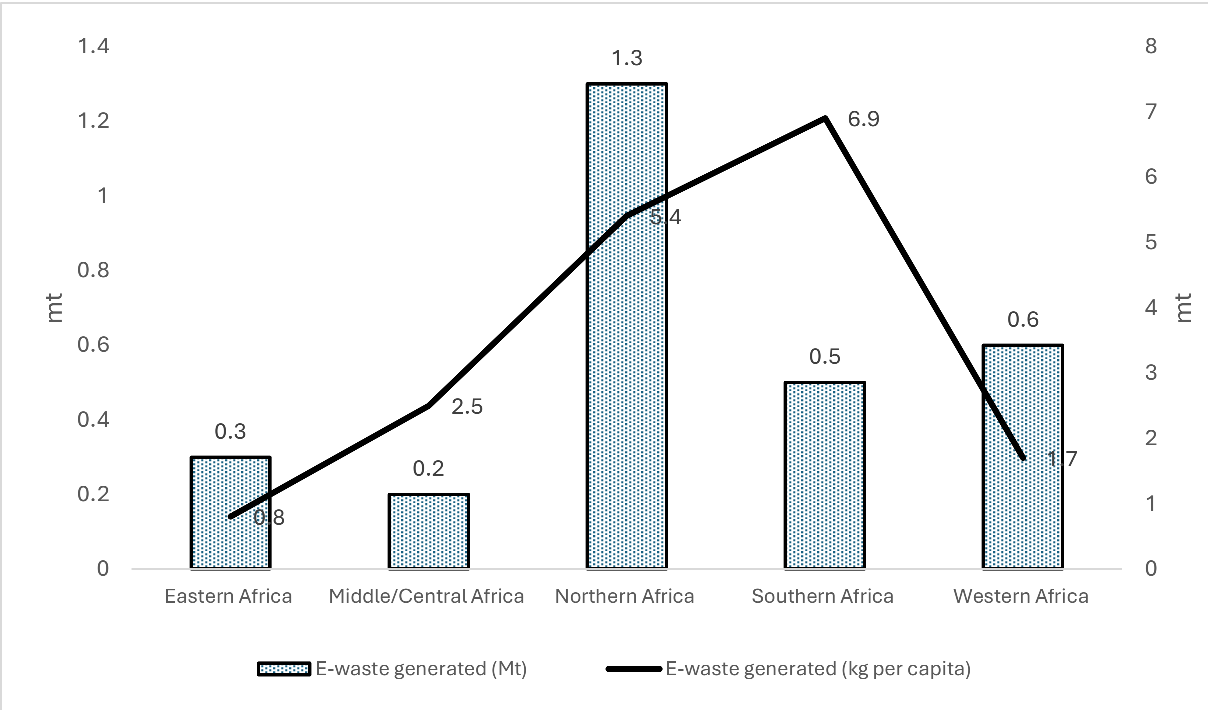
As commodities, e-waste is traded across borders (Cotta, 2020; Kellenberg, 2012; Lipman, 2015). National reporting data submitted under Article 13 of the Basel Convention provide a foundation for analyzing transboundary e-waste flows and volumes. However, this analysis faces significant limitations due to incomplete reporting, ambiguous definitions, incorrect categorization, data discrepancies, and inaccuracies. Moreover, the data only capture legal shipments of hazardous e-waste, omitting trade in second-hand EEE and illegal shipments.

Table 1. Transboundary flow of e-waste in Africa, 2022

Indicator	Kg
Total exports	132
Controlled e-waste reported as hazardous	12
Printed circuit board waste	7
Uncontrolled undocumented exports of mixed-used EEE and e-waste	113
Total controlled imports	546
Controlled e-waste reported as hazardous	19
Printed circuit board waste	0
Uncontrolled and undocumented exports of mixed-used EEE and e-waste	527

Source: Adapted from Baldé et al., (2022)

Figure 3. E-waste generation in Africa



Source: Adapted from Andeobu et al. (2023)

According to Daum et al. (2017), a significant portion of e-waste imported into Africa arrives under the banner of “charitable donations” and “second-hand goods”, presupposing that they must be functional and usable, but the data suggest otherwise. For instance, Maes and Preston-Whyte (2022) reveal that out of 0.215 tonnes of e-waste imported into Ghana in 2019, 30 percent comprised usable “new” products, an additional 14 percent was second-hand needing possible repair, leaving a staggering 56 percent as actual waste in need of processing.

Although the percentage of usage of e-waste differs, it has been shown by Schluep et al. (2011) that it typically does not exceed 30 percent. Maphosa and Maphosa (2020) report that out of the approximately 400,000 used computers that enter Nigeria every month, only around 50 percent still function. The foregoing presupposes that most imported e-waste in Africa arrives near or at the very end of its end-of-life stage, highlighting the need for sustainable management to avert adverse environmental and social impacts.

Flows within Africa

Regional variations in e-waste generation exist across Africa (Table 2). North African countries lead with the highest e-waste generation (1,500 million kg) annually, followed by West Africa (750 million kg) and Southern Africa (580 million kg).

Table 2. E-waste generation in African sub-regions

Region	Population *(million)*	E-waste generated *(million kg)*	Recycling rate	Top countries and e-waste *(million kg)*
East Africa	470	430	0.5%	1. Kenya: 88 2. Ethiopia: 88 3. Tanzania: 61
Central Africa	190	310	0%	1. Angola: 150 2. DR Congo: 56 3. Cameroon: 33
North Africa	260	1,500	0%	1. Egypt: 690 2. Algeria: 330 3. Morocco: 180
Southern Africa	68	580	4%	1. South Africa: 530 2. Botswana: 23 3. Namibia: 17
West Africa	420	750	0%	1. Nigeria: 500 2. Ghana: 72 3. Côte d'Ivoire: 42

Source: ACET, with data from the Global e-waste Monitor 2024

4. Global and Regional Conventions Impacting E-waste Flows

The governance of e-waste flows into and within Africa is shaped by a complex network of global and regional regulatory frameworks. The international community has made several attempts to regulate these flows, with the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal (the Basel Convention) serving as the primary global instrument. At the regional level, the Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa (the Bamako Convention) provides more stringent protections specifically designed for the African context. Beyond these cornerstone conventions, the African Union Agenda 2063 Implementation Plan (Agenda 2063) offers principle aspirations for African countries in managing various waste streams, including e-waste. These major instruments are complemented by additional international conventions that address specific aspects of e-waste management, collectively forming the regulatory landscape that influences how electronic waste is transported, processed, and managed across the African continent.

4.1 The Basel Convention

The Basel Convention was negotiated in 1989 under the auspices of the UNEP and entered into force in 1992, partly in response to public clamor against using developing countries as dumping grounds for toxic waste. Kummer (1998) highlights the fact that the convention initially faced rejection. Critics believe that even though it is environmentally detrimental to trade in hazardous products, it is also against the principles of free trade to ban its trade completely. The Basel Convention's overarching goal is to safeguard human health and the environment from the harmful effects of hazardous and other specially regulated waste. The convention intends to achieve this goal by reducing hazardous waste generation, promoting environmentally sound waste management, limiting transboundary movement unless aligned with sound environmental principles, and regulating permissible cross-border waste transfers. As of 1994, more than 100 countries had enacted laws prohibiting the import of hazardous waste, with some countries lacking the administrative capacity to do so unilaterally. By February 2014, 180 countries and the European Union signed the Basel Convention, making it one of the most widely accepted multilateral environmental agreements.[15]

The Basel Convention has well-crafted provisions that balance environmental and free trade concerns. It was built on a sound regulatory system based on the concept of prior informed consent, requiring the exporting country to notify the importing country of the intended hazardous waste shipment. Importation is only permitted when the states concerned have given their written consent (Articles 6 and 7). Furthermore, the convention designates the Basel Secretariat as a clearinghouse (Article 16) to facilitate cooperation among parties for the exchange of information and technical assistance, particularly to developing countries (Articles 10 and 13). Exporting countries are held liable for illegal transboundary movements of hazardous waste or incomplete disposal (Articles 6 and 7), requiring safe disposal through re-importation to the generating state or alternative means (Articles 8 and 9).

[15] https://brill.com/view/journals/ajls/9/4/article-p235_2.xml?language=en

The Basel Convention was further amended at COP3 in 1995 when states adopted the Ban Amendment that prohibited hazardous waste exports for disposal or recycling from countries listed in Annex VII (developed countries) to non-Annex VII countries. The amendment became operational in 2019. Since then, several actions have been taken to strengthen the Convention's implementation. Among them is the adoption of the Strategic Framework (2012-2021) to enhance the convention's impact. This empowered the 14 regional centers across Africa, Asia, the Caribbean, Eastern Europe, and Latin America to build capacity, educate the public, promote sound waste management, and train customs officials. Additionally, non-binding technical guidelines were developed for sound management of waste streams such as waste oil, biomedical waste, persistent organic pollutants, obsolete ships, and mobile phones.

4.2 The Bamako Convention

The primary purpose for the Bamako Convention, negotiated in 1991 under the auspices of the Organization of African Unity,[16] was to address a key criticism of the Basel Convention: that it did not provide for an outright ban of export of hazardous waste to African nations. The proponents of the ban argued that developed countries, where these hazardous wastes originated, have the regulatory and technological mechanisms to control such waste and are better positioned to deal with them. In contrast, Africa's vulnerability to political instability, economic challenges, corruption, and limited knowledge in waste management raised concerns that some leaders might legitimize the transboundary movement of hazardous waste, allowing environmentally harmful practices.

The Bamako Convention prohibits importing and dumping hazardous waste, including radioactive waste, into Africa and its inland and water bodies. It focuses on minimizing and controlling transboundary movements of hazardous waste within the continent. It also seeks to enhance ecologically sound handling of hazardous waste across the continent and foster cooperation among African nations.

Since its inception, the Bamako Convention has faced challenges in curbing the transboundary movement of hazardous waste into Africa, primarily due to economic pressures, lack of political will, and inadequate technological and international support. Many African countries, driven by economic hardships such as balance of payments deficits and civil wars, engage in illegal waste transactions for financial gain despite the environmental and health risks.[17] Slow ratification and insufficient commitment from member states further weaken the Bamako Convention's implementation. Additionally, the absence of waste management technologies and lack of collaboration with international bodies such as the Basel Secretariat hinder its effectiveness in addressing hazardous waste issues across the continent. The situation is complicated by low awareness among policymakers, businesses, and the public of the environmental and health risks of e-waste, along with the lack of skilled labor and technical expertise for managing e-waste safely and sustainably at the local and municipality level (Njoku et al., 2023).

4.3 Other notable policies and conventions

Although the adoption—and subsequent ratification—of the Basel and Bamako conventions indicates the global and regional consensus on restraining the transboundary movement of hazardous waste, studies have shown that they do not provide a watertight regulatory framework needed to deal with illicit

[16] The Organization of African Unity was formally dissolved in 2002 and replaced by the African Union.

[17] https://brill.com/view/journals/ajls/9/4/article-p235_2.xml

activities of such scale and nature (Agbor, 2016). The international and continental conventions are insufficient; they lack robust mechanisms to curb illegal activities.[18] Member states must adopt complementary national policies and, along with civil society organizations, raise awareness about the health and environmental risks of e-waste. Abolishing the importation and transportation of hazardous waste into and within Africa would be difficult unless every stakeholder is involved.

Beyond the Basel and Bamako conventions, the African Union Agenda 2063 Implementation Plan (2014-2023) is a key policy document guiding African countries in the management of various streams of waste. It underscores the need to transform waste management as part of broader development objectives. Goal 1 of the first Aspiration emphasizes "(a) high standard of living, quality of life, and wellbeing for all citizens." Priority Area 4 also emphasizes creating modern, affordable, and livable habitats with high-quality essential services. A central target is for cities to recycle at least 50 percent of the waste they generate by 2023 (AUC, 2015b).

Other international conventions address e-waste management. These include the:

- **Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (1975)** – aims to prevent the disposal of hazardous waste at sea to protect human health, marine life, and ocean resources.
- **Minamata Convention on Mercury (2013)** – targets mercury pollution and its adverse impact.
- **Stockholm Convention on Persistent Organic Pollutants (2001)** – seeks to eliminate or restrict the production, import, export, disposal and use of POPs.
- **United Nations Framework Convention on Climate Change (1992)** – addresses the broader environmental impacts of waste and climate change.

These conventions, coupled with some domestic policies and regulations, collectively require parties to manage waste and, by extension, e-waste in ways that safeguard human health and the environment. Many countries have not implemented these conventions even though they are signatories. For instance, Ghana has yet to implement the Basel Convention. There are also issues with statistics due to varied definitions of e-waste.

[18] Incidents such as the 2006 Abidjan toxic disaster and the alleged radioactive waste dumping in Nigeria in 2007 highlight the inadequacy of existing frameworks.

5. Extended Producer Responsibility: A Key Trend in E-waste Management Law and Policy

5.1 Background

Extended Producer Responsibility (EPR) policies have emerged as a key domestic strategy widely adopted in the developed world to address e-waste management. The Organisation for Economic Co-operation and Development (OECD) defines EPR as "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle."[19] EPRs reduce the cost of e-waste management to the state by shifting end-of-life management costs from local authorities to producers under the "polluter pays" principle. They also increase recycling and material recovery rates and encourage producers to adopt sustainable product designs through Design for Environment initiatives. There has been remarkable growth in EPR policies, with over 400 schemes globally across various product types, from packaging and used tires to vehicles and electronics. According to Serra (2023), the electronics sector leads in products under EPR systems. Geographically, while EPR systems are prevalent in Europe, Asia, and North America, they are becoming accepted in emerging and developing economies as sustainable waste management strategies.

According to Serra (2023), introducing EPR schemes in OECD countries has notably reduced material intensity and boosted municipal solid waste recycling rates. EPR systems have also significantly improved packaging material collection, sorting, and recycling. EPR schemes are fiscal instruments; they can potentially raise significant revenue for the government. For instance, the Flanders region of Belgium raised about €200 million in 2018, while France generated €1.4 billion in 2015 through EPR initiatives, which is about 10 percent of the sum that local municipalities need to manage waste (Serra, 2023). These successes have inspired policymakers, industry associations, and civil society organizations to initiate discussions on the possibility of including new product groups, such as textiles and pharmaceuticals, to address other environmental challenges, such as littering and the proliferation of microplastics. The EPR concept aligns with current global goals, especially SDG 12, which stresses sustainable consumption and production. It is an essential policy tool for the development of a circular economy.

5.2 Types of EPR schemes

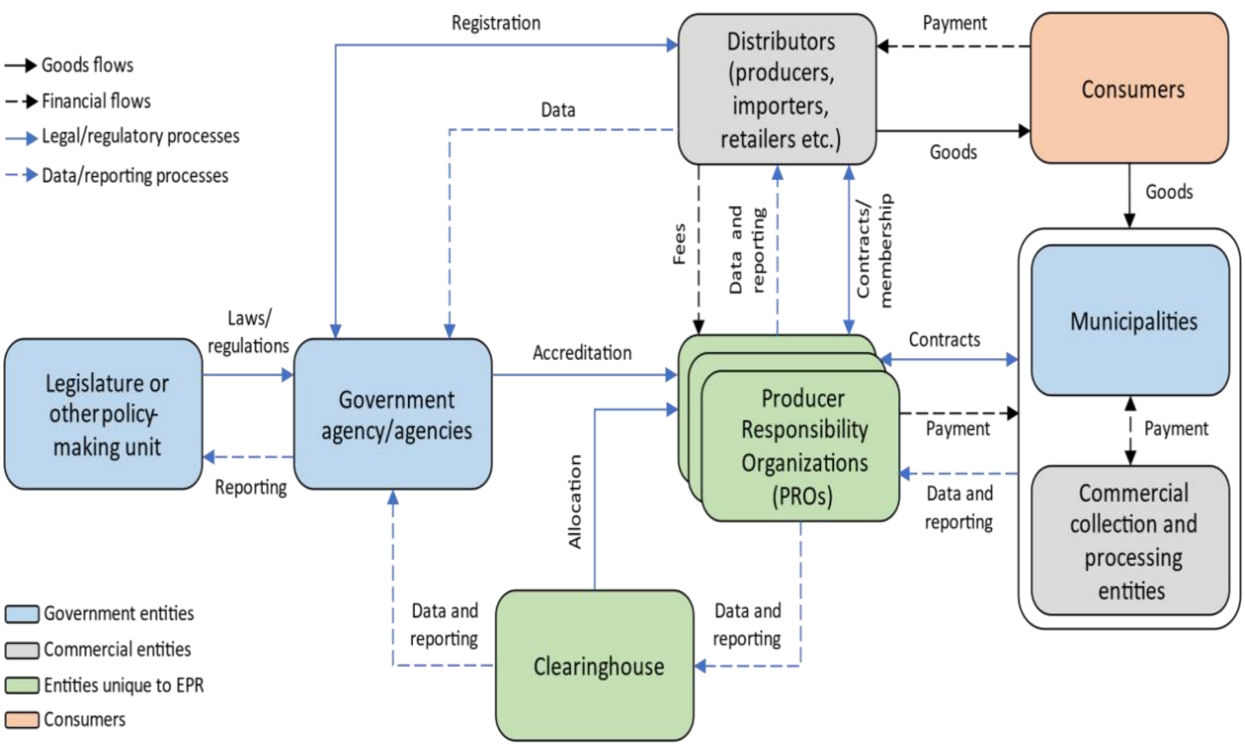
There are two prominent types of EPR schemes: individual producer responsibility and collective producer responsibility. Individual producer responsibility allocates responsibility to each producer to design his or her own system. Collective producer responsibility schemes require producers to collaborate on shared solutions for managing waste. In its standard form, an EPR fee system is established, and the producers delegate all post-consumer management of their e-waste to a Producer Responsibility Organization (PRO), often under government oversight. Examples of PRO EPR schemes in Africa include the EPR Waste Association of South Africa (eWASA), the E-waste Recycling Authority (ERA) NPC in South Africa, and E-waste Producer Responsibility Organization Nigeria (EPRON) in Nigeria.

