Helpdesk Report

Knowledge, evidence and learning for development

Drivers, barriers and opportunities of e-waste management in Africa

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Question

What are the current drivers, barriers and opportunities of e-waste management in Africa? Are there any current analysis on volumes generated and how e-waste is managed? How might a transition to renewable energy and rechargeable products affect volumes?

Contents

1. Summary

Population growth, increasing prosperity and changing consumer habits globally are increasing demand for consumer electronics. Further to this, rapid changes in technology, falling prices and consumer appetite for better products have exacerbated e-waste management challenges and seen millions of tons of electronic devices become obsolete. This rapid literature review collates evidence from academic, policy focussed and grey literature on e-waste management in Africa. The report is structured as follows:

- Section two provides an overview of what constitutes e-waste as well as global data on quantities and management. The section includes a specific overview of quantities of e-waste generated in Africa, sources of e-waste and whether countries have policies in place.
- Section three provides a brief overview of the environmental and health impacts of e-waste including on air, soil and water and on the health of those who earn an income from the reclamation of valuable materials from e-waste.
- Section four provides an overview of some of the barriers to effective e-waste management, with a focus on African countries. It highlights crosscutting issues as well as challenges in terms of reuse, repair and recycling of e-waste.
- Section five provides an overview of the opportunities associated with effective e-waste management. This includes discussion of the economic benefits of managing e-waste, the potential for maintenance repair and collection services as well as the role of a circular economy.
- Finally, section six provides a brief overview of the limited literature available that estimate future volumes of e-waste in Africa, including solar.

E-waste is any electrical or electronic equipment, which is waste, including all components, subassemblies and consumables, which are part of the equipment at the time the equipment becomes waste. In 2019, an estimated 53.6 million metric tons (Mt) of e-waste was generated globally (an average of 7.3 kg per capita). Africa generated a total of 2.9 million Mt of e-waste, or 2.5 kg per capita, the lowest regional rate in the world.

Of the estimated 53.6 million Mt of e-waste generated globally in 2019, 82.6% or 44.3 million Mt was not documented (of this figure 43.7 million Mt of e-waste is unknown (this is dumped, traded or recycled) and 0.6 million Mt of e-waste is estimated to have ended up in residual waste bins in EU countries). The remaining 17.4% or 9.3 million Mt of e-waste is documented as collected and properly recycled. Small equipment (38%) and large equipment (20%) represent the main forms of e-waste.

A number of countries in Global North have developed policies and established infrastructure to recycle e-waste, however, it remains lucrative to transport waste to the Global South, where there are no or limited policies or legislation to govern its management.

Africa’s e-waste is the product of two main sources

- **Local Sources**: Electronics manufacturing within Africa is growing. The production, use, recycling, and disposal of these items has also increased.
- **Import of Used Electronic and Electrical Equipment (UEEE)**: There is growing demand for electronic devices in the Global South. In some low-income countries this

has led to increasing import of UEEE which is more affordable than new electronic equipment.

Reports have emerged of illegal transboundary movement of hazardous waste from the Global North disguised as commercial goods. It is also reported that there is an increase in intra-African e-waste movement from countries such as South Africa, to other countries with porous borders e.g. Democratic Republic of Congo, Zimbabwe, and Mozambique etc.

Challenges in e-waste management in Africa are exacerbated by a lack of awareness, environmental legislation and limited financial resources. Proper disposal of e-waste requires training and investment in recycling and management technology as improper processing can have severe environmental and health effects. Countries that import UEEE and e-waste often lack policies, knowledge, and appropriate disposal facilities, thus resulting in the accumulation of e-waste.

In Africa, thirteen countries have been identified as having a national e-waste legislation/policy. As of 2017, Western Africa, including Nigeria and Ghana, had the highest regional coverage of e-waste legislation but are also destinations for significant amounts of imported e-waste. This suggests that despite legislation in place, illegal importation of e-waste continues to occur through poor adherence and weak enforcement of laws. The main barriers to effective e-waste management include:

- **Insufficient legislative frameworks and government agencies' lack of capacity to enforce regulations**
- **Infrastructure**: Currently, there is limited infrastructure for e-waste collection.
- **Operating standards and transparency**: it is not always clear where companies tasked with and collectors move e-waste products.
- **Illegal imports:** Linked to the above, there are issues associated with the illegal import of e-waste.
- **Security:** Security is a concern for e-waste managers, particularly when tasked with the destruction of hard-drives from institutions and organisations.
- **Data gaps:** Data gaps on the quantity, location and material make-up of e-waste create a challenge for downstream recycling partners.
- **Trust**: Ensuring product performance in repair processes and maintaining the trust of consumers, waste partners and industry peers in collaborations are further challenges
- **Informality**: The prevalence of unstructured collection by informal workers challenges the formalisation of e-waste management.
- **Costs**: High cost remains one of the most significant barriers to improving e-waste management practices, including the costs involved in accessing waste, transporting it, treating it, and, when necessary, shipping it overseas.

Whilst the aspirations associated with energy transition and net zero are laudable, products associated with these goals can become major contributors to the e-waste challenge. The necessary wind turbines, solar panels, electric car batteries, and other "green" technologies require vast amounts of resources. Further to this, at the end of their lifetime, they can pose environmental hazards. An example of e-waste associated with energy transitions can be gleaned from the solar power sector (photovoltaics – PV). Global installed PV reached around 400 Giga Watts (GW) at the end of 2017 and is expected to rise further to 4500 GW by 2050 and the worldwide solar PV waste is estimated to reach around 78 million tonnes by 2050

(Chowdhury et al., 2020). Different types of solar power cells need to undergo different treatments (mechanical, thermal, chemical) depending on type to recover the valuable metals contained. Similar issues apply to waste associated with other energy transition technologies e.g. batteries.

To cater for the waste from the net zero / energy transition, the sourcing and recycling of input materials must be improved dramatically to make the energy transition truly sustainable. The push towards a circular economy has provided stakeholders across the value chain with an impetus to initiate systemic improvements and invest in infrastructure and awareness raising.

Although e-waste contains toxic and hazardous metals such as barium and mercury among others, it also contains non-ferrous metals such as copper, aluminium and precious metals such as gold and copper, which if recycled could have a value exceeding 55 billion euros. There thus exists an opportunity to convert existing e-waste challenges into an economic opportunity.

2. E-Waste

Population growth, increasing prosperity and changing consumer habits globally are increasing demand for consumer electronics. Further to this, rapid changes in technology, falling prices and consumer appetite for better products have exacerbated e-waste management challenges and seen millions of tons of electronic devices become obsolete (Forti et al., 2020). The lifespan of computers and peripherals has reduced from 5–10 years previously and now ranges between 3–4 years as this equipment is built with a focus on replacement instead of repair (Agamuthu et al., 2015).

E-waste (also referred to as Waste of Electrical and Electronic Equipment – WEEE or Electronic waste) is defined in various ways. Davis & Heart (2008) define e-waste as obsolete, end-of-life or discarded appliances that use electricity. In contrast, Peralta & Fontanos (2005) define e-waste as electronic products that no longer satisfy the needs of the initial purchaser. The term e-waste encompasses computers and peripherals, consumer electronics, fridges, etc. that have been disposed of by first-hand users. However, the term is also used generically to describe all waste containing electrically powered components which are valuable, but hazardous and may require special handling and recycling methods.

