Electronic waste management practices in Nigeria

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Innocent C. Nnorom[1,2] *and Olusegun A. Odeyingbo*[3]
[1]Department of Pure and Industrial Chemistry, Abia State University, Uturu, Nigeria, [2]Visiting Research Fellow, Manchester Institute of Biotechnology, University of Manchester, United Kingdom, [3]Department of Environmental Technology, Chair of Circular Economy and Recycling Technology, Technische Universität Berlin, Straße Berlin, Germany

14.1 Introduction

E-waste is a term used to cover items of all types of electrical and electronic equipment (EEE) and its parts that have been discarded by the owner as waste without the intention of reuse (StEP, 2014). In different regions it is also named WEEE (waste electrical and electronic equipment) or e-scrap. Various definitions for electronic waste in literature accept that E-waste includes both the whole device and all its component parts that have been discarded by the owner as waste without the intention of reuse, whether functional or not. Electrical and electronic equipment (EEE) includes a wide range of products—almost any household and business item with power or battery supply. The past 2−3 decades have witnessed the discarding of huge quantities of electronic waste and it is obvious that this and its environmentally sound management represent no doubt one of the foremost environmental challenges of the 21st century. This is a globalized problem affecting both developed and developing countries (Osibanjo et al., 2016).

Literature in the past 1−2 decades has proven that E-waste is one of the fastest growing waste types in the world (Widmer et al., 2005; Lundgren, 2012). The exponential increase in the total amount of E-waste generation could be associated to many factors, which include consumer demand for upgraded designs and options, high obsolescence rate due to low quality of EEE products and unnecessary purchases of EEE—for example the purchase of a new mobile phone considering that new mobile phone models are released at highly regular intervals among others. Meanwhile new designs, models, or upgrades of mobile phones come with new accessories, such as chargers, headsets thereby forcing the early retirement of functional accessories. These short innovation cycles, increasing affordability of electronic devices especially in developing countries, coupled with low recycling rates contribute to rapidly rising quantities of E-waste. Even hand-held devices like mobile phones that appear very small in size or weight contribute hugely to the cumulative waste generation by this sector (Osibanjo et al., 2008). The past two

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decades have witnessed a steady decline in the average lifespan of most electronic products ranging from computers to mobile phones, causing significant addition to E-waste. For some electronics, such as computers, the average lifespan has been reported to have dropped in recent years by about 50% from 4 to 2 years (BAN/SVTC, 2002). E-waste has become a global, interregional and domestic problem, and significant quantities collected for recycling in the developed countries are moved across international boundaries toward developing countries. Baldé et al. (2017) observed that about 44.7 million metric tons (Mt) of WEEE were generated all over the world in 2016 and the amount of WEEE is expected to increase to 52.2 million metric tons by 2021. Of about 44.7 million metric tons generated yearly, it is estimated that vast majority of the generated WEEE is shipped to countries in Asia and Africa for reuse or recovery. This trade is consequent on the composition of UEEE—reusable equipment which even when un-reusable could be salvaged for their valuable parts/components/modules and used in repairs of salvaged for the materials contents that can be used as secondary raw material. E-waste is unique as it contains both hazardous substances (e.g., cadmium, lead, mercury, and persistent organic pollutants) as well as precious metals (e.g., gold, silver, and rare earth metals) which could cause some irreversible health and environmental damages if treated and discarded improperly. The dumping of UEEE and E-waste in developing countries worsen the challenges faced in E-waste management in these countries. The management practices adopted in Nigeria, the challenges, and the way out are discussed in this chapter.