[19] https://www.unido.org/sites/default/files/unido-publications/2023-11/GACERE_Circular%20Economy%20and%20Extended%20Producer%20Responsibility_webinar%20report.pdf

The governance of EPR systems depends on the regulatory regime, but they share common structures. State institutions are charged with implementation; they also register distributors (e.g., producers, importers, or retailers), accredit the PROs, and ensure compliance through fees and reporting. PROs then manage contracts and fees with distributors, municipalities, and private entities for collection and processing.

EPR systems can take a wide range of formats, with the two main formats being simple monopolistic and complex competitive. A simple monopolistic EPR systems use a single PRO to manage the collection and recycling of waste for all producers within a specific sector, while complex competitive models may include multiple PROs, giving producers the option to choose among them, and coordinated by a clearing house or employ tradable credits for end-of-life product processing. This flexibility enables adaptation to specific waste management objectives. Monopolistic producer responsibility schemes can be very effective in smaller economies, while competition-based schemes may be preferable when economies of scale are a major factor. Figure 4 diagrams operational model of EPRs.

Figure 4. Operational model of EPR schemes



Source: Adopted from Serra (2023).

5.3 EPR schemes in Africa

African countries were latecomers in the EPR conversation and have suffered disproportionately as a result. According to the European Environmental Bureau, Africa loses €340 million-€380 million annually in EPR fees associated with imported second-hand electronics and €294.6 million-€409.4 million for second-hand vehicles imported into their markets.[20] African countries have had to use their limited resources to manage imported e-waste, exacerbating their already strained economies. Limited funding for collection, remanufacturing, and recycling often leads to informal landfilling and incineration, worsening environmental and health risks. Existing EPR frameworks fail to address the multi-use cycles and cross-border trade of electronics. African countries must establish an ultimate producer responsibility scheme to address this gap, compelling international producers to manage e-waste under the polluter-pays principle. Thus, in Africa, where informal channels handle the importation of electrical products, which are sometimes repaired, reused, and resold in a different country many times before finally being discarded, current EPR schemes fail to capture this multi-use lifecycle but a designed for linear product life cycles and single market jurisdictions. This reality gives producers based outside the African continent to escape responsibility under their EPR schemes.

The EPR policy space in Africa is a complex ecosystem that is still in its early stages. Only 13 of the 54 African countries have adopted some policies on e-waste (Adetuyi, A. and Williams, N., 2022), with nine being on the EPR principle.[21] Most countries are examining how best to create EPR systems despite many obstacles. One significant obstacle is data tracking and verification. Without traceable and verified data, effective policy development and designing evidence-based interventions is hampered and interventions may lead to unintended negative consequences. Moreover, a scan of the policy literature on EPR schemes seems to indicate that the political conditions around environmental issues appear less stringent than in Europe, with most governments only in the inception stages of addressing some of these limitations.

Multinational private sector players often exploit policy gaps and engage in greenwashing with a few voluntary initiatives. Meanwhile, the local private sector lacks environmental sustainability awareness and struggles with limited access to capital, energy, and resources. Additionally, the few EPR schemes in Africa seem to have been modeled on European frameworks; they rely on robust infrastructure and public awareness, focusing on EPRs to incentivize repairable and recyclable designs. In Africa, where imports dominate, EPR must shift responsibility to importers. But it is important to also recognize the possible drawbacks of focusing on one responsible partner.

The EPR schemes in Africa have different arrangements, switching between government-led and private sector-led EPRs. For instance, South Africa has established EPR Regulations with product-specific notices for the paper, packaging and some single-use products, lighting, portable battery sector and the EEE sector. While its system has room for improvement, substantial progress has been made, particularly in encouraging waste reduction from the design stage onwards. South Africa's mandatory EPR model, legislated under the National Environmental Management: Waste Act (NEMWA), is implemented by PROs like the EPR Waste Association of South Africa (eWASA), with eco-levies funding recyclers and tax breaks incentivizing private sector participation.

[20] https://www.renewablematter.eu/en/africa-is-working-on-an-ultimate-producer-responsibility

[21] This was revealed in the 2024 E-waste Monitor.

Rwanda’s government-led approach, informed by the 2021 National E-Waste Policy, includes a formal recycling facility, strict import regulations, and strong public-private partnerships. Nigeria’s private sector-led EPR initiative, EPRON, backed by major manufacturers, integrates informal collectors and funds recovery through an eco-tax on electronics. Key lessons in implementing EPR schemes include the importance of government enforcement for compliance, industry funding for sustainability, informal sector integration for efficient collection, and eco-levies for financial stability.

Other notable countries establishing EPR systems include Kenya and West African neighbors Côte d'Ivoire, Ghana, and Nigeria. Côte d'Ivoire benefits from large French corporations promoting voluntary initiatives such as the Association ivoirienne pour la valorisation des déchets plastiques (AIVP), which covers all Ivorian plastic producers. Voluntary schemes may not consistently achieve the best outcomes. This is because a lack of enforcement and accountability breeds low participation and non-compliance. Also, free riding may proliferate, creating an uneven playing field for responsible producers and undermining the financial sustainability of the scheme.

Ghana has recognized the role of importers and has introduced an eco-levy on imported EEE products. Kenya’s draft regulations mandate that EEE producers report their sales data and future projections to the government, ensuring they contribute financially to e-waste management and recycling. While these efforts are commendable, effective implementation of EPR schemes throughout Africa will require collaboration between governments and companies, with the government playing a key role in driving this initiative. Nigeria has operational schemes that are being refined.

Box 1. Nigeria’s EPR Scheme

Nigeria's EPR system is setting a benchmark for sustainable waste management in Africa. Introduced in 2011 by the National Environmental Standards and Regulations Enforcement Agency (NESREA), the policy focuses on three key waste categories through producer alliances: the Food and Beverage Recycling Alliance, the Alliance for Responsible Battery Recycling, and the E-Waste Producer Responsibility Organisation Nigeria (EPRON), which oversees e-waste management.

Key developments

Significant advancements in Nigeria's e-waste EPR framework occurred in 2022, building on the foundation of the 2020 EPR guidance document and amendments to the National Environmental (Electrical and Electronic Sector) Regulations. These updates, supported by the UNEP-led Circular Economy Approaches for the Electronics Sector in Nigeria project, introduced mandatory EPR subscriptions and prohibited sub-optimal e-waste treatment practices.

The revised regulations require manufacturers, importers, e-waste collection centers, and recycling facilities to register with EPRON. NESREA Director-General Professor Aliyu Jauro described this step as “an essential milestone towards the operationalization of a financially self-sustaining circular electronics network.” Partnerships with the African Alliance of Producers (including Dell, HP, and Microsoft), and collaborations with European producer responsibility organizations (PROs) have strengthened EPRON’s capacity to manage recycling fees and ensure environmentally sound practices. Training programs, protective equipment distribution, and UNEP-facilitated knowledge sharing have further improved the livelihoods and safety of e-waste workers while advancing circular economy principles across Africa.

Challenges

Nigeria faces significant hurdles despite progress. As Africa's largest importer of electrical and electronic equipment, the country processes over 500,000 tonnes of discarded electronics annually. Informal recycling employs about 100,000 workers but often involves harmful practices that release persistent organic pollutants (POPs) and mercury, posing severe health and environmental risks. Critical challenges include limited recognition and support for informal waste pickers and a lack of formalized stakeholder engagement, particularly with the Waste Pickers' Association of Nigeria. Additionally, non-compliance by some producers and insufficient awareness of the EPR scheme hinder its full implementation.

Impact and the way forward

Nigeria's enhanced EPR framework positions the country as a leader in sustainable waste management, offering a scalable model for other African nations. The scheme balances environmental protection with social and economic benefits by addressing local challenges, fostering collaboration, and enforcing compliance, advancing Africa's circular economy ambitions.

To ensure the scheme's success, authorities must enforce mandatory producer participation, require registration with NESREA and EPRON, and penalize non-compliance. Broadening the definition of producers, criminalizing the import of non-functional used electronics without EPR adherence, and strengthening stakeholder engagement will be crucial for building a robust and enforceable system.

6. Potential of E-waste in a Circular Economy in Africa

This section focuses on how e-waste can be leveraged to develop and create a circular economy. It examines e-waste's role in resource recovery and Africa's circular economy, focusing on material reclamation, recycling innovations, economic opportunities, and challenges in regulation and management.

6.1 Circular economy in Africa

Various definitions have been advanced for the circular economy. The European Parliament defines it as “a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible.”[22] According to UNESCO, it is “an economic system where waste is designed out, everything is used at its highest possible value for as long as possible and natural systems are regenerated.”[23] Within Africa, a commonly accepted definition by ACEN is “an alternative model that will allow African cities to pursue their development agenda along a pathway that ensures economic growth is decoupled from use of finite materials, enabling green growth and industrialization by closing the loop of resources and by developing regenerative and circular systems.”[24] A circular economy model for e-waste management in Africa promotes job creation, resource recovery and offers safer working conditions while reducing environmental and health risks for Africans. Moreover, it supports local manufacturing, aligns with African Unions’ Agenda 2063, and advances key SDGs on sustainability, decent work, and climate action.[25]

6.2 E-waste as a recoverable resource

Discarding EEE means losing valuable resources, as these devices contain scarce and expensive precious metals like silver, gold, and copper, along with rare earth elements obtained through mining. Regardless of how responsibly mining is conducted, it often involves vegetation loss in surface mining or significant disruption to the earth’s crust in underground mining, leading to environmental degradation, habitat destruction, and biodiversity loss. Recycling e-waste offers a sustainable alternative by recovering these valuable materials without harming the environment. By retrieving precious metals from old devices, recycling reduces the need for additional mining, helping to conserve natural resources and mitigate environmental damage.

For instance, a ton of electronic waste is estimated to contain at least 10 times more gold than a ton of the ore from which gold is extracted.[26] In 2024, urban mining of e-waste prevented the extraction of approximately 900 billion kilograms of ore needed for rare earth mineral production globally. The key minerals recovered included copper (around 50 percent), gold (approximately 20 percent), iron (about 10

[22] https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefits
[23] https://unevoc.unesco.org/pub/closing_the_institutional_gap.pdf
[24] https://acen.africa/wp-content/uploads/2024/08/Circular-Economy-in-Africa-Perspectives-Potential.pdf
[25] https://www.afdb.org/en/news-and-events/events/2021-african-circular-economy-alliance-acea-annual-meeting-43048
[26] https://news.cornell.edu/stories/2025/01/e-waste-gold-pathway-co2-sustainability

percent), and palladium (less than 5 percent).[27] The savings were based on a well-established rule that extracting just 1 kg of gold requires mining approximately 3 million kg of ore.

In contrast, recycling or urban mining of e-waste reintroduces valuable secondary raw materials into the economy, reducing reliance on primary mining and contributing to environmental conservation. Cui and Forssberg (2003) and Widmer et al. (2005) estimate energy savings of up to 95 percent for aluminum, 85 percent for copper, and 74 percent for lead and steel from urban mining. This suggests that repurposing old electronics and e-waste promotes a sustainable circular economy that prioritizes the reuse and recycling of materials over single-use disposal.

Promoting recycling and a circular economy offers significant benefits. The production of EEE components involves extensive processes like extraction, refining, and processing raw materials, which consume large amounts of fossil fuel-driven energy, emitting greenhouse gases and accelerating climate change. Recycling e-waste provides a more energy-efficient alternative, requiring far less energy than mining and processing virgin raw materials. This reduces reliance on fossil fuels and contributes to a cleaner, greener environment for future generations. Second, recycling facilitates pollution prevention and protects the environment by offering a safer disposal technique for e-waste, which hitherto would have heaped on dumpsites, destroying community aesthetics. By diverting unrecycled or improperly treated e-waste from landfills and incinerators and ensuring proper handling and recycling, a healthier and more sustainable world is secured while advancing progress toward the Sustainable Development Goals (Van Yken et al., 2021).

Promoting a circular economy for e-waste inherently involves significant economic gains. It fosters the creation and development of innovative business models centered on repair, refurbishment, recycling, and other services. This, in turn, will generate jobs within the sector and enhance long-term economic resilience. In 2021, the Coalition for American Electronics Recycling (CAER) revealed that the heightened pace of e-waste disposal will add about 42,000 new jobs yearly, resulting in nearly $1 billion of additional payroll.[28] As governments increasingly develop and enforce regulations for e-waste management and recycling, the private sector's response to ensure compliance will create wealth and new employment opportunities, reduce poverty, and drive sustainable economic growth across Africa.

6.3 Innovation and technology in e-waste recycling

Proper technologies and supportive processes provide the foundations of effective promotion of recycling and circular economy activities but effectiveness depends on social acceptance, regulatory frameworks, and inclusive stakeholder engagement. As discussed, informal rudimentary methods for processing and recycling e-waste are unsustainable, posing significant risks to ecosystems and human health. Advanced and appropriate technologies are essential for addressing these challenges as they mark a paradigm shift in conventional waste management. Joy (2023) highlights that effective extraction and purification of recyclable components from mixed waste streams require sophisticated techniques. Innovations such as robotics and optical sorting improve the quality and quantity of recovered materials, facilitating their reintegration into production cycles. Researchers have developed several innovative solutions to revolutionize the e-waste recycling industry, streamlining processes, enhancing material recovery, and

[27] https://ewastemonitor.info/wp-content/uploads/2024/03/GEM_2024_18-03_web_page_per_page_web.pdf

[28] https://ebionline.org/2013/02/12/study-tightening-e-waste-exports-could-create-42000-us-jobs/

minimizing environmental impact. These advancements are promising and must be considered in e-waste policy conversations and practice.

Artificial intelligence (AI) technologies have emerged as a key innovation in e-waste sorting and segregation, addressing the challenges posed by the complex composition of e-waste, which includes plastics, non-biodegradable, and hazardous materials (Wang et al., 2022). Contamination and poor segregation diminish material recovery quality (Olawade et al., 2024). While traditional manual methods, such as burning and leaching, are time-consuming and destructive, AI technologies have revolutionized these processes (Anitha et al., 2022; Mahboob, 2022).

AI sorting systems leverage machine learning and computer vision to automate and optimize sorting. These systems accurately identify and categorize materials such as metals, plastics, and circuit boards, significantly improving efficiency, reducing errors and costs, and enhancing the overall effectiveness of e-waste recycling. AI techniques, including machine learning and deep learning algorithms, are expected to play an increasingly significant role in waste management (Munir et al., 2023). Advancing policies[29] and support for their adoption is crucial, as this technology holds promise in enhancing waste classification and sorting processes (Adeleke et al., 2023).