Box 1: ***What is e-waste? (WHO, 2021)***

E-waste is any electrical or electronic equipment, which is waste, including all components, subassemblies and consumables, which are part of the equipment at the time the equipment becomes waste. Such items include:

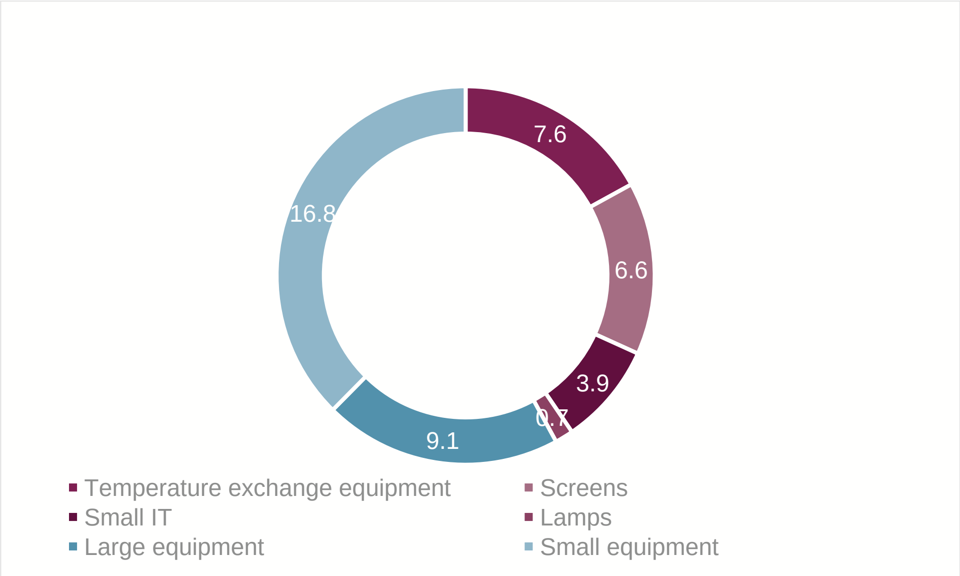
• computers, monitors and motherboards, chips • wireless devices and other peripheral items • printers, copiers and fax machines • telephones, mobile phones and tablets • video cameras • televisions • stereo equipment • cathode ray tubes • transformers • cables and batteries • lamps and light bulbs (including mercury-containing CFL and fluorescent bulbs) • large household appliances (refrigerators, washers, dryers, microwaves) • toys and sports equipment • tools • medical devices (some microscopes, electronic blood pressure monitoring devices, electrocardiogram machines, spectrophotometers, etc.).

Electronics are often grouped into six categories that correspond to their afterlife management. These groups are (World Economic Forum, New Vision for Electronics, 2019):

1) temperature exchange equipment;
2) screens and monitors;
3) lamps;
4) large equipment;
5) small equipment;
6) small IT and telecommunication equipment.

In 2019, an estimated 53.6 million metric tons (Mt) of e-waste was generated globally (an average of 7.3 kg per capita) (Forti et al., 2020). Africa generated a total of 2.9 million Mt of e-waste in 2019, or 2.5 kg per capita, the lowest regional rate in the world. Small equipment (38%) and large equipment (20%) represent the main forms of e-waste (see figure 1).

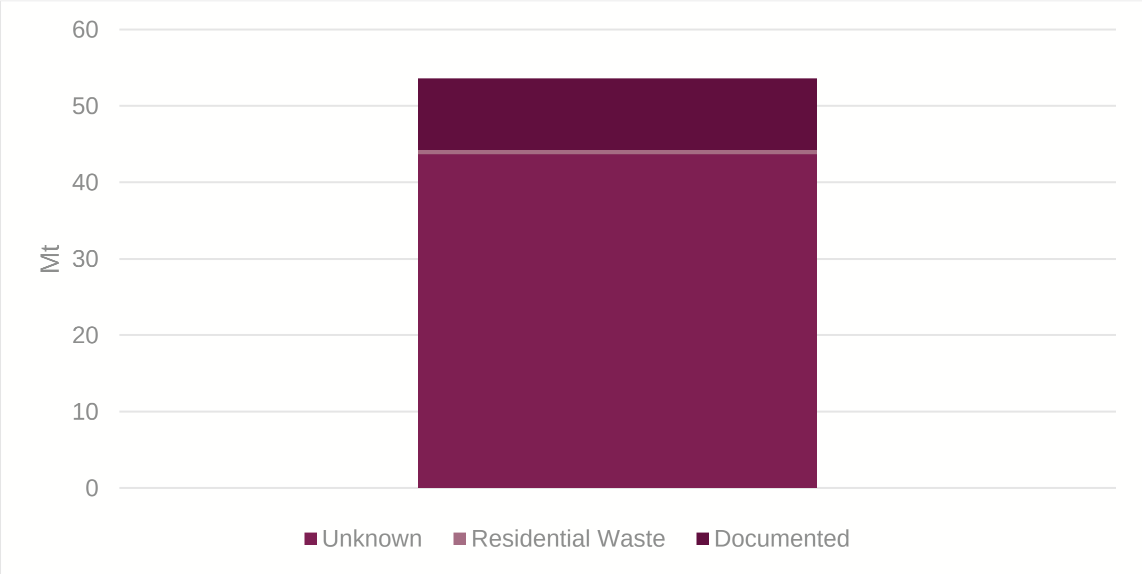
Figure 1: ***E-Waste in Mt 2019***



*Source: (World Economic Forum, 2019a**)** reproduced under CC Attribution-NonCommercial-NoDerivatives 4.0 International*

Of the 53.6 million Mt of e-waste generated globally in 2019, 82.6% or 44.3 million Mt of global e-waste produced was not documented (of this figure 43.7 million Mt of e-waste is unknown (this is probably dumped, traded or recycled) and 0.6 million Mt of e-waste is estimated to have ended up in residual waste bins in EU countries). The remaining 17.4% or 9.3 million Mt of e-waste is documented as collected and properly recycled (see figure 2 and bullets below).

Figure 2: ***Proportion of e-waste treated in accordance with best available technology***



Source: Forti et al., 2020 reproduced under CC BY-NC-SA 3.0 IGO

- **Residential:** This refers to WEEE estimated to be disposed of in household waste and destined for landfill or incinerations.
- **Documented:** This refers to the amount of e-waste documented to be formally collected and recycled.
- **Unknown**: The e-waste gap is the amount of e-waste that is unaccounted for. The unknown flows are calculated by subtracting the e-waste quantities officially collected and the e-waste found in waste bins from the total amount of e-waste generated.

A number of countries in Global North have developed policies and established infrastructure to recycle e-waste, however, it remains lucrative to transport waste to the Global South, where there are no or limited policies or legislation to govern its management.

At the international and regional levels, efforts have been made to adopt policies and legislation addressing e-waste. The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1989 (Basel Convention)[1], is the most relevant existing international agreement to address the e-waste challenge. E-waste is listed in Annex VIII as A1180 (hazardous waste) and Annex IX as B1110 (non-hazardous waste) of the Convention. Specifically, e-wastes are characterised as hazardous wastes under the Convention when they contain components such as accumulators and other batteries, mercury switches, glass from cathode-ray tubes (CRTs) and other activated glass, printed circuit boards (PCBs) containing capacitors or when contaminated with cadmium, mercury, lead or PCBs. In addition, precious metal ash from the incineration of printed wiring boards, Liquid Crystal Display (LCD) panels and glass waste from CRTs and other activated glasses are characterised as hazardous wastes. The plastics associated with e-wastes may also be covered under Annex II of the Basel Convention which addresses household wastes[2].

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[1] http://www.basel.int/TheConvention/Overview/tabid/1271/Default.aspx

[2] http://www.basel.int/TheConvention/Overview/tabid/1271/Default.aspx

Since 2014, the number of countries that have adopted a national e-waste policy, legislation, or regulation has increased from 61 to 78 (Forti et al., 2020). Although there has been improvement in the legal and institutional infrastructure for managing e-waste, it is still weak.

E-Waste and its Management in Africa

The Ellen MacArthur Foundation (2021) reports that in Africa, the demand for Electrical Electronic Equipment (EEE) has increased at a rate of 2.5% annually. Sales of refrigerators, television sets, and mobile phones have surged, and consumer spending in Africa, primarily by a growing middle class, reached an estimated US$ 1.3 trillion in 2010 (equivalent to 60% of Africa's GDP) and is projected to double by 2030. Many countries in Africa also import a significant amount of used consumer electronics, in part, to help bridge the digital divide. Africa is ranked as the world's fastest-growing mobile phone market, creating multiple economic and education opportunities for the continent. The increasing consumption of electronics is, however, leading to an increase in e-waste. In addition to recyclables, such waste also contains pollutants that are harmful to human health and the environment if improperly handled (see next section) (GIZ, 2021).