14.2 UEEE/E-waste flows into developing countries

One key factor that drives the flows of UEEE into developing countries is the high demand for electronic devices by low income earners—either by those that do not have access or those that desire to upgrade to newer models/brands that have better features—sound quality, camera, and memory size. Consumer electrical and electronic products have been instrumental to the revolution witnessed in the communication, entertainment, transport, education, and healthcare sectors around the world (Osibanjo and Nnorom, 2007). Most developing countries have need for ICT wares to facilitate the following: technology transfer; technical assistance; capacity building; warning systems; information, resource management systems; monitoring and assessment mechanisms; communication; education; awareness-raising; promoting and facilitating the exchange of information on best practices; knowledge sharing; dissemination of scientific or technical knowledge; and the wider application of techniques and assessment methodologies, among others (Lall and Garai, 2005). The effective application of ICT has the potential to benefit all aspects of human life. While there are many factors contributing to the digital divide, the high price of information technology hardware is no doubt a significant one (Williams, 2003). Due to lack of financial resources to most people in developing countries like Nigeria, much of the growth in the ICT sector rely on second-hand equipment

imported from rich, developed countries (Nnorom, 2012). Presently, large quantities of UEEE mixed with E-waste are imported into Nigeria annually. Majority of the imported devices are nonfunctional (E-waste) and are posing serious management challenges (Nnorom and Osibanjo, 2008). E-waste generation and management is one of the most obvious global environmental problems, and unfortunately the infrastructure to manage it properly is still poorly developed and scarce in most developing countries. Globally, the recycling of E-waste (especially some categories such as CRTs) poses huge technical challenge because it is not feasible economically, while the recovered materials hardly find ready applications. Meanwhile most developing countries lack the appropriate physical infrastructure which require huge investments to acquire. In some developing countries, the obvious challenges are provision of food, shelter, and roads such that E-waste management is least considered for investment. Some of the factors driving the flows of UEEE/E-waste into Nigeria are as follows:

- The digital divide—the high demand for electronics.
- Low cost of UEEE which meets the purchasing power of most low income earners.
- General acceptance that UEEE are of higher quality compared to some new EEE imported from Asia.
- The profit margin of the importers.
- Durability of certain UEEE compared to some new devices.
- Lax laws.

14.2.1 Bridging the ICT digital divide in Nigeria: merits and demerits

Studies have shown that access to ICT is a key indicator of a country's economic and social situation (Nnorom, 2012). The "*unequal access to ICT to people relative to their geographical location, living standard, level of education, and sex*" have been defined as digital divide (Ya'u, 2002; Marine and Blanchard, 2004). This refers to the gap that exists in the opportunities to access and use advanced information and communication technologies (ICTs) between countries or geographic regions or by individuals at different socio-economic levels (Monge and Chacón, 2002). Indices of the Digital Divide include PC penetration, Internet usage, bandwidth consumption, content creation, and online representation. In Nigeria, as in many other developing countries, digital divide is so glaring—only a small number of wealthy people have access to certain ICT-wares especially the branded new equipment (Nnorom, 2012). As a result, most low-income earners rely on used ICT-wares as new devices are relatively expensive for ordinary people. Digital divide would not have attracted so much attention but for its impact on development within a global economy, which is increasingly based on the exchange of information and knowledge (Marine and Blanchard, 2004). Some of the effects of the digital divide on countries and individuals are presented in Table 14.1.

Donations by nonprofit organizations and individuals in developed countries have facilitated access to used computers in developing countries. Such computers

Table 14.1 The effects of the digital divide on countries and individuals.

Issue	Notes
Unfair competition	Disadvantaged countries are unable to compete with their counterparts in the developed countries due to lack of access to information and knowledge (e.g., access to funding for research and scholarships)
Cost of access to ICT	Worsening/deepening poverty as the digitally disadvantaged spends more to access the technology (higher costs of access to the Internet and phone calls)
Unfair playing field	The digital divide reduces the possibility of a global "level field" in trade, investment, and relations
Maintaining the divide	Higher costs of "maintaining" the digital divide or even attempting to bridge it has negative effects on economic stability