Chemical recycling is another groundbreaking technology transforming e-waste processing. It involves breaking down electronic waste into essential chemical components to recover hard-to-extract materials. Two primary methods, hydrometallurgy and pyrometallurgy, drive this innovation. Hydrometallurgy uses chemical solutions to dissolve and selectively recover high purity metals like gold, silver, and copper while operating at lower temperatures, reducing energy consumption. This process has demonstrated high efficiency in metal recovery through precipitation and ionic liquid techniques (Ambaye et al., 2020). Pyrometallurgy employs high temperatures to smelt and refine metals, efficiently processing large waste volumes and extracting multiple metals simultaneously, including deeply embedded ones (Xiao et al., 2023). Pyrometallurgy is excelling as a recognized thermal treatment for reclaiming metals from electronic waste. Together, these two chemical methods enhance material recovery and reduce the environmental impact of e-waste recycling.

Traditional recycling has focused on transforming e-waste into new components after products reach the end of their life. However, a growing trend shifts this perspective to the product design stage through modular design. Modularly designed products satisfy the principles advocating for sustainable design that prioritize repair, upgrade, and recyclability. This approach breaks products into interchangeable modules or components that can be easily assembled, disassembled, and replaced. By using standardized connectors and fasteners, manufacturers simplify the separation of materials, making recycling more efficient. Modular design makes products more flexible and adaptable to different recycling scenarios; it extends the lifespan of electronic products by enabling straightforward repairs and component replacements, ultimately promoting resource efficiency and significantly reducing e-waste (Zghaibeh, 2023).

3D printing has also emerged as a transformative frontier e-waste management technology for upcycling e-waste into valuable products and components. Ononiwu et al. (2024) describe it as an additive manufacturing technology that builds three-dimensional parts layer by layer from computer-aided design

[29] Regulatory frameworks and industry standards must be developed to ensure the responsible and ethical use of AI in waste management.

files. Unlike traditional subtractive machining methods, 3D printing offers important advantages such as customization, rapid prototyping, lightweight production, automation, energy efficiency, cost reduction, e-waste minimization, and environmental benefits (Pecorini et al., 2022; Romani et al., 2021). This technology can be used to repurpose discarded electronics, such as shredded circuit boards, into 3D printer filaments for creating customized parts. By reducing waste and adding value to recycled materials, 3D printing advances circular economy principles, lessens dependence on virgin resources, and fosters innovation in manufacturing and designing e-waste products.[30] Examples exist where e-waste has also been used to build 3D printers. For instance, the BuniHub maker space in Dar es Salaam in Tanzania has built a 3D printer entirely from e-waste parts. Similarly, in Ghana, the KLAKS 3D team in Kumasi builds 3D printers from e-waste.[31]

Blockchain technology has also emerged as a cutting-edge solution to the challenge of irresponsible e-waste disposal, gaining traction in Western societies. Its decentralized and transparent ledger system enables comprehensive tracking of electronic devices throughout their lifecycle—from production and distribution to recycling—providing critical insights into their whereabouts and eventual e-waste status. By securely recording transactional data, blockchain allows stakeholders to verify the authenticity and origin of EEE and their components; blockchain technology tackles the irresponsible disposal problems of e-waste, ridding cities of the unpleasant aesthetics and environmental problems imposed by e-waste. Blockchain automates the tracking and verification of e-waste transactions, ensuring safety, authenticity, and environmental compliance while improving recycling performance (Centobelli, 2022). This technology mitigates illegal disposal and unethical export practices, promoting responsible e-waste management. By fostering trust among consumers, regulators, and recycling organizations, blockchain advances a sustainable and circular approach to e-waste management (Esmaeilian et al., 2020).

These emerging technologies are shaping the e-waste management space. Their significance transcends instigating circularity in the e-waste sector. These technologies can be deployed to improve operational efficiency and transparency and mitigate crime within recycling value chains. Critical innovations such as drone imagery, blockchain, and the publishing of real-time price indexes for recyclable e-waste commodities can improve accountability and trade practices. Technology can spur digital solutions to bring transparency in implementing the Basel Convention's "prior informed consent" requirement. This requirement mandates that countries provide photographic evidence to comply with the Convention and ensure that materials are traded as resources rather than exported as waste. The move from paper to digital formats will boost compliance and strengthen global e-waste management efforts.

6.4 Economic opportunities in a circular economy

E-waste recycling presents significant potential for the government and the private sector as a catalyst for economic growth, job creation, and government revenue generation while aligning environmental sustainability with economic development. The circular economy in Africa has been touted to hold an annual market opportunity of approximately $8 billion.[32] By engaging in the multilayered value chain,

[30] https://disruptafrica.com/2015/02/19/tanzanias-buni-hub-builds-3d-printer-made-e-waste/

[31] https://emf.thirdlight.com/file/24/RrpCWLERr.MelnURr2SgR05.vzR/%5BEN%5D%20Circular%20economy%20in%20Africa%3A%20Electronics%20and%20e-waste.pdf

[32] https://www.afdb.org/en/news-and-events/circular-economy-connecting-dots-between-climate-change-resilience-and-opportunities-africa-67427

governments and SMEs alike deploy e-waste as a catalyst for employment, innovation, and value creation for consumers. A circular economy model for e-waste offers notable benefits, potentially reducing consumer costs by 7 percent by 2030 and 14 percent by 2040 (Morlet et al., 2018). Given their dominance in Africa's private sector, SMEs will be pivotal in this transformation. They foster innovation through localized technologies and business models, enhance accessibility by operating at the community level, facilitate refurbishment and reuse to extend product lifespans and establish localized supply chains to reduce import reliance. SMEs can also engage informal waste workers, creating pathways to formal employment and advancing the formalization of the e-waste sector, making them essential drivers of a sustainable and inclusive circular economy.

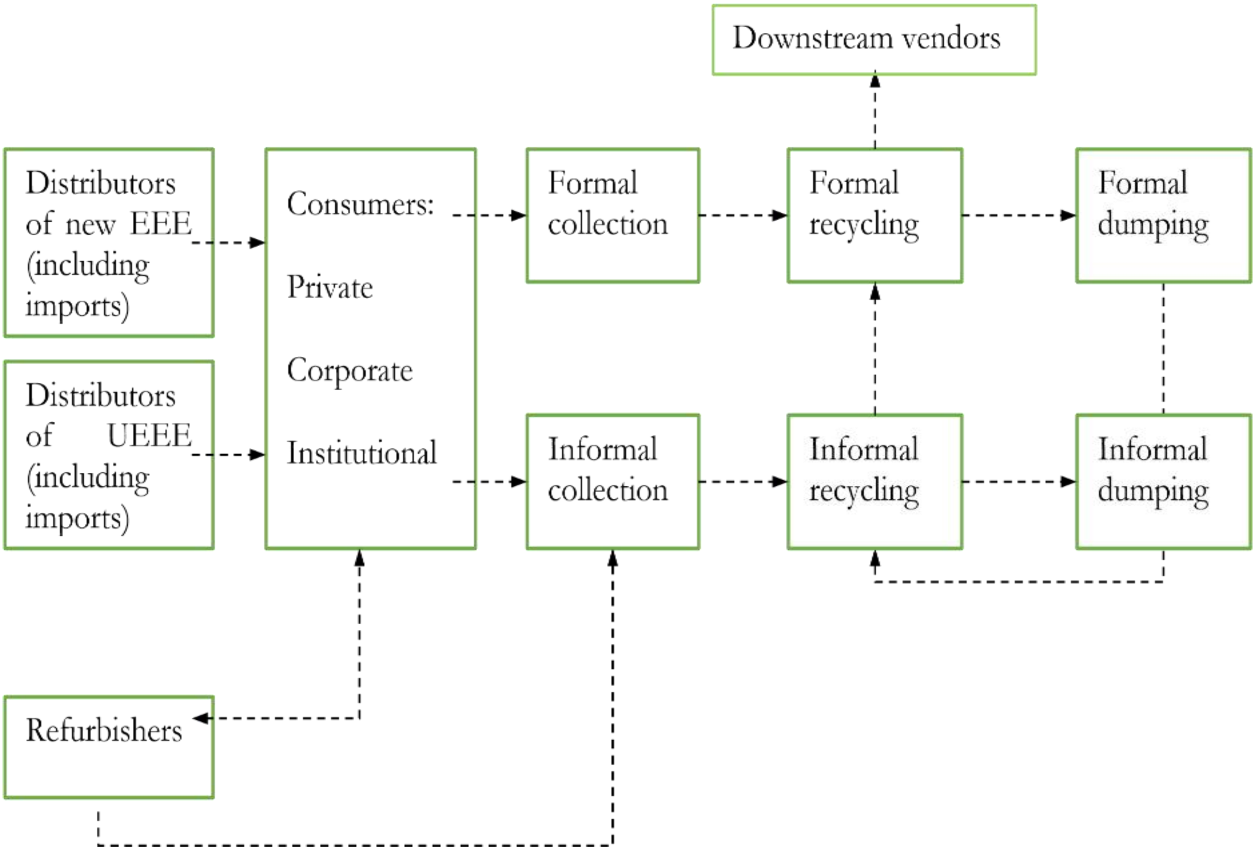
E-waste management in Africa is organized around a diverse range of actors – as can be seen in Figures 5 and 6 detailing the value chain actors in Nigeria and Egypt—including distributors, repairers, consumers, collectors, recyclers, and final disposers, with each playing their role along the value chain. The distributors mostly import and sell new and used electrical and electronic equipment to consumers (private, institutional, and corporate). At the same time, repairers and refurbishers extend the lifespan of the products sold, and the irreparable items become e-waste. Individuals and micro-organizations ("scavengers") also specialize in gathering recyclable materials as a livelihood, which is mostly conducted informally.

Recyclers then disassemble and dismantle the e-waste to recover valuable metals like aluminum, copper, and steel that are then sold to manufacturers as secondary raw materials. Downstream vendors purchase these recovered components for reuse, primarily in the formal sector. However, unrepairable or non-recyclable e-waste is frequently disposed of with municipal waste or dumped in uncontrolled areas such as Alaba in Lagos or the erstwhile Agbogbloshie dumpsite in Accra, highlighting the need for formalized systems and improved enforcement of proper disposal practices.

The value chain structure is broadly similar to global trends, such as those in Brazil, the largest e-waste producer in South America and Asia. However, the critical distinctions lie in the degree of formalization and the actors in the management of dumping sites.

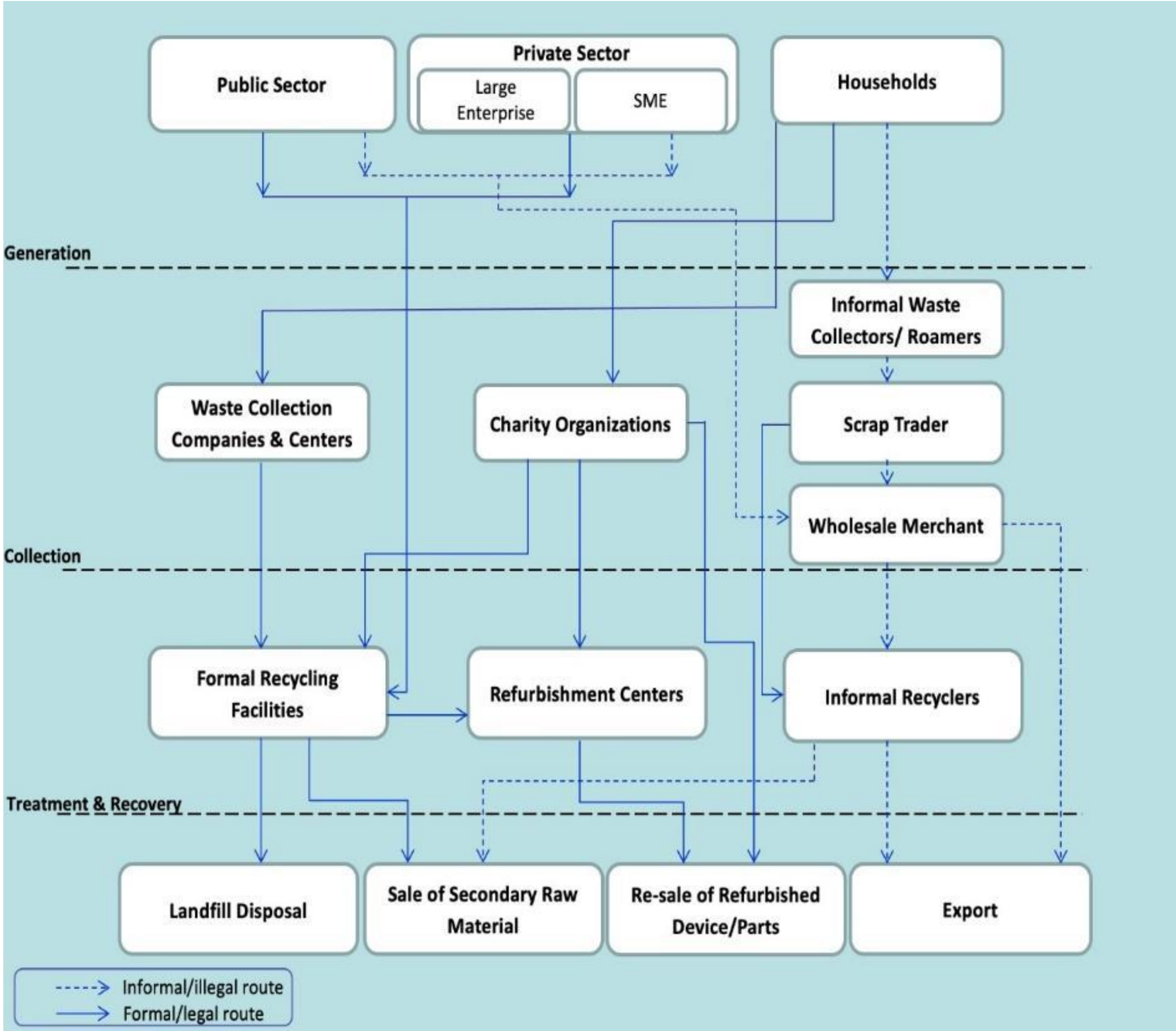
One of Africa's key challenges in e-waste management is the lack of collaboration and coordination among actors in the value chain to drive meaningful change. In contrast, countries like Brazil and others in Asia have successfully formed cooperatives among stakeholders in the collection and recovery stages, fostering formalization and raising awareness. For example, cooperatives in Brazil actively engage in implementing and enforcing regulations, effectively driving the formalization of the e-waste sector and promoting sustainable practices across the value chain. Many have called for their legal recognition (Dias et al., 2022). Figure 7 illustrates the Brazilian e-waste value chain actors.

Figure 5. E-waste value chain in Nigeria



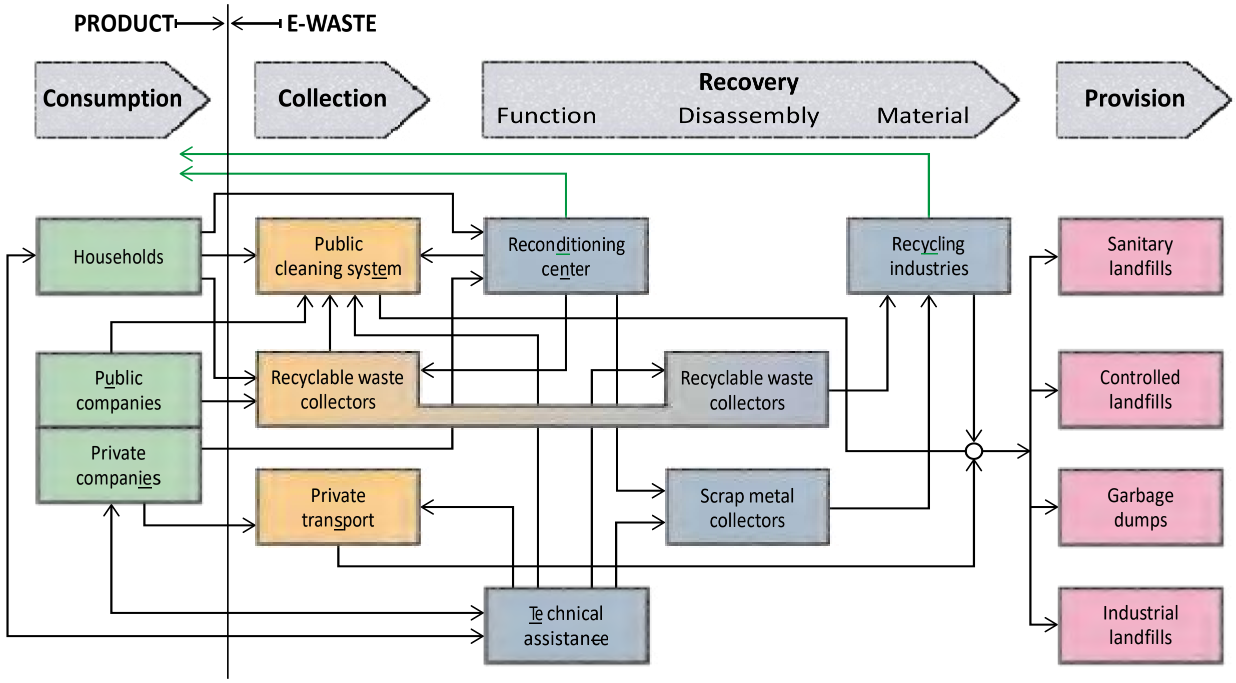
Source: ILO (2019).