In 2019, the continent of Africa generated 2.9 million Mt of e-waste which translates to 2.5 kg per capita (Forti et al., 2020). This figure, however, masks a diversity of contexts from high (e.g. Egypt and South Africa) to low (e.g. Guinea-Bissau and Sao Tome and Principe) total waste generators. Similarly, certain countries record higher per capita rates than others i.e. the Seychelles at 12.6 kg compared with Guinea-Bissau at 0.5 kg. The continent is also reported to have the lowest documented rate of collection and proper recycling, at only 0.9% of waste. Although the per capita e-waste generation in Africa is the second lowest globally, over 60% is derived from imports (WEF, 2021). See figures 3 and 4. This includes Large equipment, cooling and freezing, small equipment, small IT, screens and lamps (see annex for items).

Figure 3: ***E-waste generated (kt) in African countries in 2019***

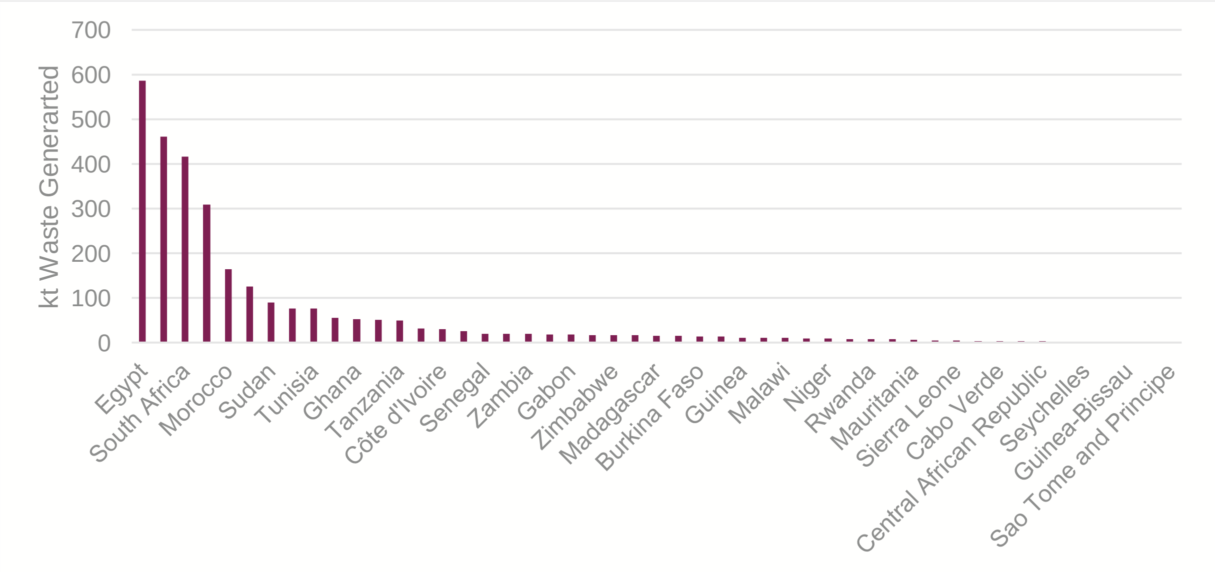

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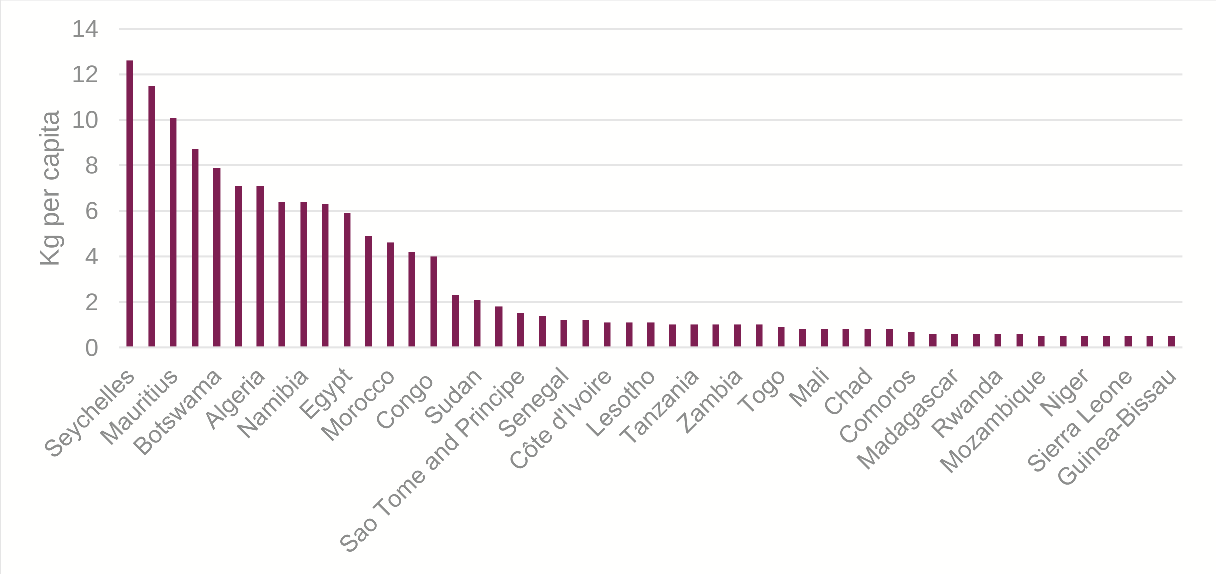
Figure 4: ***E-waste generated (kg per capita) in 2019***



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Africa's e-waste is thus the product of two main sources:

- **Local Sources**: Electronics manufacturing within Africa is growing. The production, use, recycling, and disposal of these items has also increased. Local production of e-waste in Africa in 2019 was estimated to be 2.9 Mt, with the largest quantities produced in Egypt (0.585 Mt), Nigeria (0.461 Mt) and South Africa (0.415 Mt) (Forti et al., 2020). Most African countries do not have a formal system for collection and recycling of discarded electronic equipment. In many Africa countries, e-waste is mixed with municipal waste, and dumpsite scavenging for e-waste items is common. There is little documentation on electronic products that are scavenged from landfills (Ongondo et al., 2011).
- **Import of Used Electronic and Electrical Equipment (UEEE)**: There is growing demand for electronic devices in the Global South. In some low-income countries this has led to increasing import of UEEE which is more affordable than new electronic equipment. As much as 75% of UEEE is shipped legally under the pre-tense that it is usable or can be repaired. However, studies in Kenya by Mureithi and Waema (2008) reported that 60% of UEEE given to beneficiaries in Kenya was beyond repair. There is also significant import of UEEE into Africa that is mislabelled. In 2015 and 2016, approximately 60,000 tons of UEEE were shipped into Nigeria in this manner (Odeyingbo et al., 2017). The greatest amounts came from China (24%), followed by the US (20%), Spain (12%) and the UK (9%) (Odeyingbo et al., 2017). Many of the items are used, irreparable or have outlived their usefulness. Illegal imports of UEEE are a driver of e-waste in Africa. While the Basel Convention forbids countries from carrying out unauthorised dumping of e-waste, enforcement challenges have led to a lucrative illicit trade. Mislabelling of e-waste as usable electric appliances poses is a significant challenge given limited capacity to inspect imports and low levels of enforcement.
- **Import of substandard Electronic and Electrical Equipment**: Whilst many governments within the African continent have put in place stringent requirements to ensure their consumers are protected from sub-standard products and goods, enforcement remains a challenge. The import of products that are either not suited to the

African context or that become obsolete/redundant or irreparable because of poor design is an issue.