Source: *From* Nnorom, I.C., 2012. Bridging the digital divide and creating an ICT dump: an overview of the unsustainability of exporting used and end-of-life ICT-wares to developing. In: E-Waste: Management, Types and Challenges. Editors: Yuan Chun Li and Banci Lian Wang. Series: Computer Science, Technology and Applications; Environmental Remediation Technologies, Regulations and Safety. ISBN: 978-1-61942-217-9s, Nova Science Publishers, Inc. New York, NY, pp. 67–88.

are received, stored, refurbished, packed, and shipped by volunteers who donate their time and expertise. Some of these programs are aimed at assisting the educational institutions in the developing countries with low cost new computers, second hand, and refurbished computers. These programs have been in the forefront of assisting the developing countries with ICT wares. ICT diffusion stands to assist developing countries in achieving the improvements that are so desperately needed, especially in the areas of economic and social changes, education, and technological advancement. In Nigeria, so much has been achieved in Internet penetration and access to ICT-wares in the last decade and significant proportion of the ICT-wares are imported and used. Nigeria achieved a teledensity of 100% as at January 2015 from 0.4 per cent in 2001 (NCC, 2018). Since then, the telecoms sector has maintained a steady teledensity growth reaching 114.66 per cent in April 2018 with telecoms subscribers number reaching 160,524,590 (This Day, 2018a). There have been improvements since then (Fig. 14.1).

Mobile internet subscription in Nigeria also maintained a steady growth, increasing from 91.4 million in July 2017 to 98.4 million in December 2017. Consequently, Google ranked Nigeria highest in online presence in Africa, above South Africa and Kenya (This Day, 2018b). The Google research study also ranked Nigeria among the top three countries of the world that spend quality time online in search of various goods and services. The increased access to ICT-ware and Internet in Nigeria in the last decade has seen a leap in access to knowledge, citizen's participation in socioeconomic activities and effective use of ICT in key sectors such as governance and commerce, education, and healthcare. Presently, electronic commerce is flourishing including Internet banking, because online money transfers/payments, ATM services, and use of POS (point of sale) are readily

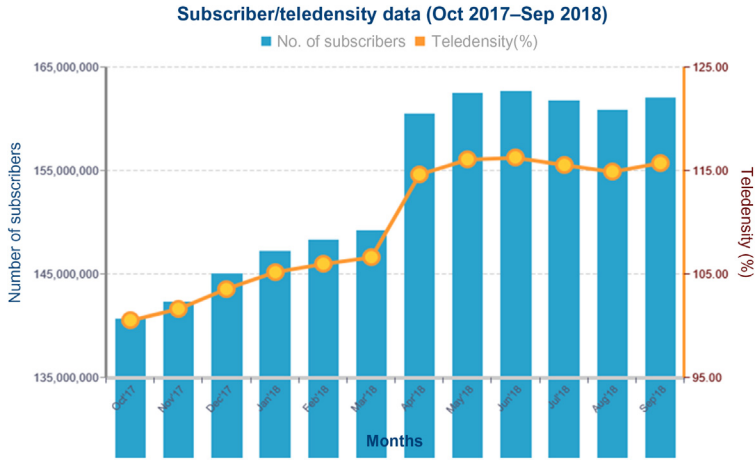

Figure 14.1 Teledensity in Nigeria.
Source: From National Communications Commission (https://www.ncc.gov.ng/stakeholder/statistics-reports/industry-overview) (accessed 20.11.18.).

accepted or used. Online hotel reservations, flight bookings, and flight management that we now enjoy from our homes and offices are delivered by telecommunication (NCC, 2018). Some other benefits of access to EEE are presented in Table 14.2.

Though export and donation of used electronics have been recognized as important means for bridging the digital divide, it however presents some demerits. Huge amounts of nonfunctional used electronics are imported and sold by individuals and registered businesses. Studies have identified Lagos as a hub for trade in UEEEs (Ogungbuyi et al., 2012; Odeyingbo et al., 2017). Thus, the export of used electronics has been used as a channel to dump un-reusable electronics in the developing countries. The adoption of crude technology in the management of end-of-life electronics poses substantial risks. Literature abounds on the negative impacts of material extraction of valuable from E-waste using crude technologies in the developing countries.