Figure 6. E-waste value chain in Egypt



Source: Mostafa Lotfy (2024).

Figure 7. E-waste value chain actors in Brazil



Source: ILO (2014).

6.5 Challenges and barriers to the circular economy in Africa

The push for circularity is gaining momentum, and Africa intends to join the bandwagon. However, significant hurdles remain for Africa to fully integrate circular economy principles into the various e-waste policies and implement them. Policymakers and development practitioners must understand and address these challenges within the continent's unique economic and social context.

Despite efforts to regulate and streamline the sector, weak e-waste and circular economy regulatory and institutional frameworks remain a significant challenge in most African countries. Comprehensive policies and enforcement mechanisms to govern e-waste management are often lacking while existing regulations tend to be fragmented, poorly implemented, or misaligned with circular economy principles. The dominance of informal actors in collecting, dismantling, sorting, and recycling e-waste further complicates attempts to formalize the sector and align policies with these activities.[33]

At a broader level, leveraging e-waste for circular economy policymaking requires coordination across multiple ministries, departments, and agencies. However, in many developing countries, institutional silos and lack of collaboration hinder effective policy development and implementation. Turf wars and disjointed activities among these institutions result in sub-optimal outcomes.

Government structures are often organized along sectoral lines, limiting the cross-sectoral integration necessary for advancing circular economy initiatives. In most of these countries, environment ministries

[33] Formalizing the sector may displace informal workers without adequate support, creating resistance to change.

are frequently among the weakest departments of government (Tsitohery and Zafimahova, 2022), with limited influence over the industrial, innovation and financial strategies needed to advance a circular economy. Fostering a circular economy requires working closely with ministries of finance and industry and other stakeholders to build political support and ensure cross-government ownership of circular economy policies.

A shortage of e-waste management infrastructure continues to limit the potential role of e-waste in implementing circular economy policies in Africa. Globally, Insufficient recycling facilities and waste collection systems hinder effective e-waste processing and resource recovery (Forti et al., 2020). In contrast, the growth of formal, environmentally sound recycling plants remains outpaced by the increase in e-waste. Additionally, there is limited access to modern recycling technologies and an absence of technical expertise in Africa, preventing the adoption of advanced, sustainable e-waste processing methods. These challenges together undermine circular economy efforts.

Reconfiguring African economies to incorporate more circular economy activities in e-waste management requires substantial investment in infrastructure, industrial processes, and innovation. However, African countries are already grappling with a $1.3 trillion annual funding gap to achieve the Sustainable Development Goals.[50] The high costs associated with formal e-waste recycling systems further exacerbate Africa's development challenges, leaving industries and cities driving circular economy initiatives in dire need of financing to support the transition, funds that remain largely unavailable.

Non-existent proper local municipal financing frameworks in Africa mean that cities will seek this investment from central governments, which are already hard-pressed by their thin domestic resource mobilization revenue. Multilateral development banks (MDBs) should come to the rescue but face significant hurdles in scaling up funding for circular economic activities. They are reactive in their financing and respond to specific requests for support from public and private-sector clients, where awareness of the circular economy's potential is lacking.

Investment in unproven business models and new technologies may be seen as high-risk by many MDBs (Lankes, 2021), while the scale of funding required may be too small. MDBs often work with national agencies and cannot offer smaller-scale funding for subnational or municipal projects.[34] At the same time, traditional project-based finance provided by MDBs is not well suited to the systemic and multi-stakeholder approaches often inherent to circular economy solutions. These financial challenges constrain the funding of circular economic activities in Africa.

Resolving these challenges will require a combination of robust policies, strategic investment in infrastructure and technology through blended finance, stakeholder education, and coordinated efforts to formalize the e-waste sector, while ensuring inclusivity and sustainability.

6.6 Regulatory frameworks and legislative drivers for e-waste in Africa

Beyond the Basel and Bamako conventions that govern transboundary e-waste movement, there are noticeable attempts to regulate e-waste in Africa and beyond, with varying degrees of progress across regions. As of 2024, 81 countries, representing 42 percent of all countries globally, had adopted e-waste

[34] https://www.chathamhouse.org/2019/05/inclusive-circular-economy/2-challenges-scaling-circular-economy-developing-countries

policies; this covers 72 percent[35] of the global population, up from the 2019 figure of 71 percent. However, only 13 out of a total of 54 African countries have implemented such frameworks (Lebbie et al., 2021). East and Southern Africa lead the continent, each with four countries covered by comprehensive e-waste regulations. In West Africa, Nigeria and Ghana stand out as pioneers despite being among the highest e-waste generators in Africa, highlighting the persistent challenges in implementing environmental regulations. No e-waste legislation existed in North or Southern Africa as of 2015 (Abafe and Martincigh, 2015). However, progress has been made, with four Southern African countries and one North African country now having regulations. Table 3 provides a regional overview of African e-waste regulation and legislation.

Table 3. Countries with or without national legislation regulating e-waste management

Central Africa		East Africa		North Africa		Southern Africa		West Africa	
Central African Republic	No	Burundi	No	Algeria	No	Angola	No	Benin	No
Cameroon		Comoros	No	**Egypt**		Botswana	No	Burkina Faso	No
Chad	No	Djibouti	No	Libya	No	Lesotho	No	Cape Verde	No
Congo	No	Ethiopia	No	Mauritania	No	**Madagascar**		**Côte d'Ivoire**	
DR Congo	—	**Kenya**		Morocco	No	Malawi	No	Gambia	No
Equatorial Guinea	—	**Rwanda**		Tunisia	No	Mauritius	No	**Ghana**	
Gabon	No	Seychelles	No			Mozambique	No	Guinea	No
		Somalia	—			Namibia	No	Guinea Bissau	No
		South Sudan	—			**Sao Tome and Principe**		Liberia	—
		Sudan	No			**South Africa**		Mali	No
		Tanzania				Eswatini	No	Niger	No
		Uganda				**Zambia**		**Nigeria**	
						Zimbabwe	No	Senegal	No
								Sierra Leone	No
								Togo	No

Source: Lebbie (2021).

[35] See page 13 of the Global E-waste Monitor 2024.

North Africa has taken significant steps toward formalizing e-waste management, with Egypt emerging as a leader. Law No. 202 of 2020 established a dedicated regulatory agency for waste management, while Decree 165/2002 bans the importation of hazardous substances and waste. Tunisia is drafting a regulation to adopt the polluter pays principle for importers of EEE, signaling intent to align with international best practices. However, the region still lacks a broader framework for comprehensive e-waste management.

West Africa demonstrates progress in developing specific e-waste management regulations, particularly in Ghana, Nigeria, and Côte d'Ivoire. Ghana's Hazardous and Electronic Waste Control Act, 2016 (Act 917) and Nigeria's National Environmental (Electrical and Electronic Sector) Regulations (2022) highlight the adoption of extended producer responsibility. In Ghana, EEE producers must pay an "eco levy" based on market share, which funds formal recycling infrastructure through the Environmental Protection Agency (Bimpong et al., 2024). While these initiatives reflect a commitment to structured e-waste management, implementation challenges persist due to limited enforcement capacity and informal sector dominance.

Cameroon, a pioneer in e-waste legislation within Central Africa, starkly contrasts with neighboring countries, most of which lack specific legal frameworks. Although some Central African countries have integrated circular economy principles into broader sustainable development policies, formal e-waste regulations remain absent.

East Africa is becoming a regulatory hub in response to the region's increasing e-waste generation. Kenya's Environmental Management and Coordination Act, 1999 (Cap. 387), and accompanying e-waste regulations mandate licensing for waste handling, transportation, and disposal, administered by the National Environment Management Authority. Rwanda enacted e-waste management regulations in 2018 and is drafting further regulation to strengthen the framework. Similarly, Tanzania and Uganda have progressed with general environmental management regulations addressing e-waste restrictions. These efforts position East Africa as a model for other regions, although challenges in enforcement and infrastructure persist. The bloc has also taken collaborative action: The East African Community Regional E-waste Management Strategy aims to create a sustainable e-waste management system and a harmonized monitoring framework for e-waste in member states.[36]

Southern Africa has seen varied progress in e-waste management. Botswana and Namibia have recently drafted and validated national e-waste strategies and policies, which are awaiting approval. South Africa, however, has made the most significant strides, with mandatory EPR introduced in 2021 under the National Environmental Management Waste Act. Producers of EEE are required to register and establish EPR schemes, enabling more structured e-waste recycling processes. Zambia's Statutory Instrument No. 65 (2018) is a legally binding EPR framework but suffers from inconsistent implementation. Meanwhile, Malawi's 2024 National E-waste Management Policy aims to align waste management with the Sustainable Development Goals, focusing on environmental and public health protection.

Although there is noticeable progress across regions, the overall landscape in Africa remains fragmented. Limited enforcement, informal sector dominance, and gaps in technical expertise continue to hinder the effective implementation of regulations and circular economy principles. Regional collaboration and capacity building are critical for addressing challenges and promoting sustainable e-waste management.

[36] https://www.eaco.int/admin/docs/publications/EACO%20Regional%20E-waste%20Management%20Strategy%202022-2027.pdf

7. Country Case Studies and Comparative Analysis

This section provides a comprehensive comparative analysis of electronic waste management in Ghana and South Africa, two nations representing different regional contexts and developmental stages within Africa. Our analysis examines current e-waste management practices in both countries, highlighting similarities and differences in collection systems, processing methods, and disposal techniques. We also map the complete e-waste value chain in each country, identifying key stakeholders from informal collectors to formal recyclers and examining their roles, interactions, and economic impacts. The policy and regulatory frameworks governing e-waste in Ghana and South Africa are assessed, considering both the implementation of international conventions and the development of national legislation. Finally, we explore the challenges and opportunities each country faces in implementing circular economy principles within their e-waste sectors, identifying potential pathways for sustainable development and resource recovery.

7.1 Ghana case study

Ghana is one of the major hubs for the e-waste industry in Africa. The country is a net importer of EEE, UEEE, and e-waste, attracting imports primarily from Europe and other countries in West Africa. Although clarity and accuracy in e-waste import figures are not readily verifiable, data from the UNDP indicate that Ghana receives approximately 150,000 tonnes[37] of e-waste annually through legal and illegal means. In stark contrast, the e-waste generated in the country was a mere 52,000 tonnes in 2019, of which between 93 percent and 97 percent was collected and recycled by the informal sector through door-to-door collection (Owusu-Sekyere et al., 2022).

Ghana currently hosts a thriving and lucrative business ecosystem that contributes significantly to the economy. According to UNDP, e-waste activities in Ghana rake in between $105 and $268 million in revenue annually. The sector is also a major employment generation avenue for Ghana's youth, particularly in informal recycling and refurbishing activities, employing about 200,000 people nationwide.[38]

Ghana was home to one of the world's biggest e-waste dumpsites, at Agbogbloshie in Accra. As of 2010, it directly employed about 4,000-6,000 people (Prakash et al., 2010), supporting strong entrepreneurship and economic opportunities in the e-waste space by developing community-based collection, recovery, and recycling businesses. In addition to the direct jobs, about 80,000 men, women, and children relied on the dumpsite for survival, living either on-site or in the adjacent slum. These workers were classified among the poorest of the over 5 million inhabitants of Accra, the capital of Ghana, many of whom come from the northern regions of Ghana and neighboring countries such as Niger, Mali, and Côte d'Ivoire.[39]

In July 2021, the Ghanaian government demolished the Agbogbloshie scrapyard (Owusu-Sekyere, 2022). Thereafter, several informal e-waste recycling sites and private waste collection yards aggregating e-waste have emerged across Accra and nearby cities. Notably, Dagomba Line and Suame Magazine in Kumasi, the Ashanti region capital, now host active e-waste dumpsites comparable to, with some more extensive than,

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[37] https://issafrica.org/iss-today/despite-the-hazards-ghanas-illicit-waste-trade-is-booming

[38] https://www.undp.org/ghana/blog/shaping-sustainable-paths-e-waste-management-ghana

[39] https://www.bloomberg.com/news/articles/2019-05-29/the-rich-world-s-electronic-waste-dumped-in-ghana

Agbogbloshie. Atiemo et al. (2016) reports that in Dagomba Line, over 1,000 people are engaged in e-waste and general scrap processing. While this figure may be overestimated, Atiemo et al. (2016) confirm that large-scale scrap processing occurs in the area, adding that Aboabo and Anloga in Kumasi are also key hubs for extensive e-waste recycling activities.

Current e-waste management practices

There is a disagreement on whether Ghana's e-waste management is informal or formally managed. Some government officials believe that the legal framework has touched almost every aspect of e-waste. However, the collection and final disposal of e-waste remains problematic due to a lack of enforcement. The impact of improper waste handling in Ghana is immediately visible, with large dumpsites emerging in urban centers, constituting health hazards and fostering criminal activities.

In practice, Ghana has an e-waste sector where informal operators are found side-by-side with the formal sector. Interviews with industry stakeholders highlight a network of private-sector players prepared to handle aggregated e-waste, including metal, plastic, and reusable components. Some companies allow collectors to sell directly to them, while others employ an agency system in which informal collectors sell to licensed agents. This approach enables recycling entities, particularly metal fabrication companies, to avoid the complications of dealing with informal actors, mainly to avoid involvement in illegal e-waste transactions by ensuring that only authorized agents handle purchases from informal collectors. The activities of the agents are then monitored and regulated by the companies that license them.

A visit to an agent in the Dawhenya enclave (AA Aminu Enterprise) revealed a bustling trade, with subsistence motivated e-waste and scrap dealers earning a modest fee. Some suppliers arrived in large dump trucks from as far as Burkina Faso, transporting aluminum-related e-waste sold by weight. The truck drivers frequently complained about police harassment along the route. The business owner likened e-waste transportation to "dealing in cocaine" due to frequent stops at police checkpoints. After-sales processing primarily involves hazardous methods such as burning and leaching to extract metals from plastic components before they are sent to their final recycler. The sentiment shared highlighted minimal support from the government to enhance their activities despite their environmental services.

The e-waste value chain and stakeholders

Ghana’s e-waste industry is a complex and multifaceted ecosystem comprising diverse value chain actors playing distinct yet interconnected roles. At the top of the value chain are collectors who gather EEE and trade with dismantlers, who mainly employ rudimentary techniques to extract valuable components. These recovered components are then supplied to refurbishers, who repair and repurpose them for resale.

Despite the sector's profitability, private sector involvement in the past was on a limited scale. However, a field visit to parts of Accra, Tema, and Dawhenya found that private individuals have gradually injected capital in building scrapyards that also act as aggregation centers specializing in aluminum and copper-based e-waste. The shift was partly influenced by the displacement of scrap dealers from the Agbogbloshie dumpsite, prompting them to establish independent operations. However, these facilities remain largely informal, relying on rudimentary processing methods rather than advanced recycling technologies. This underscores the urgent need for more efficient and environmentally sustainable e-waste management practices.