Reports have also emerged of illegal transboundary movement of hazardous waste from the Global North disguised as commercial goods (Amankwah-Amoah, 2016). Estimates have suggested that up to 80% of the e-waste produced by the Global North was exported illegally to countries in the Global South (Yu, et al., 2017). Alongside this, Doyon-Martin (2015) have reported an increase in intra-African e-waste movement from countries such as South Africa, Nigeria, and Tunisia to other countries with porous borders e.g. Democratic Republic of Congo, Zimbabwe, and Mozambique etc.

Challenges in e-waste management in Africa are exacerbated by a lack of awareness, environmental legislation and limited financial resources. Proper disposal of e-waste requires training and investment in recycling and management technology as improper processing can have severe environmental and health effects (Nganji & Brayshaw, 2010).

E-waste management in Africa is dominated by the informal sector, including collectors and recyclers. There is a limited/absent organised system for take-back or licensed provisions for sorting and dismantling e-waste (Bakhiyi et al., 2018). The handling of e-waste is often processed by the informal sector, with electronic boards manually stripped for resale, unprotected burning of wires to recover base elements (e.g. copper, aluminium and iron), and the disposal of bulk components in dumps. In some countries, e-waste handlers process e-waste through incinerating or open burning in dumpsites (Bakhiyi et al., 2018).

The presence of an unstructured informal sector can also inhibit the growth of recycling facilities. In countries such as South Africa and Morocco, facilities have struggled to scale up processing. The informal sector competes for waste with recycling facilities, is more localised and faces lower compliance costs, increasing access to e-waste at lower prices. Other challenges include lack of adequate public awareness, lack of effective collection and extended producer responsibility (EPR) infrastructure, lack of adequate recycling facilities and poor financing of hazardous waste management activities (WEF,2021).

E-waste management has thus emerged as a policy priority in Africa, with countries such as Ghana, Rwanda, Nigeria, and South Africa publishing policy frameworks to improve e-waste management, including introducing EPR policies (Ellen MacArthur Foundation, 2021). Despite these efforts, 70% of e-waste within Africa is still disposed of at dumpsites, and the inherent value of the materials and the potential economic opportunities are lost.

In Africa, thirteen countries have been identified as having a national e-waste legislation/policy (Forti et al., 2020 and see table 1). As of 2017, Western Africa, including Nigeria and Ghana, had the highest regional coverage of e-waste legislation but are also destinations for significant amounts of imported e-waste. This suggests that despite legislation in place, illegal importation of e-waste continues to occur through poor adherence and weak enforcement of, laws.

Table 1: ***African countries with e-waste legislation/policy regulations.***

Key: Yes; No; No information on e-waste legislation/policy regulation.

Central Africa	East Africa	North Africa	Southern Africa	West Africa
Central African Republic	Burundi	Algeria	Angola	Benin
Cameroon	Comoros	Egypt	Botswana	Burkina Faso

Chad	Djibouti	Libya	Lesotho	Cabo Verde
Congo	Ethiopia	Mauritania	Madagascar	Cote d'Ivoire
DR Congo	Kenya	Morocco	Malawi	Gambia
Equatorial Guinea	Rwanda	Tunisia	Mauritius	Ghana
Gabon	Seychelles		Mozambique	Guinea
	Somalia		Namibia	Guinea Bissau
	South Sudan		South Tome and Principe	Liberia
	Sudan		South Africa	Mali
	Tanzania		Swaziland	Niger
	Uganda		Zambia	Nigeria
			Zimbabwe	Senegal
				Sierra Leone
				Togo

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A number of regional conventions and localised interventions have attempted to fill in the gaps in national e-waste legislation in African countries, these include:

- **The Bamako Convention**, On the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa, was set up to ban the importation of toxic substances from the global north[3].
- **The East Africa Communication Organisation** (EACO) has developed working groups to address e-waste issues. EACO has held regional conferences and produced several reports and strategies addressing e-waste management, awareness, and the status of e-waste in member nations. EACO aims to train national representatives in better e-waste management, facilitating interventions, and the development of more reliable regional and national statistics[4].
- **The e-Waste Association of South Africa** (eWASA) was formed to establish sustainable ways of managing e-waste. Its members include electronics manufacturers, importers, and retailers. eWASA has struggled to affect the import of e-waste in South Africa. One reason for this is that e-waste and its economic benefits have been championed by business-people who may not consider or be aware of short- and long-term impacts of e-waste (Tetteh & Lengel, 2017).
- In Ghana, **Pure Earth**, has partnered with government and advocacy groups on a recycling centre to improve working conditions through safer recycling of cables and cords. The facility trains recyclers in the use of machines that strip plastics from valuable metals and aims to reduce air pollution from burning while ensuring that workers do not lose their livelihoods (Heacock et al., 2018).
- **GIZ** in partnership with the **Ghana's Ministry of Environment, Science, Technology and Innovation** (MESTI) established a training workshop to train e-waste workers on cleaner and safer recycling methods; including technical support, to develop a legislation on e-waste. Equipment to access resources from e-waste tend to require more time and

[3] https://www.unep.org/explore-topics/environmental-rights-and-governance/what-we-do/meeting-international-environmental

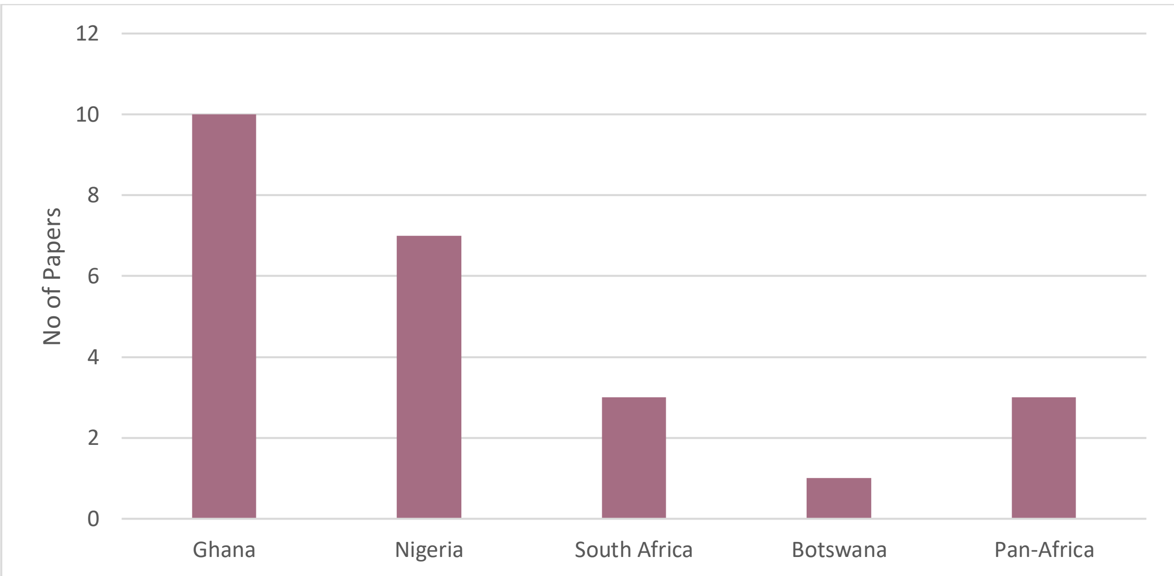
[4] https://www.eaco.int/

electricity at extra cost to the recyclers to produce the quantity of recovered products. More broadly, economically viable business models to replace the e-waste burning as a recycling option are limited.