14.2.2 Quantity and quality of UEEE imports into Nigeria

Every year, Nigerian ports at Lagos receive millions of units of various types of UEEE which are imported from different countries including United State, Europe, Japan, China, and South Korea (Odeyingbo et al., 2017). Many developing countries including Nigeria rely on these imported second-hand ICT equipment from developed countries, primarily from Europe and North America to meet their digital gadget and electronic equipment needs (Odeyingbo et al., 2017). Low income earners in Nigeria depend on such imports of used EEE as a means to seek and stay abreast of technological developments in an increasingly globalized world. The domestic need of UEEE stimulates the international trade and transboundary

Table 14.2 Some benefits of access to EEE.

Sector	Notes on benefits
Cost	The new ICTs is less expensive and more powerful as they bring greater access to information and knowledge
Governance	The new ICT have been supporting e-governance around the globe. Increasing use of ICTs to provide information on election, voters' registration, and candidates in national elections. For example, SMS (short text messages) are sent to potential voters as part of the campaign strategy
Business	Drastic revolutions in the way people in developing countries communicate and conduct business. ICTs allow businesses to make more informed and strategic decisions as well as electronic commerce (e-commerce)
Education	ICT is opening educational opportunities for many including distance education. It also plays an important role as a tool in public education, and in pressing for changes in government policies
Poverty eradication	Payment of government stipends to unemployed youths
Environment	Dissemination of information on oil spills
Healthcare	Cheaper and better telecommunication services are also carrying telemedicine. ICT have assisted in rescue operations and in providing information to doctors in remote areas on life-saving operations/surgeries
Agriculture	Distribution of government subsidized agro-chemicals such as fertilizers to farmers

movement of used EEE/WEEE into Nigeria. Studies have monitored UEEE and E-waste importation into Nigeria. Presented in Table 14.3 is a summary of information on amounts, quantity, and origin of UEEE imports into Nigeria.

The recently published report of the "person-in-the-port" (PiP) presented more reliable information about quantities and qualities of the UEEE imports into Nigeria. An overview of the PiP is presented in the section below.

14.2.3 Overview of the "person in port" project

The PiP observed that many electronic devices that fall under the WEEE Directive categories were imported to Nigeria. Most of the UEEE were imported from Europe, United State, and Asia. The PiP further revealed that, the majority of imported used LCD TV was from United Kingdom origin and other parts of Europe, while majority of CRT TVs were imported from China. The quantity of UEEE imported into Nigeria via the two relevant ports in Lagos for UEEE imports into Nigeria in 2015 and 2016 was calculated to be around 60,000 t annually (Odeyingbo et al., 2017). The importation of UEEE with (roll-on/roll-off) RoRo-imported vehicles was estimated to be around 41,500 t or 69% of UEEE import per

Table 14.3 Summary of import figures of UEEE into Nigeria.

Source	Estimated quantities and qualities of imported UEEE	Year of study
Basel Action Net-work (BAN)—The digital dump, exporting reuse and abuse to Africa (BAN, 2005) www.ban.org	500 containers of computer scrap of various age enter Nigeria every month	2005
ÖKOPOL—Institute for Environmental Strategies Transboundary shipment of waste electrical and electronic equipment/electronic-scrap—optimization of material flows and control (2010) http://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/3933.pdf	• Total import to Nigeria in year 2006 was estimated at 2,885,999 tons (authors calculation) • 536,475 tons were imported from Germany in year 2006. (authors calculation)	2010
E-waste country assessment Nigeria (Ogungbuyi et al. (2012) http://www.basel.int/Portals/4/Basel%20Convention/docs/eWaste/EwasteAfrica_Nigeria-Assessment.pdf	600,000 tons	2010
Waste crimes, waste risks: gaps and challenges in the waste sector (UNEP, 2014) http://www.unep.org/newscentre/default.aspx?DocumentID = 26816&ArticleID = 35021#sthash.9J7R9wSr.dpuf	About 60%−90% of waste is illegally traded or dumped	2015
Person in port (PiP) project (Odeyingbo et al., 2017)	60,000 t/y	2015−2016

year, representing the largest share and the commonly used importing route for UEEE import. Annual import of UEEE import via container was estimated to be about 18,300 tons in total, with 8,800 t being imported in containers with vehicles and 9,500 t in containers without vehicles per year.