The legal framework for regulating the sector in Ghana begins with the Ministry of Environment, Science, Technology, and Innovation (MESTI). MESTI establishes policies and regulations that ensure sectoral alignment with national goals. The Environmental Protection Agency (EPA), which is under the ministerial portfolio of the Ministry of Environment, Science and Technology, exercises direct sector supervision and offers technical guidance to stakeholders within the e-waste management ecosystem. To promote e-waste recycling and proper management of e-waste, the EPA has started aggregating e-waste and keeping it adequately stored and then released to private sector partners for recycling and disposal in an environmentally sustainable manner.

NGOs and development partners have also been engaged in the e-waste sector in Ghana. Among the notable NGOs are Pure Earth, Caritas Ghana, Green Advocacy Ghana, and the Global Alliance for Health and Pollution, which provide research materials, public health advocacy, and community engagement. Development partners such as Germany's GIZ development agency, the European Union, UNDP, and UNEP continue to play critical roles by providing technical assistance, funding, and policy support to strengthen e-waste management practices in Ghana.

Policy and regulatory framework

The e-waste sector in Ghana is directly regulated by the Hazardous and Electronic Waste Control and Management Act, 2016 (Act 917). The enabling legislation, the Hazardous and Electronic Waste Control and Management Regulation (LI 2250) of 2016 provides intensive guidelines on classifying, controlling, and managing waste and related issues. Key provisions in the Act include:

- Provisions require producers and importers of e-waste equipment to register with the Environmental Protection Agency for the payment of an eco-tax. The intent is to utilize the tax funds to formalize and enforce e-waste management practices.
- Act 917 has provisions for operationalizing extended producer responsibility in Ghana. The Act contains provisions to force producers to take responsibility for their products' end-of-life and hold them accountable for the entire lifecycle of their products, especially their disposal.
- Act 917 meticulously identifies and assigns specific roles to key stakeholders within the e-waste value chain identified above. These stakeholders included MESTI, the EPA, the Energy Commission, NGOs, informal and formal recyclers, and local governmental authorities.

However, the implementation of Act 917 has faced challenges. Owing to weak publicity and education, there is low awareness among stakeholders. This lack of awareness has not reduced informal sector activities. Instead, they continue unabated, with unsustainable e-waste disposal practices, such as burning and indiscriminate dumping, posing environmental and health risks. Additionally, EPA authorities have not implemented all the key measures in Act 917, such as formal recycling infrastructure and implementing the EPR provisions.

Despite enacting an advanced regulatory framework, Ghana has yet to adopt an e-waste policy. This is an anomaly since policy should have preceded regulation. Nevertheless, Larry Kotoe of the EPA asserts that they are currently "in the consultative phase of a specific policy" to govern e-waste. Another EPA representative revealed that the new policy would focus on circular economy principles, extended producer responsibility, regulation of electric vehicles (EVs) and EV batteries, strengthening port inspection regimes on second-hand EVs and batteries, and infrastructure development.

Progress towards a circular economy

Opportunities in Ghana's e-waste sector mirror global trends, where efficient collection systems, recycling infrastructure, responsible disposal, and innovative reuse of recovered materials are precursors to harnessing these opportunities. Practically, the economic viability of these opportunities is key to securing the continuous participation of informal sector players in formalizing the sector to harness the opportunities. Financial viability usually outweighs these players' environmental concerns. Ensuring sustainability, therefore, requires offering compensation that meets or exceeds their current earnings.

Data on the international market indicate that gold recovery could present the highest economic potential as one of the untapped avenues for promoting some circularity in e-waste in Ghana. However, while Nigeria has developed e-waste gold recovery processes, Ghana is yet to capitalize on this opportunity. Ghana could establish a circular economy around gold recovery from e-waste by reverse-engineering existing technologies.

Reverse-engineering existing technologies notwithstanding, a more immediate, lower-hanging opportunity could lie in supplying e-waste components to the country's growing steel industry. With new steel plants emerging, demand for recyclable materials is increasing. The demand is creating a viable market for specific e-waste components as raw material.

Nana Yaw Konadu of Electro Recycling, a company specializing in e-waste recycling, revealed that they have had to import used televisions and electronic items from other countries as raw materials for refurbishment due to insufficient local supply. While the EPA and the GIZ support e-waste aggregation efforts, demand still outstrips supply due to logistical issues despite the flows of e-waste into the country. The agency acknowledges that current efforts to collect e-waste in their aggregation programs have captured less than 1 percent of Ghana's total e-waste, highlighting vast untapped opportunities for supplying materials to the recycling industry.

GIZ's incentive-based collection program generated renewed interest and engagement in Ghana's e-waste management landscape. Through the program, government agencies such as the EPA and private sector entities received support that promotes circularity and enhanced profitability of the private entities. For instance, the EPA introduced a buyback initiative for households and individuals with e-waste. This initiative also enabled informal collectors to sell their cables to registered collection and recycling companies that process them in an environmentally responsible manner. The EPA has established storage facilities to manage collected materials before handing them to licensed recyclers. Private companies such as Electro Recycling and Zeal International in the Western region have benefited from these materials.

The way forward

The operation of the informal sector continues to stall sustainable e-waste management in Ghana. Academics and practitioners continue to advocate for formalization. Ghana has taken another direction. Discussions with authorities indicate that the EPA continues to regulate and improve the sector through various initiatives. Current initiatives border on registering and issuing identification cards to collectors in various districts of Ghana to better regulate and integrate informal collectors among formal recyclers, beginning with a pilot project in Agbogbloshie before it was closed.

The EPA emphasizes that this process is integration, not formalization. The goal is to create a structured pathway for them to participate in the formal e-waste value chain, ensuring economic viability and environmental sustainability. The initiative is being implemented in Accra, Kumasi, and Tamale, with further expansion planned. While these efforts are commendable, conversations with stakeholders highlighted the urgent need for transformative and innovative policy frameworks that move beyond pilot initiatives to deliver systemic change. Such policies should embed circular economy principles, foster private sector participation, and improve the enforcement of e-waste regulations. These paths, if adhered to, will offer scalable models and policy lessons for other African countries grappling with similar challenges and help accelerate practical progress in Ghana's e-waste management.

7.2 South Africa case study

South Africa is experiencing a rapid increase in electronic waste (e-waste) generation. Ranked among the top three e-waste-generating countries in Africa,[40] South Africa, on average, produces about 360,000 tonnes of e-waste annually (Baldé et al., 2017; DEA, 2015a; as cited in Sadan, 2019). Despite e-waste constituting just 5-8 percent of municipal solid waste, it is the fastest-growing waste stream, growing at a rate three times that of general municipal waste (Lydall et al., 2017; DEA, 2015a; as cited in Sadan, 2019).

The rapid increase in e-waste generation makes effective management crucial for environmental sustainability, public health, and economic development (Ichikowitz and Hattingh, 2020). However, only 11 percent of generated e-waste is formally recycled, while the remainder is stockpiled, informally processed, or landfilled, posing significant environmental and health risks and undermining economic opportunities (Lydall et al., 2017; Schoeman and Ramutanda, 2022; Sadan, 2019). Without urgent intervention, hazardous waste accumulation could lead to increased soil and water contamination, worsening public health outcomes, and lost economic opportunities in resource recovery.

In recent years, though, South Africa has made significant progress towards transitioning from a waste management model focused on landfills and disposal to a circular economy approach. This shift is driven by pressure on municipalities in the face of the landfill crisis, positive policy and regulatory reforms, and increased sustainability awareness (GreenCape, 2020; Moyo et al., 2022; Jaarsveldt, 2016). The national regulatory frameworks such as the EPR regulations underscore the country's commitment to transitioning towards sustainable e-waste management, diverting nearly 68,000 tonnes of e-waste from landfills (DFFE, 2024). Through continued legislative reforms, investment in recycling infrastructure, and enhanced public education, South Africa is still working to overcome the current barriers to sustainable e-waste management.

This brief case study evaluates e-waste management in South Africa by assessing policy frameworks, value chain dynamics, management challenges, and circular economy initiatives. It concludes with key lessons and policy recommendations for enhancing sustainability and efficiency in e-waste handling.

Current E-waste management practices

E-waste collection in South Africa operates through both formal and informal channels, with PROs, municipal drop-off points, and corporate programs ensuring regulatory compliance. However, the informal sector, comprising over 10,000 waste pickers, dominates due to limited formal infrastructure and high unemployment (GreenCape, 2020). While informal collectors play a vital role in e-waste aggregation,

[40] The other two are Egypt and Nigeria.

unsafe practices like open burning and manual dismantling pose serious environmental and health risks (Lydall et al., 2017).

South Africa's e-waste recycling infrastructure remains underdeveloped, with over 100 registered businesses primarily focused on collection and dismantling rather than full-scale recycling (GreenCape, 2020). The country has only two major e-waste processing facilities (SA Precious Metals and Rand Refinery), leaving most non-metal fractions to be stockpiled, discarded, or exported (Lydall et al., 2017). Limited local processing capacity, including the absence of degassing facilities for refrigerators and air conditioners, leads to environmental hazards such as uncontrolled refrigerant emissions (Sadan, 2019).

Refurbishing and reselling second-hand electronics in South Africa, particularly in the informal sector, provides economic opportunities and extends product lifecycles. However, weak regulatory oversight and unclear guidelines pose challenges, impacting product safety and proper disposal of unsalvageable components (Sadan, 2019). Comparative insights from Ghana and Nigeria show that informal refurbishers improve affordability of electronic equipment for low-income people, yet fragmented regulations and low consumer awareness limit the sector's potential in South Africa.

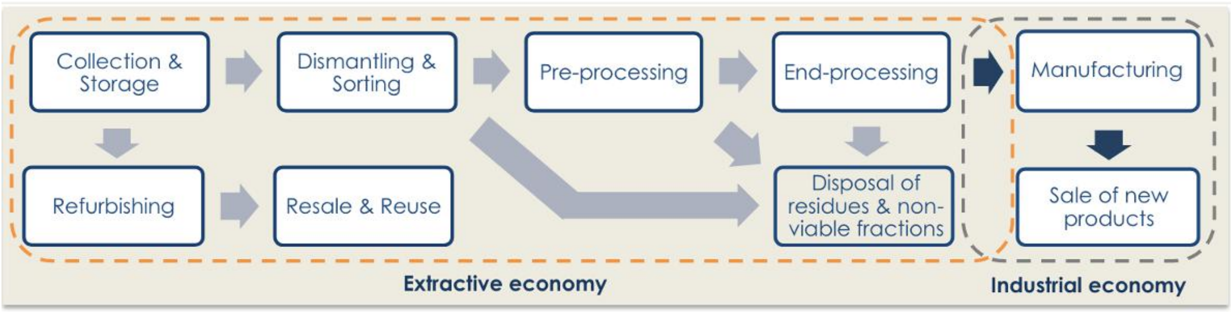
Overall, e-waste management in South Africa faces significant challenges, including the dominance of the informal sector, which relies on unsafe recycling methods that pose severe environmental and health risks (Lebbie et al., 2021). Limited public awareness and inadequate collection infrastructure lead to stockpiling and improper disposal, while weak enforcement and regulatory gaps hinder compliance (Moyo et al., 2022). Financial constraints, including insufficient investment incentives[41] and weak EPR implementation further restrict formal recycling efforts. Regulatory requirements involving significant administrative and financial strain to become compliant hinders the ability of e-waste management facilities to expand. Additional challenges include skills shortages, and technological limitations prevent the adoption of advanced recycling processes, while most recovered materials are exported due to limited local processing capacity (Sadan, 2019).

The e-waste value chain and stakeholders

The e-waste value chain in South Africa comprises four main stages: collection and storage, dismantling and sorting, pre-processing, and end-processing (final materials recovery), with additional activities including refurbishment and re-use, as well as residue disposal/final disposal that further shape the value chain (Sadan, 2019; Lydall et al., 2017, p. 26).

[41] Absence of tax breaks, subsidies, and structured investment programs.

Figure 8. Stages in the e-waste value chain



Source: Sadan (2019).

From an institutional perspective, multiple government agencies oversee e-waste regulations. The Department of Forestry, Fisheries, and the Environment enforces environmental laws, while the National Treasury manages fiscal incentives supporting waste reduction. The Department of Trade, Industry, and Competition facilitates trade policies promoting sustainable product design and incentivizes recycling and recovery technologies, and the PROs such as eWASA E-Waste Recycling Authority establish and manage EPR schemes and oversees compliance with EPR regulations (GreenCape, 2020; Godfrey et al., 2021).

The collection of e-waste in South Africa is done via formal and informal channels, with the informal sector playing a dominant role. Producer responsibility organizations (PROs) and waste management companies facilitate the formal collection, while informal collectors retrieve e-waste from households, businesses, and dumpsites (Lydall et al., 2017). Once collected, e-waste is dismantled, with formal recyclers using advanced technologies for safe material recovery, whereas informal dismantlers often employ hazardous methods to salvage high-value parts.

Pre-processing involves mechanical and chemical extraction of valuable materials. Industrial recyclers utilize advanced processing techniques such as shredding, grinding, and magnetic separation techniques, while informal recyclers employ rudimentary methods like open burning to extract metals. Even with a growing formal recycling sector, the number of players active in pre-processing is considerably less than in the dismantling stage (Lydall et al., 2017).

The final stage, end-processing, where recovered materials are refined and reused in manufacturing, faces constraints due to South Africa's limited refining facilities, resulting in the export of high-value e-waste fractions for processing abroad. High capital costs limit entry into processing, though dismantling and refurbishment offer lower barriers.[42] For non-recyclable e-waste, disposal remains a challenge. Despite landfill restrictions on hazardous e-waste, enforcement gaps result in large volumes of electronic waste still being dumped in landfills or incinerated illegally.

Both the formal and informal sectors engage in "cherry-picking" and discarding the rest of the equipment, which is usually the bulk mass of EEE. Cherry-picking is the process whereby high-value fractions are stripped, and the rest of the equipment is disposed of. The disposal involves passing the fractions to any downstream processor that is willing to take the discarded parts. If none exist, it is likely to end in a landfill or illegally dumped.

[42] Refurbishment contributes up to 60 percent of small business revenues but the sector is underdeveloped.

The division of responsibilities in the e-waste value chain involves government bodies overseeing legislation and compliance, while private sector companies handle formal recycling and refurbishment. Informal workers collect and dismantle e-waste and NGOs act as watchdogs, educating the public and advocating for better systems. Government agencies face enforcement challenges. The private sector, on the other hand, requires stronger incentives to expand eco-friendly initiatives and comply with EPR policies, and the informal sector operates outside regulatory frameworks.

The sequential treatment process of the e-waste value chain is such that the efficiency of these processes impacts the volume of waste that is either recycled or disposed of in landfills. For instance, the primary challenge of the e-waste recycling industry is the limited availability of e-waste for processing, with insufficient volumes constraining the "transition from manual dismantling to advanced processing and value recovery" (Lydall et al., 2017). Ultimately, the industry's performance as a system—particularly in integrating formal and informal waste management actors and improving collection systems—determines the environmental and economic outcomes of e-waste management.

Policy and regulatory framework

South Africa's e-waste management is governed the principal act, the National Environmental Management Act (NEMA) (1998) alongside a specialized act—the National Environmental Management: Waste Act (NEMWA) (2008). Key policies include the National Waste Management Strategy (NWMS) (2020) and the Draft National Policy for the Management of Waste Electrical and Electronic Equipment (2024). Early policies such as the 1999 NWMS and the 2000 White Paper on Integrated Pollution and Waste Management marked a transition to recycling as an alternative to landfilling (Moyo et al., 2022).[43] The enactment of the NEMWA in 2008, followed by a suite of related regulations, norms, and standards, formalized a legal framework for waste classification, pollution control, and sustainability-driven waste management (Moyo et al., 2022; Sadan, 2019).

A major milestone was the introduction of EPR regulations, building upon the preceding voluntary EPR initiatives initially led by industry and non-profit organizations. In 2021, EPR become mandatory as stipulated in the Extended Producer Responsibility Regulations (2021) (Appendix 1) and the product specific notices on EEE, lighting, and paper, packaging and some single-use products. These dynamic and progressive frameworks are the result of significant historical evolution from basic landfill management to a system that promotes recycling, waste reduction, and producer responsibility. The EPR regulations sought to establish a more structured and responsible approach to managing e-waste involving producer responsibility organizations. In short, it made producers and importers become more accountable for the waste their products generated. In 2021, a landfill ban on e-waste was enforced, further driving industry to find alternative solutions to the e-waste problem.