- **Solving the E-waste Problem** (StEP) has a number of projects running in Africa. **The Person in the Port Project** assessed the quantities, qualities, composition, origins and economic impacts of UEEE imports into ports in Nigeria over a two-year period. Other StEP interventions include collaboration between the Ethiopian Government and international partners to develop a national e-waste management strategy and e-waste management pilot projects in West African countries[5].
- The **International Labour Organisation** (ILO) has produced strategies on ensuring the safety of e-waste workers that can be adapted to African contexts (ILO, 2019).
- The **E-waste Coalition** has three functions: *advocacy* including awareness raising and campaigns; *knowledge* and best practice sharing; and the development of an *intervention* model for the implementation of e-waste work (WEF, 2019).

While research on the scale, extent and impact of e-waste (as well as its management) in Africa are emerging, research is limited in a range of contexts. Findings from a systematic review of E-waste management in Sub-Saharan Africa revealed that about 80% of research on e-waste management in the region was undertaken in three countries: Ghana, Nigeria, and South Africa (Maphosa et al., 2020 – see figure 5).

Figure 5. ***Selected articles by country.***



Source: Maphosa et al., 2020 reproduced under CC BY license

3. Impacts of E-Waste on the Environment and Health

According to the WHO (2021), the popularity of electronic and electrical devices, combined with ineffective waste management and disposal, is triggering a crisis of e-waste environmental and health risks. The problem is considered most severe in low- and middle-income countries, where

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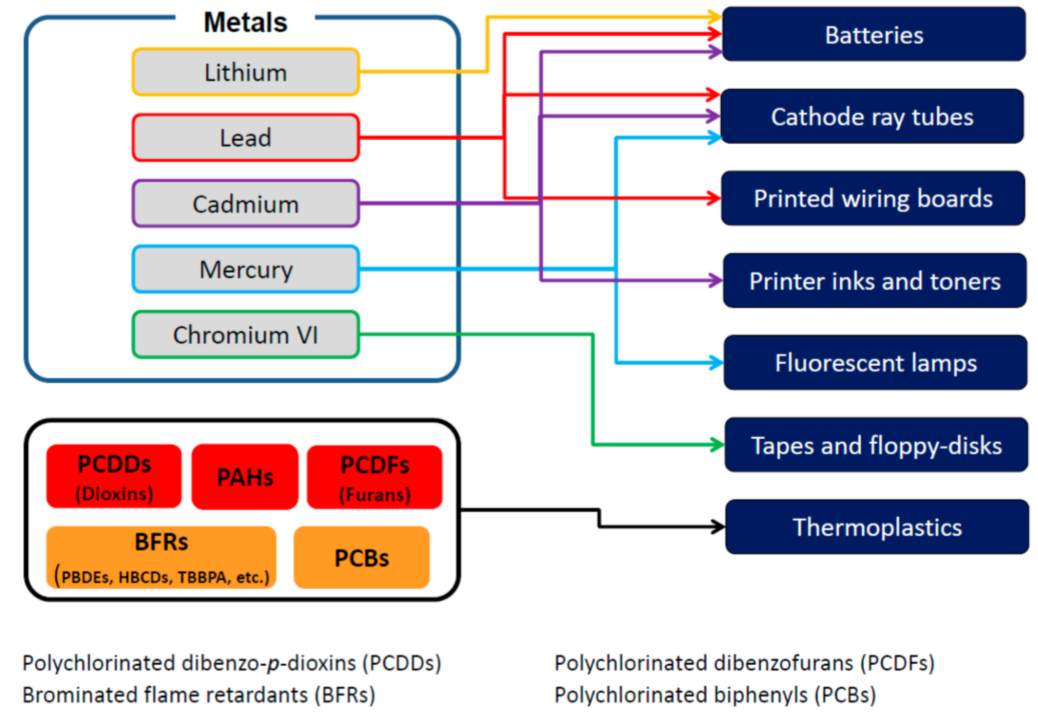
[5] https://www.step-initiative.org/projects-59.html

significant numbers work or live near informal dumps and landfills. Open dumping, burning and landfilling are the predominant disposal methods used in Africa, with potential serious implications for human health and the environment.

Environmental impacts

Research has shown that common electronic items and their components, such as batteries, switches, relays, and PCBs, may contain antimony, barium, beryllium, cadmium, copper, gold, lead, lithium, mercury, nickel, silver, palladium, and zinc. Items are also known to contain a variety of organic chemicals and rare earth metals, many of which have not been studied for their environmental and health effects (Tsydenova and Bengtsson, 2011). Plastics may constitute as much as 30% of e-waste by weight and brominated flame retardants (BFRs) are added to most plastics to reduce flammability (Schlummer et al., 2007). BFRs are often found in computers and other electronics for the same reason. As many plastics contain chlorine, combustion of plastic results in the formation of both chlorinated and brominated dioxins and furans (Lebbie et al., 2021). Image 1 identify sources of some of these chemicals.

Image 1: ***Common Toxins Released from E-Waste Activities.***



Source: Lebbie et al., 2021 reproduced under CC BY license

Many countries in Africa resort to unregulated recycling that use manual processes to reclaim precious metals found in e-waste, these activities damage the environment through acid leaching and open burning, causing landfills and dumpsites to be some of the most polluted sites globally (Tetteh & Lengel, 2017). Rudimentary recycling processes, in combination with the lack of safety measures and personal protection, account for both severe environmental contamination and high risks for the health of workers and people living around e-waste sites.

Current practices in the informal waste management sectors are reported to release heavy metals and toxic chemicals into the air, soil and water. In Africa, the potential release of harmful substances from undocumented disposal is estimated at 9.4 mega tonnes of CO_2 Green House Gas emissions, 0.01 kilo tonnes of mercury and 5.6 kilo tonnes of BFR annually (WEF, 2021: 29).

E-waste burning and dismantling activities are frequently undertaken at e-waste sites, often in or near homes. As a result, children and people living in the surrounding areas are exposed, even if they are not directly involved in the recycling. While toxic substances are dangerous to individuals at any age, children are more vulnerable as they are going through important developmental processes, and some adverse health impacts may have long-term impacts (WHO, 2021).

In terms of the practice of burning of waste, hazardous mixtures of e-waste toxicants are released into the environment in the form of airborne particulate matter ($PM_{2.5}$) emitted by dismantling activities. For a more detailed analysis of air pollution in the vicinity of dumpsites see Avis et al. (2018).

Landfills in African countries containing e-waste have shown elevations of many different potentially hazardous metals. Soils around an informal e-waste recycling site in Nigeria have displayed elevated levels of copper, lead, zinc, manganese, nickel, antimony, chromium, cadmium (Isimekhai et al., 2017).

Health Impacts

The impact of e-waste on human health is also of concern. An expanding body of epidemiological research has found associations between e-waste recycling and adverse health effects, including negative birth outcomes, impaired neurological and behavioural development, impaired thyroid function, and increased risk of diseases (Grant et al., 2013).

People are exposed to e-waste emissions through multiple routes, including air, soil, dust, water and food. Exposure to the toxic components of e-waste thus occurs through various pathways, including (WHO, 2021):

- Ingestion of food, water, soil and dust;
- Inhalation of aerosol gases and particles;
- Dermal exposure.

Foetuses and children can also be exposed through unique pathways:

- ingestion of breast milk;
- transplacental exposure.

Communities who live near e-waste recycling sites are prone to health and safety concerns such as inhalation of toxic chemicals and exposure to radiation (Jibiri et al., 2014). A study by Machete (2017) in South Africa confirmed human exposure to toxic metals such as arsenic, mercury, and cadmium whose effect on human health is significant. A study in Ghana showed that pollutants released during burning trigger respiratory infections, eye irritation, and asthma, among others (Acquah et al., 2019). Peluola (2016) also established that workers who dismantled EEE had skin and eye irritation while others complained of persistent coughing.

Research conducted in Nigeria revealed that e-waste had caused congenital disabilities and infant mortality, damage to the brain and other vital organs as well as respiratory, stomach, and skin infections (Nwagwu & Okuneye, 2016). In Ghana, informal workers at an e-waste recycling site displayed significantly higher concentrations of blood lead, cadmium, chromium, and urinary nickel when compared to non-e-waste workers (Wittsiepe et al., 2017).