The UEEE imported into Nigeria could be categorized as follows:

- Functional for reuse as a product.
- Nonfunctional but serviceable for reuse.
- E-waste/scrap (nonfunctional and un-serviceable)—in some cases these can be cannibalized and some components may be retrieved for use as replacement parts.

The study observed that UEEE and E-waste are imported in 20 feet (67 m^3 of inner in volume) or 40 (33 m^3 of inner in volume) feet shipping containers, with and without vehicles and UEEE stuffed inside RoRo imported used vehicles, that is, trucks, lorries, and cars (Fig. 14.2).

The PiP presents the approach and results of the inspection of containers and vehicles and the review of import documents for UEEE imports via the Tin Can Island Port Complex (TCIPC) and the Lagos Port Complex Apapa (LPCA), the two hubs for UEEE imports in Nigeria, in 2015 and 2016. The person in the port (PiP) inspected 201 containers and 2,184 (RoRo vehicles with used electrical and electronic equipment (UEEE), and reviewed 3,622 import documents of UEEE in containers. The containers with imported UEEE represent around 0.7% of all containers with goods imported via the LPCA and the TCIPC in 2015 and 2016. Thus, on the average one out of 143 imported containers was found to contain UEEE.

It was observed that UEEE of virtually all categories (except automatic dispensers) are imported into Nigeria, often mixed with other goods such as sewing machines, bicycles, kitchen wares, sports equipment, and other household items/furnishings. UEEE are imported in containers with and without vehicles and stuffed inside RoRo imported used vehicles.

Figure 14.2 UEEE importation into Nigeria in containers: (A) with vehicles; (B) without vehicles; and (C) in RoRo imported vehicles.

The major sources of UEEE imports in containers based on the number of containers imported during the PiP are China (23%) followed by United States (21%), Spain (11%), United Kingdom (9%), UAE and Morocco (4%), Malaysia, Germany, Belgium, and Hong Kong with around 3% each. These 10 countries accounted for around 80% of the total imports observed during this study. Around 30% of the exports by number originated from ports located in the EU and Norway (Fig. 14.3).

Generally, the condition of the imported UEEE is not known to the Nigerian Port Authorities and goods are imported without prior functional test at the country of origin. An evaluation of the condition of UEEE by the PiP is presented in Table 14.4. Further, the value of individual UEEE is classified by marketers and retailers based on the age, make and model, size and cosmetic appearance of the UEEE at the selling point. Functionality condition is not always known at the time of entry.

UEEE import is motivated by the financial gain made by the various operators in the UEEE flow network in Nigeria. This trade generates considerable profits when sold for reuse. The profitability is driving individuals and companies that are not registered with the regulatory agency, NESREA (National Environmental Standard and Regulation Enforcement Agency) to import UEEE to be most active in the business. The Person in Port report observed that importers registered formally for the importation of UEEE accounted for just 3.5% of all UEEE importations for 2015 and 2016 (Odeyingbo et al., 2017). This may be one of the reasons why most declarations of imported UEEE in the import documents were found to be wrong, vague, or incomplete (Fig. 14.4). For instance the record might just indicate importation of a vehicle(s) and used sewing machines, whereas the container actually contained huge amounts of UEEE. Containers with goods imported into