Today, the country's e-waste management policies and regulations are firmly embedded within a broader environmental sustainability agenda, with a clear focus on circular economy principles. Current efforts are focused on strengthening enforcement mechanisms and expanding the scope of EPR to cover more product categories.

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[43] Related developments, particularly the Polokwane Declaration in 2001, set forth ambitious targets for waste reduction and recycling that drove private sector investment in recycling even in the absence of legislation.

Broadly, South Africa's e-waste policies and regulations align closely with frameworks such as the Basel Convention, which governs transboundary hazardous waste movement (GreenCape, 2020). They are in line with global objectives such as the SDGs, the Southern African Development Community (SADC) regional waste management guidelines. They also reflect best practices from international frameworks, such as the European Union's Waste Electrical and Electronic Equipment (WEEE) directive (Godfrey et al., 2021; GreenCape, 2020).

Compared with some SADC countries, South Africa has stricter e-waste regulations (GreenCape, 2020). Challenges in harmonizing these regulations with less developed frameworks in neighboring countries often lead to cross-border issues such as illegal dumping and inconsistent compliance mechanisms (GreenCape, 2020).

Several compliance mechanisms support the implementation and enforcement of regulations. These include mandatory registration and reporting to the DFFE by electronic and electrical equipment producers, importers and agents; regular site inspections and audits of recycling facilities, landfill sites, and businesses handling e-waste by DFFE and local municipalities; and penalties and fines for non-compliance. Others include licensing and accreditation of e-waste operators and recycling facilities, reporting obligations through the South African Waste Information System—a centralized database for tracking waste generation, recycling, and disposal. Furthermore, manufacturers and importers are required to make mandatory financial contributions to EPR schemes and establish tack-back schemes or register with PROs for this purpose (DFFE, 2020; DFFE, 2021).

Still, enforcement gaps remain despite a strong legislative framework and many compliance mechanisms. This is due to inadequate collection and recycling infrastructure, low public awareness of proper e-waste disposal, e-waste regulations and recycling options, and regulatory overlaps (GreenCape, 2020; Sadan, 2019; Netherlands Enterprise Agency, 2023; Southern African-German Chamber of Commerce and Industry NPC, 2016). A large, informal, e-waste sector operates without sufficient oversight, contributing to environmental risks (Godfrey et al., 2021). Limited resources within regulatory agencies and municipalities also hinder policy enforcement (GreenCape, 2020; Netherlands Enterprise Agency, 2023). Over-regulation and the consequent growing cost of compliance administration along with weak coordination among government entities pose challenges to effective e-waste management (Moyo et al., 2022; Netherlands Enterprise Agency, 2023; Ichikowitz and Hattingh, 2020; Sadan, 2019).

Progress toward a circular economy

South Africa's transition towards a circular economy in the e-waste sector is gaining momentum. The country is advancing circular economy principles in e-waste management through public-private partnerships and regulatory measures. Extended producer responsibility schemes in South Africa are implemented by Producer Responsibility Organizations (PROs) such as the e-Waste Association of South Africa (eWASA) and the WEEE initiative in iLembe District, which focus on responsible e-waste management. These initiatives emphasize sustainable waste collection, improved recycling systems, and economic benefits derived from secondary raw materials.

- **The Gauteng E-Waste Management System.** This is a pioneering initiative addressing the province's growing e-waste crisis while creating economic opportunities. Developed through a collaboration between the Gauteng Department of e-Government (e-Gov) and the University of Johannesburg, the system enhances waste collection, processing, and recycling through centralized collection hubs and public-private partnerships. Key innovations include centralized collection hubs, public-private-academic-academic partnerships, and support for MSMEs and informal sector entrepreneurs in repurposing and recycling e-waste. Additionally, the initiative promotes extended producer responsibility**,** encouraging manufacturers to integrate recyclability into product design. Public awareness campaigns also play a crucial role in educating communities on responsible e-waste disposal. Gauteng's e-Waste Management System exemplifies a scalable, forward-thinking approach to tackling electronic waste, demonstrating how innovation, strategic partnerships, and economic incentives can drive environmental sustainability and inclusive growth in South Africa's green economy.

- **iLembe Waste Electrical and Electronic Equipment (WEEE) Initiative.** This initiative is a pioneering approach to e-waste management, enhancing collection, recycling, and policy integration in South Africa. As part of the Sustainable Recycling Industries program,[44] it fosters collaboration between government, businesses, and the informal sector to improve waste collection, promote responsible recycling, and support local beneficiation. The initiative strengthens compliance with EPR regulations while creating income opportunities by formalizing informal waste pickers through training and market linkages. A key innovation is its circular economy approach, which encourages refurbishment and resale of electrical and electronic equipment to extend product life cycles. Instead of exporting valuable fractions such as printed circuit boards, the initiative promotes local processing to maximize economic benefits. The Municipal E-Waste Asset Disposal Project further supports this by piloting a structured model for disposing of government-owned e-waste, ensuring compliance with procurement and environmental regulations. Public engagement through awareness campaigns, collection drives, and designated drop-off points improves waste separation and recycling rates. Beyond operational improvements, the initiative actively works with national and provincial policymakers to align municipal waste management plans with EPR regulations. By identifying legislative barriers—such as restrictions on government e-waste disposal—it advocates for policy reforms to facilitate responsible recycling.

  The iLembe WEEE Initiative is a leading example of multi-stakeholder collaboration involving government agencies, private enterprises, and NGOs. This initiative has successfully integrated local economies into the circular economy framework through partnerships with municipalities, academia, and businesses. The initiative presents a scalable model for improving e-waste management across South Africa, supporting job creation, sustainability, and the transition to a circular economy.

These initiative, in addition to the South African e-Gov WEEE strategy, have significantly enhanced South Africa's circular economy transition by integrating the informal waste sector into formal recycling frameworks. Scalable and inclusive waste management models demonstrate the importance of policy interventions that promote sustainability while protecting livelihoods.

[44] Sustainable Recycling Industries (SRI) is a Swiss-funded program that supports the sustainable integration of small and medium enterprises into global recycling systems while promoting environmental and social standards in e-waste management.

South Africa has significant potential to leverage secondary raw materials from e-waste for local manufacturing, thereby reducing reliance on virgin resources and supporting industrialization.[45] Scaling up circular economy models like the iLembe WEEE Initiative integrates e-waste collection, education, and recycling into local economies. Such initiatives ensure regulatory compliance while fostering community participation. Moreover, prioritizing waste reduction at the design stage enhances material efficiency and minimizes environmental impact, further strengthening South Africa's transition towards a sustainable, circular economy.

The way forward

South Africa has made significant progress in e-waste management through EPR schemes, public-private partnerships, and structured collection systems, exemplified by initiatives like the iLembe WEEE program. However, persistent challenges—including weak regulatory enforcement, limited municipal capacity, and the exclusion of informal collectors – hinder effective waste recovery. South Africa must strengthen regulatory enforcement, expand recycling infrastructure, integrate informal waste collectors, and attract private sector investment through incentives and green financing to address these gaps. Raising public awareness through nationwide campaigns and education programs is crucial for promoting responsible e-waste disposal. Fostering regional collaboration with SADC and the African Union can harmonize policies, enhance technical capacity, and improve cross-border recycling efforts.

7.3 Comparative analysis of e-waste management in Ghana and South Africa

E-waste management in Ghana and South Africa presents distinct yet interconnected challenges and opportunities shaped by international and domestic policy frameworks, economic factors, and infrastructure capabilities. While both countries are among Africa's largest e-waste producers and importers, their approaches to regulation, formalization, and circular economy integration differ significantly.

Ghana's e-waste sector is characterized by a dominant informal economy. The country serves as a major hub for second-hand electronics, with a thriving repair and refurbishing ecosystem that provides livelihoods for thousands of workers. The Agbogbloshie dumpsite, once a notorious symbol of hazardous waste processing, has been dismantled, yet informal recycling operations have since dispersed across various cities. Ghana's regulatory framework, led by the Hazardous and Electronic Waste Control and Management Act, 2016 (Act 917), introduces EPR provisions and an eco-tax on imported electronics. However, implementation remains incomplete, with persistent challenges in enforcement, collection systems, and formalization of the informal sector.

In contrast, South Africa has a more structured regulatory environment, with an advanced EPR scheme that mandates producer accountability and financial contributions towards waste management. Unlike Ghana, where informal recycling dominates, South Africa boasts a nascent but growing formal recycling sector. The government has introduced landfill bans on e-waste and fostered partnerships between municipalities, producer responsibility organizations (PROs), and private recycling firms. However, the high

[45] Recycling one million mobile phones, for instance, can recover approximately 16,000 kg of copper, 350 kg of silver, 34 kg of gold, and 15 kg of palladium, highlighting the economic and environmental benefits of e-waste recovery.

costs of compliance, limited consumer awareness, and infrastructural gaps still hinder efficient e-waste recovery and recycling efforts.

Despite their differences, both countries share key challenges, including the prevalence of informal recycling, limited financing for circular economy initiatives, and weak enforcement of regulations. However, South Africa's progress in formalization and regulatory enforcement serves as a model for Ghana. The Gauteng E-Waste Management System and iLembe WEEE Initiative demonstrate successful multi-stakeholder engagement, supporting small-scale recyclers and informal workers while promoting local beneficiation of recovered materials. Ghana, on the other hand, has shown promise through its eco-levy scheme, which, if effectively implemented, could generate sustainable funding for formal recycling programs.

A broader regional perspective reveals additional insights from other major African e-waste hubs such as Nigeria, Egypt, and Kenya. Nigeria, a significant e-waste destination in West Africa, faces informal sector challenges similar to those in Ghana but has made progress through the introduction of EPR regulations and partnerships with global electronics manufacturers to improve waste collection and recycling. Egypt has a more structured approach, driven by government-led waste management policies and dedicated e-waste recycling zones. Meanwhile, Kenya has leveraged public-private partnerships to establish formalized e-waste recycling centers, helping to bridge the gap between informal collectors and formal recyclers.

To enhance their e-waste management strategies, both countries must address policy gaps and enforcement weaknesses. Ghana should prioritize greater integration of informal collectors into formal recycling networks, while South Africa must strengthen financial incentives to scale up recycling infrastructure. Cross-border collaboration, particularly within ECOWAS and SADC, could also drive harmonized policies, knowledge sharing, and investment in sustainable e-waste management solutions.

In summary, while South Africa leads in policy development and formal recycling initiatives, Ghana exhibits strong potential in informal sector integration and circular economy opportunities. Both nations can benefit from mutual learning, improved regulatory enforcement, and increased investment in e-waste processing infrastructure to unlock the full potential of the e-waste value chain and contribute to a sustainable circular economy in Africa.

8. Effective Approaches to E-waste: Beyond Recycling Towards a Circular Economy

This chapter examines advanced e-waste management strategies beyond recycling, focusing on repair, refurbishment, innovative product design, and hybrid models. It highlights community initiatives, eco-design principles, and successful recycling practices in Africa, emphasizing the integration of the informal and formal sectors for better resource recovery and working conditions. The realization is that circular economic activities in the e-waste stream can be promoted without necessarily promoting recycling.

8.1 Moving up the R9 Ladder

Downstream practices such as recycling and recovery continue to be the focus of e-waste management across Africa with limited emphasis on the other dimensions of the higher-order "R-strategies" by Potting et al. (2017) that precede recycling: refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, and repurpose (Potting et al., 2017). These nine strategies can effectively drive any circularity agenda in Africa. In Africa, although informal repair and reuse are widespread, especially in West African countries like Nigeria and Ghana and Kenya in East Africa, they often operate outside the purview of key regulatory agencies, with most of them lacking the technical and financial support needed to scale their activities.[46] Africa has not made significant progress in formal policies and infrastructure needed to anchor higher-value circular practices—such as designing for disassembly, modular upgrades, or product-as-a-service models. This reveals a broader gap in circular transition in Africa; the continent has yet to tap fully the opportunities for innovation in product design and lifecycle extension. The following sections explore in detail how scaling up repair and refurbishment, alongside innovative and circular product design, can support African countries to improve circularity in the e-waste sector.

8.2 Repair and refurbishment

Repair and refurbishment are a practical approach to reducing landfill waste, conserving and preserving natural resources, stifling the supply of e-waste, and providing consumers with cost-effective alternatives to new electronic devices. This involves fixing and upgrading an unwanted or outmoded electronic device (for example, computers, radio, televisions, and phones), to restore the functionality, and or extend the lifespan of the device.[47]

Repairing and refurbishing e-waste creates significant employment opportunities in Africa; it is strongly driven by the high demand for refurbished and second-hand electronic gadgets (Maes et al., 2022) due to the low income levels in Africa. However, older refurbished devices often consume more electricity than newer models, making energy efficiency a critical consideration. According to Paul et al. (2022), average electrical energy consumption increases by 27 percent after 16 years of use, exacerbating energy supply challenges in countries like Ghana and South Africa. As a result, some governments have to restrict or even ban the purchase of old, second-hand, or repaired electronics due to energy efficiency concerns. Despite

[46] https://en.unav.edu/web/global-affairs/ghana-y-nigeria-como-las-lagunas-legales-y-factores-locales-perpetuan-la-problematica-del-e-waste

[47] https://worldgreenewaste.com/refurbishing/

these restrictions, the high cost of new products has made such bans challenging to enforce, particularly in rural areas where the demand for affordable electronics remains strong. Repair and refurbishment must target energy efficiency as a core objective. The high demand for repaired second-hand goods has made e-waste dumpsites in Africa, like Agbogbloshie, a vital market for electronic spare parts used in repair and refurbishment (Adanu et al., 2020). While official designated shops do not exist for electronic parts, the abundance of diverse scraps allows individuals to find components that meet their specific needs with relative ease.

The processes for repair and refurbishment are fairly straightforward and less time-consuming. It all begins with an assessment to evaluate the feasibility of repairing as compared to acquiring a new device. If the repairer deems it feasible, he prioritizes devices and proceeds to sanitize them, i.e., removing dust and debris, followed by secure data wiping to protect privacy. Non-functional components are repaired or replaced cost-effectively, and rigorous testing ensures reliability. Lastly, cosmetic and software upgrades improve the appearance and functionality of the device, and a refurbished product is ready.

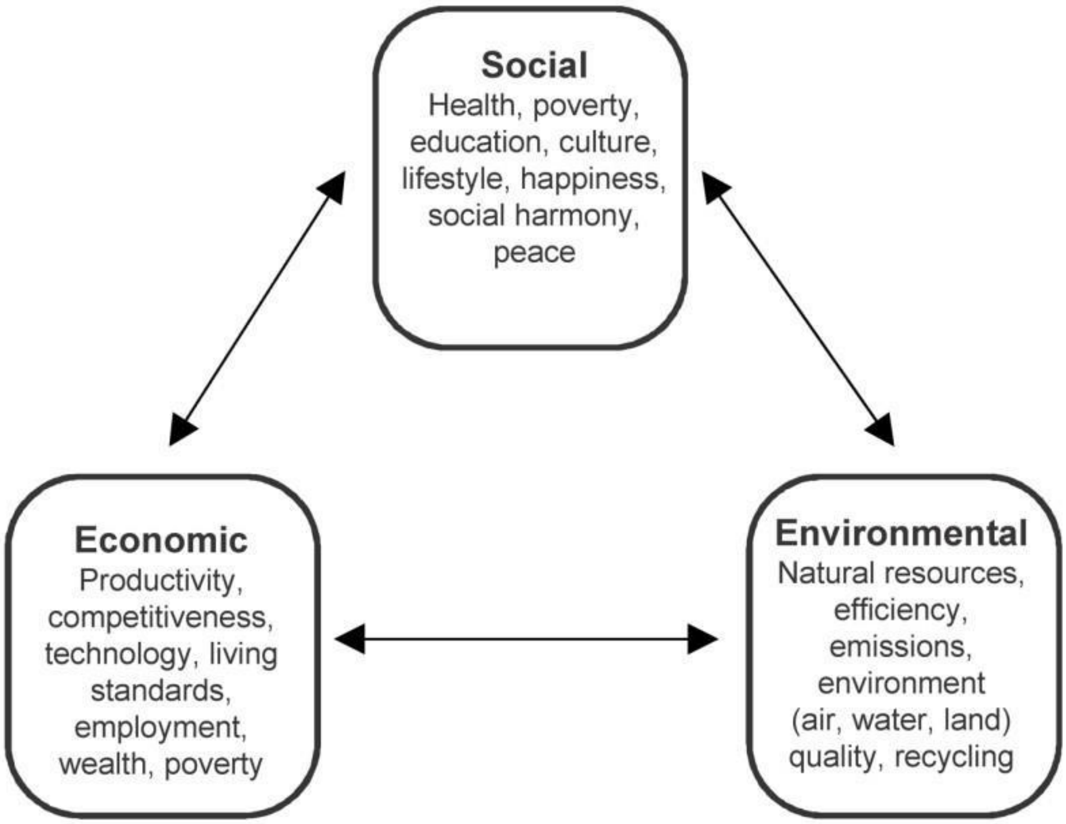
8.3 Innovative product design

Manufacturing and production centers can play a critical role in reducing e-waste. Through innovative product design, close collaboration with policymakers, and aggressive consumer education, manufacturers can prioritize sustainability from conceptualization through to production. Manufacturers can significantly influence EEE's environmental and social impact by adopting sustainable practices and addressing challenges at the source. At the pre-production stage, it can be done by integrating recycled materials into supply chains, reducing reliance on new raw materials. Post-production, producers and manufacturers can implement take-back schemes and producer responsibility programs to manage product end-of-life phases effectively.