4. Barriers to Effective E-Waste Management

Findings from the literature identify a lack of policy and limited recycling infrastructure were the main barriers to effective e-waste management in Africa. Maphosa et al., (2020) revealed that most countries in Africa principally practice informal recycling methods. The following provides an overview of broad barriers to effective e-waste Management. Many of these are associated with facilitating reduction, reuse or recycling.

Crosscutting

Insufficient legislative frameworks and government agencies' lack of capacity to enforce regulations: Regulatory advance across Africa is slow, enforcement is poor, and policy, legislation, or regulation does not yet stimulate the collection and proper management of e-waste due to lack of investment and political motivation. Even where policies have been adopted by governments, extended producer responsibility (EPR) legislation is often not implemented properly. For example, in Nigeria, NESREA (the agency tasked with environmental protection) operates with very limited power and resources (Forti et al., 2020).

Infrastructure: Currently, there is limited infrastructure for e-waste collection. Yu et al. (2017) revealed that recyclers in most African countries lacked recycling facilities and resorted to dismantling, burning, and acid leaching to recover precious metals. There are a limited number of formal e-waste dismantling operations in the region, e.g. the WEEE Centre in Kenya and Enviroserve in Rwanda.

Operating standards and transparency: it is not always clear where companies tasked with and collectors move e-waste products. Trust is an important aspect of commercial relationships concerning e-waste (WEF, 2021), i.e. is waste responsibly disposed of or dumped with other waste.

Illegal imports: Linked to the above, there are issues associated with the illegal import of e-waste. There are limited resources to tackle the illegal importation of UEEE (WEF, 2021).

Security: Security is a concern for e-waste managers, particularly when tasked with the destruction of hard-drives from institutions and organisations. There are emerging concerns about data, consumer protection, intellectual property, and product design (WEF, 2021).

Data gaps: Data gaps on the quantity, location and material make-up of e-waste create a challenge for downstream recycling partners. There is also a lack of knowledge among companies around the location of recycling facilities, particular processes and their associated costs (CLASP, 2021). Product scope in national legislation can be different than the e-waste classification systems suggested by the commonly used, internationally harmonised methodological framework on e-waste statistics. These differences lead to a lack of harmonisation of e-waste statistics across countries. Little information on the volume of e-waste in the global south often undermines systems to deal with e-waste (Orisakwe et al., 2019).

Trust: Ensuring product performance in repair processes and maintaining the trust of consumers, waste partners and industry peers in collaborations are further challenges when implementing effective e-waste management (CLASP, 2021).

Informality: The prevalence of unstructured collection by informal workers challenges the formalisation of e-waste management. Examples of efforts to address this challenge can be identified in Kenya and Nigeria. The E-Waste Initiative Kenya (EWIK) and E-Waste Collectors Association Nigeria (ECAN) are trying to tackle this problem through cooperation between the informal sector and multiple private sector companies (CLASP, 2021).

Costs: High cost remains one of the most significant barriers to improving e-waste management practices, including the costs involved in accessing waste, transporting it, treating it, and, when necessary, shipping it overseas. The lack of e-waste infrastructure and service providers in Africa is another, including the absence of recycling facilities that meet minimum standards and the difficulty of finding the spare parts necessary to repair or refurbish non-functioning products (EFAC, 2021).

Table 2: ***Challenges to E-Waste Management Initiatives***

LOW VOLUMES (HIGH UNIT COST)	• No collection points • No take-back schemes • Limited collection (3rd party and informal) • Customers hold onto waste (perceived value and low awareness of risk)
TREATMENT COSTS	• Intrinsic material value • Lack of lithium-ion batteries recycling facilities in Africa • Product design (may hard to be separate fractions) • Recyclers are only present in a few markets
HIGH RISK	• Costs uncertain • "Business models" untested • Legislation is in its infancy
WEAK (AND DIFFICULT) SUPPLY CHAIN	• Partnership not in place • Low volumes • Transport costs

Source: Author's own. Created using data from CLASP, 2021

Repair

Design: Products are not designed for repair and technical information is not widely available. This makes repairs difficult for third-party distributors and external repair shops, who cannot easily access internal components, diagnostics or repair instructions (Ellen Macarthur Foundation, 2021).

Inadequate tools and equipment: Due to the nature of informal repair operations, many technicians do not have access to high quality tools. They may be limited by capital, and do not always have an electricity supply to power a tool like a soldering iron (Ellen MacArthur Foundation, 2021).

Inaccessible or poor quality spare parts: High quality spare parts are not readily available. The source of this problem is threefold:

- For some parts such as batteries, there is an abundance of poor quality and fake branded merchandise available in the market;
- It is difficult to source and procure high quality, genuine component parts;
- Importing small volumes of spare parts is complex and costly, which makes doing so prohibitive for both distributors and informal repairers alike.

Lack of knowledge: Not all local technicians in off-grid communities have received formal training. Instead, many learn their trade from family or friends, developing skills over time through trial and error. Even for those with formal training, specialised education on products was not normally included in curricula (Ellen MacArthur Foundation, 2021).

Recycling

Lack of knowledge: A lack of awareness of responsible recycling practices among both individuals and companies, and a lack of availability of such services (WEF, 2021).

Lack of facilities that meet required standards: Where e-waste recycling services are available, operational standards may be inadequate or even harmful. For example, lead acid battery recycling processes in some facilities are sub-standard, which can lead to substantial harm to human and environmental health. It is important for recycling facilities managing e-waste to meet basic health, safety and quality management standards. The following have been identified as minimum requirements for recycling facilities (The Ellen MacArthur Foundation, 2021):

- Compliance with health, safety and operational standards as defined by ISO 45001, ISO 14001 and ISO 9001.
- Compliance with local licensing requirements.
- Data protection: disposers need to know that intellectual property is safe and will not be leaked or sold to outsiders.
- Comprehensive inventories that capture various types of product data (serial numbers, makes, models, weight of items, etc.)

Insufficient volumes for efficient recycling: At present, volumes of e-waste retrieved are low and demand for recycling services is insufficient to drive economies of scale. Figures emerging from Challenge projects initiated by CLASP (2019) indicate that the treatment of off-grid solar e-waste costs about US$ 0.75 per kg. Increasing the volumes of waste collected can drive down cost. Solar companies in Rwanda reported that the US$ 0.2 per kg cost of disposal was prohibitive, and as a result they had large quantities of products in storage.

Design Considerations: The influence of product design on the end-of-life performance of electronics and the recovery, treatment, and disposal of related secondary materials is crucial. Current approaches to product design often prevent life-span extension. The Ellen MacArthur Foundation (2021) comment that technical and perceived product obsolescence issues, and the use of toxic substances such as lead, cadmium, mercury, and plastics treated with flame-retardants need to be addressed if a global solution to e-waste generation and management are to be found (Ellen Macarthur Foundation, 2021).

Collection Cost: The logistical cost of reaching dispersed users' homes and returning waste products to a centralised location is high because of distance and terrain. There is an incentive cost because when asking for waste, the holder of the waste product assumes there is value in the product's materials and so will want compensation to give up their product (CLASP, 2021). The primary costs associated with e-waste management come from securing waste from consumers, transporting it to a central location, storing it and then processing (where such facilities exist).

Battery Diversity: Solar Home Systems (SHSs) use a variety of battery chemistries. Lithium-based batteries dominate in pico-solar products and are increasingly found in smaller SHSs (<50W), but there is currently no lithium battery recycling facility in Africa. Instead, they are sent to Europe for recycling. While larger SHSs have lead-acid batteries, for which local recycling options exist and there is a positive recycling value, not all local facilities meet environmental, health, and safety standards. Improper disposal of lead acid batteries can lead to the contamination of food and water sources (CLASP, 2021).