One practical approach is incorporating eco-design principles in the design of EEE. Eco-design principles aim to ensure easier repair, upgrade, and recycling procedures. Beyond the environmental considerations, eco-design principles in EEE have economic benefits. Manufacturers can reduce their cost of production and improve their competitive advantage by improving energy and material efficiency (Singhal et al., 2024). However, manufacturers will need increased coordination within their organization to make eco-design implementation successful (Pradeep and Kumar, 2019). A wide range of factors must be considered before integrating eco-design principles in electronic device production, such as environmental impact, economic costs, and social implications. Such considerations also mean that these factors must be balanced with some trade-offs at some point.

Figure 9 indicates a systems-thinking approach for sustainable development. It emphasizes the interconnectedness of social, economic, and environmental factors in producing a sustainable outcome, demonstrating that sustainable development approaches must be holistic. The social dimension focuses on well-being, equity, and social cohesion; the economic dimension safeguards productivity, employment, and wealth generation; and the environmental dimension looks at the responsible use of natural resources, pollution control, and ecosystem health. Tischner and Hora's (2019) sustainable manufacturing framework basically supports the production of products and systems that factor in all three dimensions and that minimize resource consumption and emissions, enhancing economic performance and contributing positively to societal needs.

Figure 9. Eco-design and manufacturing considerations



Source: Tischner and Hora (2019).

Other sustainable design strategies include:

- **Material efficiency**. Incorporating recycled materials to reduce reliance on virgin resources.
- **Modular design**. Facilitating easy repairs and upgrades to extend product lifespan.
- **Take-back schemes**. Encouraging producer responsibility in end-of-life management.

However, implementing eco-design in Africa faces challenges such as limited expertise, lack of regulatory support, and cost concerns for manufacturers. Policymakers must incentivize sustainable production by offering tax breaks, funding research, and enforcing product standards. Achieving this balance can be problematic, especially when the stakeholders involved have differing concerns (Zhong et al., 2017; Arun et al., 2016). Awareness eco-design and implementation benefits may be poor, and this can limit uptake. Eco-design requires a special expertise, resources and skillset that may not be readily available in many African countries. Where available, it may not be widely accessible or affordable, particularly for small and medium enterprises. Also, current regulatory scans in Africa do not have strong support for such innovation and initiatives. Many companies in the e-waste sector may not see a business case for adopting and implementing the eco-design principle, especially if their competitors have not done so. Therefore, the private sector will need a strong incentive to embrace it.

Many global electronic brands have made eco-design principles part of their product design and production processes. The giant electronics company Philips, for example, has implemented eco-design principles in its product line, including sustainable materials selection and energy efficiency. Philips also employs recycled materials, designs products for disassembly and recycling, and uses energy-efficient components to reduce environmental impact.

8.4 Formal and informal recycling practices in Africa

E-waste recycling in Africa is predominantly informal. Informality is difficult to define, and this will depend on the laws within a specific African country. There is also a complex interplay between formal recycling and informal practices, each uniquely addressing the continent's growing e-waste challenge.

Characteristics of the formal recycling sector

Formal e-waste management would entail an established business structure and compliance with regulatory frameworks. Formal operations would need to adhere to occupational health and safety standards as well as ergonomic considerations. Their employees would need to be well trained, with protocols in place for various safety measures, dismantling, and storage activities. Formal entities would also be expected to ensure secure data destruction and potentially venture into recovering valuable materials for reuse as part of their business activities. In some parts of Africa (notably Egypt), they have been seen collaborating with manufacturers, governments, and international organizations to support EPR programs.

The formal e-waste management sector is growing, especially in South Africa (with companies like Desco Electronic Recyclers) and Egypt (with companies like Egyptian Electronics Recycling Co.), where formal e-waste management appears to be gaining momentum. In Nigeria and Ghana, formal e-waste management progress is evident despite the dominance of the informal sector.

Formal recycling operations are desirable because of their positive environmental outcomes, decent job-creation effect, and environmental compliance with international standards. However, they are not without challenges. Some challenges faced by formal recycling include limited financing, insufficient access to e-waste, and competition from the informal sector, which provides a substantial portion of e-waste collection and initial processing. These challenges necessitate informal integration to leverage the benefits from the informal sector whilst ensuring environmental stewardship. Interventions require increased policy support, investment, and consumer participation.

Africa can learn from best practices in Asia and Europe's structured formal recycling models, where strong regulations, EPR, and financial incentives are driving efficiency. The EPR framework in Europe mandates manufacturers to finance e-waste collection and recycling, ensuring a well-funded system. Asia, particularly Japan and South Korea, integrates high-tech recycling facilities with government oversight, ensuring minimal environmental impact. A key lesson is balancing regulation with incentives—while strict enforcement ensures compliance, subsidies for recyclers and tax incentives for businesses encourage investment. For Africa, hybrid financing mechanisms—such as eco-levies on new EEE, public-private partnerships, and recycling credits—can support the sector without displacing informal workers. Additionally, integrating informal collectors into formal networks, as seen in India's model, can enhance collection rates while providing economic security.

Consumer responsibility is equally crucial in strengthening Africa's recycling efforts. Africa must learn from Germany and South Korea where public awareness campaigns have significantly improved recycling habits through clear labeling, collection incentives, and widespread education.[48] African countries can adopt strategies such as deposit-return schemes where consumers receive incentives for returning old electronics or community-driven initiatives that promote responsible disposal. The responsibility lies with governments and NGOs to use digital platforms and the media to educate consumers on e-waste hazards and the benefits of proper recycling.

Characteristics of the informal recycling sector

Informal e-waste recycling is the dominant form of e-waste management in Africa. The businesses in the sector are primarily under sole proprietorship and often operate under legacy and family-centered models. Those that have lasted for many years are usually family-run, passed down through generations, and heavily reliant on family members for the labor force. This structure fosters strong community bonds and ensures smooth operations within networks of relatives and local partners, especially when they operate within a particular geographic location. The level of education in such networks is often poor, making it difficult for them to engage appropriately with the government and hindering the adoption of advanced technology and compliance with regulations.

Operators focus on maximizing profit margins through adaptable and flexible business models. According to Lofty (2024), businesses in the informal e-waste management sector remain cautious about what the market can dictate, yet entrepreneurs quickly adjust to changing market conditions. The price of metals in the market is determined daily, with transactions predominantly cash-based, ensuring immediate liquidity and uninterrupted operations. Informal e-waste trading centers often operate in less conspicuous locations to avoid legal scrutiny. This seeming lack of oversight of informal operators has contributed to their expansion but has also led to unsustainable and potentially harmful practices.

The social fabric within informal e-waste operations is built on faith, trust, and mutual collaboration among operators. The workers and entrepreneurs provide their own form of social security based on family and friends' support systems, supporting community members in times of need, such as illness, injury, or personal crises. Collection networks often function through a "hub and spoke" model, especially in Egypt, where family members scatter across different regions to gather e-waste materials. Informal workers have a strong sense of ownership and independence, valuing their business, workspace, and materials despite the often small scale of their operations. E-waste recycling is a predominantly male-dominated sector, while women are more likely to be waste reclaimers at dumpsites. Child labor is widespread, especially at the collection and dismantling phase. Additionally, the economic and technical inefficiencies of informal recycling practices are pronounced. Outdated and wasteful methods result in material losses, reducing financial returns.

The informal e-waste management sector in Africa highlights various strengths and weaknesses. Strengths include the adaptability of the sector, extensive networks, and strong community ties. The weaknesses are seen throughout various informal economies and include limited access to land and education, non-

[48] https://clarity.eco/news/germany-and-epr-for-packaging-a-model-for-sustainable-waste-management

compliance with regulatory requirements, the increased risk of environmental degradation, and having severe impacts on the health of the handler.

8.5 Hybrid models: integrating informal and formal sectors

The informal recycling sector's dominance should be strategically leveraged to promote the capital-intensive formal recycling sector to maximize the potential of e-waste recycling in Africa. Establishing a symbiotic relationship between formal and informal practices is essential. For instance, the informal sector’s extensive collection networks and e-waste aggregators could complement the advanced processing capabilities of formal operations, which sometimes run into a scarcity of raw materials, creating a more efficient and inclusive recycling ecosystem. Four key models exist for integrating the informal sector with formal e-waste recycling systems:

- The **direct partnership/subcontractor model** puts informal workers in the supply chain of prominent formal recyclers.
- The **subsidized co-working space (E[co]work) model**, pioneered in India, establishes formal recycling facilities where all handled materials are integrated into the formal sector, ensuring that output fractions are directed toward formal recovery and recycling facilities. The motive is to create a safe working environment that aligns with the law's best standards.
- The **informal workers' association model** allows informal e-waste collectors to work together in associations and sell to formal recyclers, fostering collaboration between the sectors. This model is gaining traction in Nigeria, and it is built around the idea that bringing informal e-waste workers together will address critical welfare issues such as unfair pricing. Thus, by collectively pooling their quantities, they can negotiate better prices. This, in turn, will pave the way for more small-scale collectors to access fair pricing or compensation.
- The **intermediary organization model** advances the idea of informal e-waste collectors selling e-waste individually to properly constituted intermediary organizations, which then host auctions for formal recyclers. This approach can guarantee that e-waste collected by informal workers avoids illicit channels and undergoes environmentally responsible recycling.

Box 2. Integrating informal e-waste and formal e-waste recycling: Desco Electronic Recyclers

The case of Desco Electronic Recyclers in South Africa can be a compelling example of how formal e-waste recyclers and the informal sector can coexist and collaborate to manage e-waste sustainably. Desco began as a family-run business founded in 1992 in South Africa to recycle obsolete mainframes and IT equipment. Over time, the company has metamorphosed into a comprehensive e-waste recycling company with a keen focus on and expertise in printed circuit boards (PCBs). It has done this by seamlessly integrating informal e-waste entrepreneurs into its operations by supporting former employees and individual informal or semi-formal e-waste workers in the dismantling and collection phase to transition into formalized, independent business contractors for the company. This collaboration makes the informal e-waste contractors become Desco subcontractors. The model gained momentum and was further bolstered after the implementation of South Africa’s Black Economic Empowerment Act in 2003, marking a turning point that solidified its success and ongoing momentum.

The informal subcontractors can purchase pre-processed e-waste from the company, dismantle it for value addition, and sell fractions back to Desco or provide on-site labor for dismantling tasks at Desco's recycling plant or client locations. They may, however, sell certain e-waste materials that are not needed by Desco, such as aluminum, to other buyers. PCBs, however, must be sold back to Desco.

These informal e-waste subcontractors must adhere to strict environmental, health, and safety standards. They are first familiarized with these standards by working on-site in the company's plant under close supervision. They may later move off-site, subject to regular inspections by the company when they demonstrate consistent compliance. Non-compliance with these standards leads to partnership termination. Desco also provides administrative assistance, training and equipment, zero-interest loans, access to tools and premises, and support to the subcontractors.

The model has faced some challenges. For instance, partnerships usually have a 50 percent success rate due to disagreements and competitive pressures that make the informal subcontractor sell the materials to other competitors. The strict standards sometimes face non-compliance, especially in off-site dismantling. High-value PCBs often lead to selective handling, undermining comprehensive recycling.

Despite these challenges, Desco's model demonstrates how informal e-waste recyclers can be integrated into formal recycling systems and how they can complement each other for sustainable e-waste management. Upscaling the model to other jurisdictions, such as Egypt, where material shortages are a key issue, could further enhance recycling efforts.

Source: Adapted from Hinchliffe et al. (2020).

All four models discussed offer unique advantages and challenges but also present a distinct pathway to integrate the informal and formal e-waste sectors, which promotes effective collaboration and streamlined recycling practices. Integration cannot happen in a vacuum, so key actions must be taken to achieve this symbiotic relationship. While the subsequent chapter will offer proper policy recommendations, four first steps are proposed here:

- **First, relevant policies and regulations need to be adopted by African governments** to nurture a collaborative relationship between the informal and formal recycling sectors while ensuring compliance with environmental standards.
- **Second, the capacity of informal e-waste recyclers must be built** since their education and technical expertise are often insufficient. Such capacity-building programs are expected to improve their methods, make formal recycling methods more appreciable, reduce environmental and health risks and increase the volume of materials channeled into formal recycling systems.
- **Third, the government can build public infrastructure that supports informal e-waste collection centers** that can feed the formal sector and recycling hubs. This will streamline the interface between informal e-waste and formal sectors, creating a seamless flow of materials and collaborations for a more effective engagement of relevant stakeholders.

- **Fourth, there must be proper stakeholder engagement in the industry.** This will encourage practical cooperation between governments, businesses, NGOs, and informal e-waste workers, foster mutual trust and promote shared objectives within the e-waste community.

9. Recommendations and Conclusion

9.1 Study summary

The study has analyzed African e-waste management and recycling activities to promote a circular economy. The study explored their interactions with institutional and governance structures and assessed their alignment with the existing global, regional, and national policy and regulatory frameworks. The study identified best practices in e-waste management, providing an overview of the stakeholder ecosystem. It assessed relevant developments, and the institutional, policy, and regulatory frameworks linked to the e-waste value chain. It documented the current systems and practices associated with e-waste generation, collection, disposal, and recycling in Africa and pinpointed policy gaps that hinder recycling and the adoption of a circular economy in the e-waste space. The study was based on desk work and qualitative primary data gathered through interviews, focus group stakeholder discussions, and site visits to some e-waste management firms.

9.2 Key observations

Africa's dual role as e-waste generator and recipient

- Africa generates 2.9 million tonnes of e-waste annually, with only 1 percent formally recycled.
- Many African countries import second-hand electronics (often near the end of their lifecycle), contributing significantly to the e-waste crisis.
- Ghana, Nigeria, and Côte d'Ivoire receive large shipments of second-hand electronics, with over 50 percent found to be waste shortly after arrival.

Environmental, social, and economic impact

- E-waste has profound environmental, health, social, and economic effects, with significant challenges and opportunities depending on how it is managed.
- The beneficial impact is higher for the formal e-waste sector than for the informal, though it varies depending on the stage of the e-waste value chain.
- Most e-waste recycling in Africa is handled by the informal sector, where workers dismantle electronics without protective equipment, exposing them to toxic chemicals.
- Despite health risks, informal e-waste collection provides livelihoods for thousands of workers in urban centers like Agbogbloshie (in Accra, Ghana) and Alaba (in Lagos, Nigeria).
- The two cases from Ghana and South Africa reveal a trend toward massive informal collection and aggregation, which bodes poorly for policy.

- The informal recycling sector's dominance should be strategically leveraged to promote the capital-intensive formal recycling sector to maximize the potential of e-waste recycling in Africa. Establishing a symbiotic relationship between formal and informal practices is essential.
- Overall, transitioning to the formal sector would be desirable. Thus, African countries need to develop hybrid e-waste management models that combine the strengths of informal e-waste collection networks with the more advanced processing capabilities of formal recycling systems.
- Many countries have expressed intent, and the literature generally supports the integration of the formal and informal sectors for efficient sector management.

Regulatory and policy frameworks

- Regulatory frameworks and industry standards must be developed to ensure the responsible and ethical use of AI in waste management.
- Existing EPR frameworks fail to address the multi-use cycles and cross-border trade of EEE. African countries must establish an ultimate producer responsibility scheme to address this gap, compelling international producers to manage e-waste under the polluter-pays principle.
- Government structures are often organized along sectoral lines, limiting the cross-sectoral integration necessary for advancing circular economy initiatives.
- Effective implementation of EPR schemes throughout Africa will require collaboration between governments and companies, with the government playing a key role in driving this initiative.
- Policymakers must incentivize sustainable production by offering tax breaks, funding research, and enforcing product standards.
- It is important to balance regulation with incentives. While strict enforcement ensures compliance, subsidies for recyclers and tax incentives for businesses encourage investment. For Africa, hybrid financing mechanisms—such as eco-levies on new EEE, public-private partnerships, and recycling credits—can support the sector without displacing informal workers.
- Only 13 African countries have dedicated e-waste policies, and many lack enforcement capacity.
- Even where policies exist, implementation is weak, and many countries lack monitoring systems for tracking e-waste flows.
- Illegal e-waste imports continue despite the Basel Convention and the Bamako Convention, which regulate the hazardous waste trade.

Cross-border and international considerations

- Cross-border collaboration needs to grow through regional frameworks, knowledge-sharing platforms, and joint infrastructure projects to build the sector's efficiency and resilience.
- Most imported UEEE in Africa arrives near or at the very end of its end-of-life stage, highlighting the need for sustainable management to avert adverse environmental and social impacts.
- The international and continental conventions are insufficient and lack robust mechanisms to curb illegal activities.

Financing and investment gaps

- The high costs associated with formal e-waste recycling systems further exacerbate Africa's development challenges, leaving industries and cities driving circular economy initiatives in dire need of financing to support the transition.

- Non-existent proper local municipal financing frameworks in Africa mean that cities will seek this investment from central governments, which are already hard-pressed by their thin domestic resource mobilization revenue.
- Multilateral development banks (MDBs) face significant hurdles in scaling up funding for circular economic activities. Traditional project-based finance provided by MDBs is not well suited to the systemic and multi-stakeholder approaches often inherent to circular economy solutions.

Infrastructure needs for formal recycling

- Few countries have functional e-waste recycling plants due to high setup costs and a lack of investment incentives.
- South Africa, Rwanda, and Egypt have started developing formal e-waste collection systems, but progress is slow.
- Most e-waste is dumped in open landfills, leading to toxic contamination of soil and water.

Untapped economic potential of e-waste recovery

- E-waste contains valuable metals such as gold, silver, copper, and palladium, estimated to be worth $55 billion globally.
- The formal recycling sector remains underdeveloped, missing opportunities to create jobs and generate revenue.
- Circular economy approaches, such as refurbishment and remanufacturing, are gaining traction but require stronger policy support.
- MSMEs could help bridge the gap between informal and formal recycling systems, but there are no clear incentives for MSMEs to engage in e-waste collection, repair, or recycling.

Emerging digital solutions for e-waste tracking

- Blockchain and AI-powered tracking systems could improve e-waste monitoring and prevent illegal dumping.
- Some African countries, including Nigeria and Rwanda, are exploring digital compliance tools to track e-waste from import to disposal.
- Mobile e-waste collection platforms could connect consumers with recyclers and encourage responsible disposal.

Resource accessbility and efficiency challenges

- A paradox exists where cities accumulate excess e-waste while formal recyclers struggle to secure sufficient raw materials.
- Weak collection systems, inadequate aggregation centers, and lack of regulatory support create inefficiencies in the value chain.
- Models exist on a lower scale for formalizing collection and aggregation; government policy must support such models.

Best practices beyond recycling

- Countries could promote circular economic activities through repair, refurbishment, and innovative product design strategies. Addressing the energy efficiency concerns associated with refurbished products will be essential for some of these practices to succeed.
- Eco-design principles in product manufacturing can potentially reduce e-waste generation in Africa.
- Strategic policy interventions, capacity building for informal recyclers, and stakeholder engagement are critical steps towards building circularity around e-waste and creating sustainable solutions for the continent.

9.3 Actionable recommendations

Recommendations to integrate formal and informal e-waste actors

It is possible to develop effective collaboration, which benefits both formal and informal actors. In some jurisdictions outside Africa, such as Peru and India, this collaboration has been legalized with EPR legislation. Following the recommendations of Davis and Garb (2015), a practical framework for cooperation must first be based on a clear understanding of the local informal and formal value chains within a specific jurisdiction. African policymakers must see formalization as a gradual process and foster stakeholder engagement through cooperative policy design, creating sustainable change through financial incentives rather than penalties. Any strategy or framework aimed at integration must minimize environmental, health, and safety risks and support the strengths of the informal sector.

Recommendations to improve legislation, regulations, and enforcement

While the local economy and political context will dictate the role of various stakeholders, creating attractive conditions for partnerships will require specific measures to be taken. Inadequate legislation and regulations are one of the key missing links for a transition to a well-functioning, sustainable e-waste sector. A clear, consistent, and well-enforced WEEE regulatory framework, supported with an appropriate financial mechanism, constitutes a complete and durable solution to the e-waste problem. Law-making for the sector should not be only the government's responsibility, even though governments must provide leadership. All stakeholders willing to make a difference in that field should make this a long-term goal and put some effort into making it happen.

Recommendations for local government authorities to bring e-waste under control

A top priority for Africa is to address the public health dangers of e-waste by ensuring proper e-waste management services. In most cases, the local authorities have the responsibility of fighting waste management with capacity, resources, and infrastructure constraints to manage hazardous e-waste effectively. This reality eventually compounds challenges with existing delivery service. Incorporating EPR frameworks can ease some of this burden by shifting the costs to producers, improving public health and environmental outcomes while supporting overstretched local governments.

Recommendations for building public infrastructure

Stakeholders need to cooperate to build public e-waste infrastructure in Africa that supports informal e-waste collection centers that can feed the formal sector and recycling hubs. This will streamline the interface between informal e-waste and formal sectors, creating a seamless flow of materials and collaborations for a more effective engagement of relevant stakeholders.

Recommendations for stakeholder engagement

Proper stakeholder engagement in the industry will encourage practical cooperation between governments, businesses, NGOs, and informal e-waste workers, foster mutual trust and promote shared objectives within the e-waste community.

The following table offers actionable recommendations, broken down by roles and responsibilities.

Table 4. Actionable recommendations to improve e-waste management in Africa

Integration of formal and informal e-waste actors		
Government actions	**Producer actions** *(manufacturers, importers)*	**Worker actions** *(informal collectors, dismantlers)*
1. Create flexible regulations encouraging collaboration between formal and informal stakeholders. 2. Provide support for informal stakeholders to facilitate partnerships with formal entities. 3. Establish monitoring systems for e-waste recycling activities. 4. Develop regulations enforcing proper e-waste disposal through compliant recyclers. 5. Invest in e-waste aggregation centers.	1. Cooperate with recyclers using informal sector materials. 2. Understand informal market mechanisms and provide financial incentives. Establish engagement platforms with the informal sector to set fair pricing and improve relations. 3. Develop inclusive Extended Producer Responsibility plans. 4. Provide training and equipment support to informal e-waste workers.	1. Organize into associations, cooperatives, or partnerships to engage with stakeholders. 2. Limit activities to safe practices such as collection, sorting, and basic dismantling. 3. Explore formalization opportunities and comply with environmental standards. 4. Upgrade technical capabilities through training programs. 5. Engage with all stakeholders to identify needs and help implement policies.
Improved legislation, regulations, and enforcement		
Government actions	**Producer actions** *(manufacturers, importers)*	**Worker actions** *(informal collectors, dismantlers)*

1. Identify regulatory gaps and advocate for comprehensive e-waste policies. 2. Align national policies with international conventions like the Basel Convention. 3. Strengthen regulatory bodies and compliance enforcement. 4. Use digital technologies for monitoring e-waste activities. 5. Enact Extended Producer Responsibility frameworks.	1. Adhere to national and international e-waste regulations. 2. Collaborate with governments to develop effective e-waste frameworks. 3. Educate consumers on responsible disposal and recycling. 4. Provide data on electronic product imports and disposal.	1. Register with regulatory bodies to transition into formal operations. 2. Participate in policy consultations to voice concerns. 3. Improve traceability of collected e-waste. 4. Adopt safe recycling practices in compliance with regulations.
Local government actions to bring e-waste under control		
Government actions	**Producer actions** *(manufacturers, importers)*	**Worker actions** *(informal collectors, dismantlers)*
1. Remove unauthorized e-waste dumpsites to protect public health. 2. Prevent illegal dumping through law enforcement and awareness campaigns. 3. Provide accessible e-waste collection services. 4. Establish public infrastructure for proper e-waste disposal. 5. Support regional e-waste markets to enhance economic benefits.	1. Implement take-back schemes and support proper disposal of e-waste. 2. Fund awareness campaigns on e-waste hazards and proper disposal. 3. Collaborate with local authorities to develop collection centers and infrastructure.	1. Transition to environmentally friendly handling and collection methods. 2. Work with municipalities to route e-waste to formal recyclers. 3. Educate communities on responsible disposal. 4. Participate in training to align practices with global standards.
Building public infrastructure		
Government actions	**Producer actions** *(manufacturers, importers)*	**Worker actions** *(informal collectors, dismantlers)*
1. Fund the development of regional and community-based e-waste collection hubs. 2. Ensure policies recognize and support informal collectors as critical actors.	1. Provide financial support and infrastructure to community collection hubs. 2. Integrate informal collection networks into formal recycling supply chains.	1. Participate in the design and operation of local collection centers. 2. Follow safety protocols and sorting practices at collection points.

3. Develop national roadmaps that define the role of informal collection networks.	3. Create technical guidelines and tools for safe e-waste handling at collection centers.	3. Support data gathering to improve traceability and inform infrastructure needs.
Stakeholder engagement		
Government actions	**Producer actions** *(manufacturers, importers)*	**Worker actions** *(informal collectors, dismantlers)*
1. Convene national and local stakeholder dialogues. 2. Include informal workers in circular economy and waste management strategies. 3. Support capacity building programs to build trust and awareness.	1. Engage with NGOs and informal workers to develop inclusive CSR programs. 2. Sponsor joint training, dialogues, and public outreach events. 3. Ensure representation of informal collectors in decision-making processes.	1. Participate actively in engagement forums. 2. Provide feedback on policies, practices, and local challenges. 3. Collaborate with government and industry to promote shared e-waste goals.

9.4 Conclusion

The growing e-waste stream in Africa is a major policy concern that requires a strategic and adaptable approach. The complexity of managing the sector cannot be underestimated because management solutions must balance environmental risks with the economic and social benefits for sustainable development. Added to the problem is the recognition that a substantial quantum of e-waste in Africa is imported from other continents, often bypassing the exporting nations' waste management infrastructure and stretching Africa's limited infrastructure.

The sector has many challenges. Key among them is inadequate financial capital for the government and the private sector, which limits enforcement, infrastructure development, and capacity-building efforts. This spurs informal e-waste management and leads to unsafe and environmentally hazardous practices. Innovative financing frameworks and the integration of the informal and formal recycling sectors, leveraging the strengths of both to create a more efficient and sustainable e-waste management system, should be an urgent policy priority for Africa.

Despite the burgeoning challenges, e-waste must not be seen solely as a regulatory burden but also as a strategic tool that can be leveraged for sustainable development in Africa. E-waste can be a critical sustainable growth pole when the right policies are in place; e-waste can contribute to decent job creation, technological innovation, and circular economy growth. African governments must work closely with private sector actors, international partners, and local communities to establish sustainable collection and processing networks. They should strengthen cross-border collaboration through regional frameworks, knowledge-sharing platforms, and joint infrastructure projects to further enhance the sector’s efficiency and resilience.

The next phase of e-waste management in Africa depends on proactive policy interventions integrating environmental protection, economic development, and social inclusion. If African countries can do this, they can turn e-waste from an unwanted environmental problem into an opportunity for sustainable industrialization and environmental stewardship.

Appendix 1. List of Stakeholders Consulted

Name	Institution
Nabwomya Daniel Tengzor	Ministry of Local Government, Religious Affairs and Chieftaincy
Roland Asare	Science and Technology Policy Research Institute, CSIR
Abdul Saman Ganem	Zeal Environmental Technology (General Manager)
Prof. Benedicta Yayra Fosu-Mensah	Institute for Environmental and Sanitation Studies, University of Ghana (Acting Director)
Mercy	Deputy Director, Ministry of Local Government, Chieftaincy and Religious Affairs
Larry Kotoe	Environmental Protection Agency
Dr. Gabriel Asante	Ghana Shippers Authority, Research Monitoring and Evaluation Department
NanaYaw Konadu	Electro Recycling Ghana (CEO)
Crentsil Kofi Bempah	Ghana Atomic Energy Commission
Glady Adjei	Ghana Atomic Energy Commission
Abena Darkoa Opare-Djan	Friends of the Earth Ghana
Joseph Forson	Eco-Africa Network
Nehemiah Odjer-Bio	Friends of the Earth Ghana
Kwabena Kwakye	Green Earth and Kasigana
Gideon Akoto	Friends of the Earth Ghana
Joshua Etse Wemegah	Pure Earth
Abdulrahim Shaibu-Issah	Recycle Up Ghana
Abdul-Kadir Alhassan	Ghana Shippers Authority
Aminu Amadu	AA Aminu Enterprise

Appendix 2. Survey Instrument

E-waste management survey instrument for Ghana and South Africa

1. Introduction to the E-waste landscape

- **E-waste generation**
    - What statistics can you provide on e-waste generation, particularly in major urban centers?
    - How do you perceive the scale and impact of e-waste in these regions compared to other countries?
- **Importation and second-hand electronics**
    - How significant is the second-hand electronics market in Ghana or South Africa?
    - In what ways does this market contribute to e-waste generation and informal recycling activities?

2. Key stakeholders

- **Actors in the e-waste value chain**
    - Who are the key stakeholders in e-waste management in Ghana or South Africa and what roles do they play?
    - How do government entities, informal recyclers, and private sector firms interact and collaborate to improve e-waste management practices?
- **Role of civil society and NGOs**
    - What role(s) do NGOs and community groups play in advocating for better e-waste management in Ghana or South Africa?
    - Can you provide examples of successful initiatives led by these organizations in Ghana or South Africa?

3. Regulatory framework

- **Policy review and analysis**
    - What policies govern e-waste management in Ghana or South Africa, and how effective are they in practice?
    - What strengths and weaknesses do you observe in the regulatory approaches of both countries, particularly regarding extended producer responsibility (EPR)?
- **Challenges in implementation**
    - What challenges do you face in implementing e-waste management policies at national and local levels in both contexts?
    - How do issues like corruption, inadequate infrastructure, and financial constraints affect policy enforcement?

4. Current practices

- **Overview of recycling practices**
  - What are the common methods of informal recycling observed in Ghana or South Africa, and what risks do they pose to health and the environment?
  - How do formal recycling facilities operate compared to informal sector activities in Ghana and South Africa?
- **Environmental and social impact**
  - What ecological and health impact have you observed from current e-waste recycling practices in both countries?
  - How do these impacts affect local communities involved in e-waste processing?

5. Opportunities for circular economy

- **Assessment of circular economy potential**
  - How can Ghana or South Africa better embrace circular economy principles in the e-waste sector?
  - What key opportunities for promoting reuse, repair, and sustainable practices do you see in both contexts?
- **Current initiatives**
  - Can you describe any existing projects or initiatives in Ghana or South Africa that promote circular economy practices?
  - What role do policy and industry collaborations play in these initiatives?

6. Best practices and success stories

- **Successful interventions**
  - What programs or interventions have effectively promoted safer recycling practices in Ghana or South Africa?
  - Can you share success stories from NGOs, social enterprises, or government initiatives involved in e-waste management?

7. Challenges to progress and improvement

- **Barriers to formalization**
  - What barriers do you see that prevent the transition to more formal recycling systems in Ghana and South Africa?
  - How do enforcement gaps and financial constraints hinder progress in e-waste management in both countries?

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