Multiplier Effects: The weight of SHSs and the presence of more copper cabling increases their positive recycling value compared to Pico-Solar Products (PSPs). However, the typical distribution model of bundling SHSs with other end-use appliances increases overall waste volumes, therefore increasing collection costs. The multiplier effect is especially challenging when SHS and appliances are "locked" together by proprietary software or hardware and cannot be used independently. If just one part of a system fails, its still-functional accessories and appliances may become waste too (CLASP, 2021).

5. Opportunities

Although e-waste contains toxic and hazardous metals such as barium and mercury among others, it also contains non-ferrous metals such as copper, aluminium and precious metals such as gold and copper, which if recycled could have a value exceeding 55 billion euros (Peluola, 2016). There thus exists an opportunity to convert existing e-waste challenges into an economic opportunity using a three-step approach (WEF, 2021):

1. Create and enforce legislation focused on limiting the amount of imported e-waste;
2. Achieve a zero e-waste circular economy through EPR principles;
3. Establish proper recycling and collection facilities for current and domestic e-waste that incorporate both formal and informal operators.

Economic benefits

Reports suggest that e-waste recycling is a 55-billion-euro industry, and if proper policies and infrastructure are in place, countries that manage e-waste effectively could have a considerable stake in the recovery of precious metals such as gold and copper (Peluola, 2016). It is estimated that circa US$ 3.2 billion worth of raw materials are contained in e-waste generated in Africa (ITU, 2021).

Trade, repair, and recovery of materials from e-waste serve as a source of livelihood for many poor parts of the population. The Agbogbloshie dumpsite in Ghana is estimated to provide livelihoods for approximately 4,500 to 6,000 workers directly, and up to 1,500 people indirectly (Daum et al., 2017). Recovery of important raw materials from e-waste has become a business in Ghana and has resulted in global and transboundary trade. Ghana makes an estimated US$ 105 to 268 million annually from materials sourced from e-waste and as many as 200,000 people benefit from e-waste recycling activities. Table 3 shows the estimated value of materials from e-waste globally in 2019.

Table 3: ***The potential value of raw materials in e-waste in 2019***

Material	Kilotons (kt)	Million USD	Material	Kilotons (kt)	Million USD
Ag	1.2	579	**In**	0.2	17
Al	3046	6062	**Ir**	0.001	5
Au	0.2	9481	**Os**	0.01	108
Bi	0.1	1.3	**Pd**	0.1	3532
Co	13	1036	**Pt**	0.002	71
Cu	1808	10,960	**Rh**	0.01	320
Fe	20,466	24,645	**Ru**	0.0003	3
Ge	0.01	0.4	**Sb**	76	644

Source: Forti et al., 2020 reproduced under CC BY-NC-SA 3.0 IGO

While e-waste does contain valuable materials, the cost of recycling safely in the Global North may exceed the economic value of recovered components. However, considering the economic value of gold, plastics, and copper, certain countries will continue to be a dumping site for e-waste.

Circular Economy Strategies for Electronics and E-Waste

It is asserted that sustainable development requires changes in the way society and businesses are organised. The circular economy is identified as a means to support innovation and integration between natural ecosystems, businesses, daily lives, and waste management. The Ellen McArthur Foundation define a circular economy as follows:

> Looking beyond the current take-make-dispose extractive industrial model, a circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital. It is based on three principles: design out waste and pollution; keep products and materials in use; regenerate natural systems.[6]

The Ellen MacArthur Foundation (2021) comment that a circular economy for e-waste will provide the following socio-economic and environmental benefits:

1. **Repairing, remanufacturing, and upcycling to extend use cycles and create employment**. Businesses focused on repairing, remanufacturing, and upcycling electronics benefit people by providing income opportunities, and benefit the environment by extending a product's end-of-life, therefore reducing the need for virgin materials and decreasing harmful waste and pollutants.
2. **Capturing the economic opportunity of urban mining**. Urban mining is the process by which resources are extracted from complex waste streams. The economic opportunity

[6] https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

for e-waste urban mining in African countries is significant. Smartphones are a good example of urban mining in practice: almost 1.5 billion are shipped every year, with each unit containing components worth over US$ 100 – this represents a potential US$ 150 billion of value that enters the market each year.

3. **Scaling up e-waste recycling to create income generation opportunities**. The development of e-waste collection, grading, and recycling facilities represents a key opportunity in terms of value creation through the capture and effective recycling of commodities. A significant percentage of the e-waste generated from African communities is not recycled due to poor access to collection facilities. The establishment of community e-waste collection centres will provide technical and material supply chains for the recycling of electronic products, and harness the value of e-waste at the grassroots level.
4. **Harnessing the enabling role of technology for e-waste management**. Employing digital solutions to enhance operational efficiency is seen as particularly relevant for the high transport and logistical costs associated with the trade of recyclables and haulage. Another area in which technology can play a role is in increasing the transparency in trade and the mitigation of waste crime. This can include the use of drone imagery and block chain, as well as the publication and real-time update of price indexes for popularly traded recyclable commodities.

Additionally the Ellen MacArthur Foundation (2021) assert that governments must:

Create and enforce legislation to limit the import of e-waste. In addressing this issue, African countries will have to find the balance between preventing the import of e-waste and near-end-of-life equipment and maintaining the socio-economically valuable trade of good-quality UEEE. This requires ensuring the proper definition of waste and adopting the technical guidelines on transboundary movements of e-waste. This will reduce the import of devices that are at the end of their life cycle or completely non-functional.

Implement EPR principles. As Africa continues to import electronic devices and grows its manufacturing, there is a need to push for increased producer responsibility and accountability.

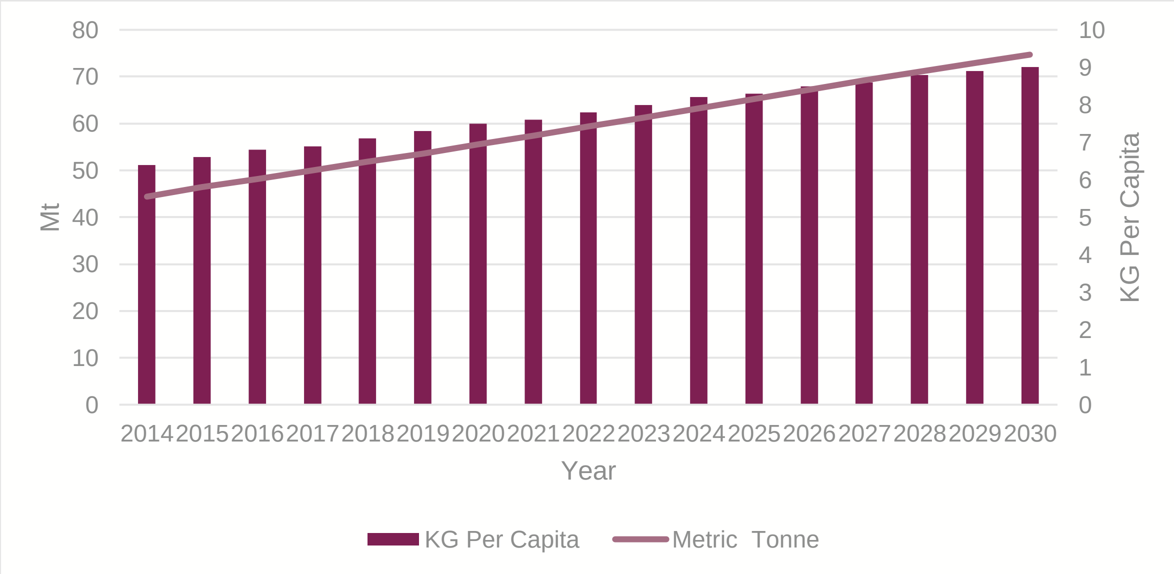
Products should be designed for durability, reuse and safe recycling, with unsustainable inputs phased out. Higher usage rates can be achieved through reintegration of manufacturing scrap, repair, second life and durability, including adopting product-as-a-service models. Higher product collection with incentives for returns and advancing recycling will preserve materials. The main barriers for an EPR policy are enforcement, lack of clarity on the definition of a producer, the prevalence of “no-brand” equipment and lack of formal treatment facilities.

Establish proper recycling and collection facilities for current and domestic e-waste that incorporate both formal and informal operators. Countries need to work on building a recycling system that is inclusive of formal and informal sectors. This requires investing in recycling plants and developing collection systems that promote green recovery methods.

6. Estimating Future Volumes of E-Waste

Whilst there is a broad expectation that the quantity of e-waste generated globally and in Afric will increase significantly, estimates are limited. A range of factors problematise efforts including predictions of consumer behaviour, developments in technology and the impact of policy interventions. Irrespective of these challenges, consensus suggests an increasing quantity of e-waste. Forti et al. (2021) estimate that global e-waste generated by year by 2030 will exceed 74 million Mt, equating to 9 kg per capita (see figure 6).

Figure 6: ***Global E-waste Generated by year***



Source: Forti et al., 2020: 24 reproduced under CC BY-NC-SA 3.0 IGO

Solar

The rapid expansion of the off-grid solar sector over the past decade has been one of the most exciting trends in clean energy generation, reducing CO_2 emissions and granting energy access to hundreds of millions of people living in off- or weak-grid environments. But this success has come at a cost. The proliferation of solar e-waste in communities around the world poses a threat to the environment and to the health of the very people benefiting from off-grid energy services (CLASP, 2021).

According to Magalini et al, (2016), depending on component, product lifespan is estimated to be three years for PSPs and up to 5 years for SHSs. To estimate future figures of e-waste generated from solar products, Magalini et al, (2016) paired average lifespan with sales figures to conclude that in 2017, the off-grid solar sector would produce 3,600 Mt of e-waste across 14 countries in sub-Saharan Africa. This number is estimated to rise to 10,000 Mt by 2020 (Magalini et al, 2016). Cross and Murray (2018) challenged the accuracy of these estimates. They assert that forecasting volumes of solar e-waste is complicated by the after-sales delay in waste appearance and lack of data on sales volumes of non-verified products. CLASP (2021) conclude that there is a critical knowledge gap on estimates and understandings of product lifespans in practice.

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About this report

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8. Annex 1

Overview of e-waste generation and management in Africa

Country	E-waste generated (kt) (2019)	E-waste generated (kg per capita) (2019)	E-waste documented to be collected and recycled (kt)	National e-waste legislation/policy or regulation in place
Algeria	309	7.1	N/A	No
Angola	125	4.2	N/A	No
Benin	9.4	0.8	N/A	No
Botswama	19	7.9	N/A	No
Burkina Faso	13	0.6	N/A	No
Burundi	5.3	0.5	N/A	No
Cabo Verde	2.8	4.9	N/A	No
Cameroon	26	1	0.05	Yes
Central African Republic	2.5	0.5	N/A	No
Chad	10	0.8	N/A	No
Comoros	0.6	0.7	N/A	No
Congo	18	4	N/A	No
Côte d'Ivoire	30	1.1	N/A	Yes
Djibouti	1.1	1	N/A	No
Egypt	586	5.9	N/A	Yes
Eritrea	3.4	0.6	N/A	No
Ethiopia	55	0.6	N/A	No
Gabon	18	8.7	N/A	No
Gambia	2.7	1.2	N/A	No
Ghana	53	1.8	N/A	Yes
Guinea	11	0.8	N/A	No
Guinea-Bissau	1	0.5	N/A	No
Kenya	51	1	N/A	Yes
Lesotho	2.3	1.1	N/A	No
Libya	76	11.5	N/A	No
Madagascar	15	0.6	N/A	Yes
Malawi	10	0.5	N/A	No
Mali	15	0.8	N/A	No
Mauritania	6.4	1.4	N/A	No
Mauritius	13	10.1	2	No
Morocco	164	4.6	N/A	No
Mozambique	17	0.5	N/A	No
Namibia	16	6.4	0.05	No
Niger	9.3	0.5	N/A	No
Nigeria	461	2.3	N/A	Yes
Rwanda	7	0.6	0.7	Yes
Sao Tome and Principe	0.3	1.5	N/A	Yes
Senegal	20	1.2	N/A	No

Seychelles	1.2	12.6	N/A	No
Sierra Leone	4.2	0.5	N/A	No
South Africa	416	7.1	18	Yes
Sudan	90	2.1	N/A	No
Swaziland	7	6.3	N/A	No
Togo	7.5	0.9	N/A	No
Tunisia	76	6.4	N/A	No
Uganda	32	0.8	0.18	Yes
Tanzania	50	1	N/A	Yes
Zambia	19	1	N/A	Yes
Zimbabwe	17	1.1	0.3	No

Detailed description of the UNU product classification

Large Equipment	• Central Heating (household installed) • Photovoltaic Panels (incl. converters) • Professional Heating & Ventilation (excl. cooling equipment) • Dishwashers • Kitchen (f.i. large furnaces, ovens, cooking equipment) • Washing Machines (incl. combined dryers) • Dryers (wash dryers, centrifuges) • Household Heating & Ventilation (f.i. hoods, ventilators, space heaters) • Professional Tools (f.i. for welding, soldering, milling) • Leisure (f.i. large exercise, sports equipment) • Professional Medical (f.i. hospital, dentist, diagnostics) • Professional Monitoring & Control (f.i. laboratory, control panels) • Non Cooled Dispensers (f.i. for vending, hot drinks, tickets, money) • Professional IT (f.i. servers, routers, data storage, copiers)
Cooling and Freezing	• Fridges (incl. combi-fridges) • Freezers • Air Conditioners (household installed and portable) • Other Cooling (f.i. dehumidifiers, heat pump dryers) • Professional Cooling (f.i. large air conditioners, cooling displays) • Cooled Dispensers (f.i. for vending, cold drinks)
Small Equipment	• Microwaves (incl. combined, excl. grills) • Other Small Household (f.i. small ventilators, irons, clocks, adapters)

	• Food (f.i. toaster, grills, food processing, frying pans) • Hot Water (f.i. coffee, tea, water cookers) • Vacuum Cleaners (excl. professional) • Personal Care (f.i. tooth brushes, hair dryers, razors) • Small Consumer Electronics (f.i. headphones, remote controls) • Portable Audio & Video (f.i. MP3, e-readers, car navigation) • Music Instruments, Radio, HiFi (incl. audio sets) • Video (f.i. Video recorders, DVD, Blue Ray, set-top boxes) • Speakers Cameras (f.i. camcorders, photo & digital still cameras) • Household Luminaires (incl. household incandescent fittings) • Household Medical (f.i. thermometers, blood pressure meters) • Household Monitoring & Control (alarm, heat, smoke, excl. screens) • Professional Luminaires (offices, public space, industry) • Household Tools (f.i. drills, saws, high pressure cleaners, lawn mowers) • Toys (f.i. car racing sets, electric trains, music toys, biking computers)
Small IT	• Small IT (f.i. routers, mice, keyboards, external drives & accessories) • Desktop PCs (excl. monitors, accessories) • Printers (f.i. scanners, multifunctionals, faxes) • Telecom (f.i. (cordless) phones, answering machines) • Mobile Phones (incl. smartphones, pagers) • Game Consoles
Screens	• Laptops (incl. tablets) • Cathode Ray Tube Monitors • Flat Display Panel Monitors (LCD, LED) • Cathode Ray Tube TVs • Flat Display Panel TVs (LCD, LED, Plasma)
Lamps	• Lamps (f.i. pocket, Christmas, excl. LED & incandescent) • Compact Fluorescent Lamps (incl. retrofit & non-retrofit) • Straight Tube Fluorescent Lamps • Special Lamps (f.i. professional mercury, high & low pressure sodium) • LED Lamps (incl. retrofit LED lamps & household LED luminaires)