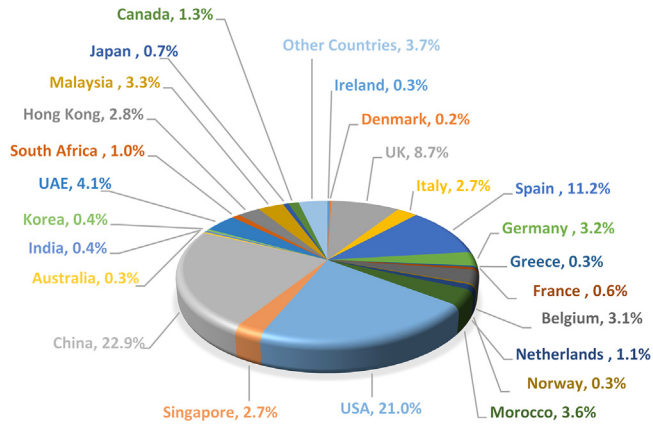

Figure 14.3 Countries of origin of UEEE imports in containers into Nigeria 2016−2017 (number of exports) (Odeyingbo et al., 2017).

Table 14.4 Condition of the various categories of UEEE imports according to country of origin.

EEE category	Examples of UEE imported	Major country of origin	Average age	Condition at entry
Large household appliances	Refrigerators, freezers, washing machines, and air conditioner	Mostly from Europe	5–10 years	Nontested
Small household appliances	Coffee machine, bread toaster, pressing iron, microwave oven, and electric blenders	UK and Germany	5–10 years	Nontested
IT and telecommunication equipment	Computers, CPU, monitors, and mobile phones	USA, China	5–8 years	Nontested
Consumer equipment	Television (CRT and LCD), radio, DVD, and Hi-Fi	China, USA, Europe (mostly UK and Spain)	5–15 years	Nontested

Source: From Odeyingbo, O., Nnorom, I.C., Deubzer, O.K., 2019. Used and waste electronics flows into Nigeria: assessment of the quantities, types, sources, and functionality status. Sci. Total Environ (accepted for publication).

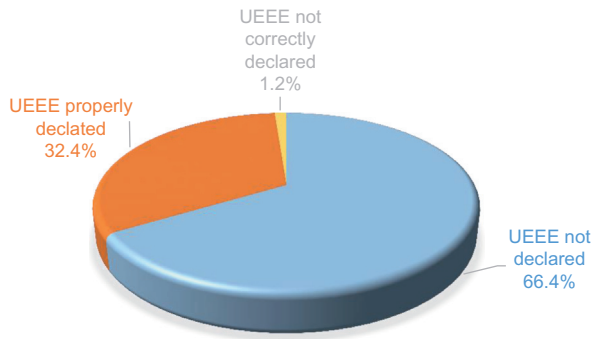

Figure 14.4 Comparison of import declarations in shipping manifests with physical inspection.

Nigeria could be declared as "a car and some personal effects" on the shipping manifest, whereas physical examination would reveal—a vehicle, 25 CRT TVs, 40 electric cookers, and 5 radio sets.

Importers also register the content of their containers as "used electronics" without indicating the type of used equipment loaded in the container. This could be a strategy adopted to divert suspicions which would attract search by the regulatory agency. The comparison of import declarations and inspection results show that almost 70% of imports in containers are not properly declared, especially when the UEEE is imported in a containerized vehicle.

Although some values could be obtained from imported nonfunctioning equipment, resulting from reuse of component parts in refurbishments and repairs, the value is however lower compared to that when there is direct reuse of the product/equipment. The effective refurbishing sector in Nigeria also contributes to the motivation of importers to import both functioning and nonfunctioning equipment. The refurbishing sector can fix and replace many damaged equipment hence it encourages importer to import such class of equipment and consumers to buy equipment sold at nontested status. The main factor driving the flow of UEEE into Nigeria is the profit margin of the importers and the demand for cheap UEEE of perceived good quality and durability. Behind the scene, the issues are as follows:

- Unfavorable economic conditions in the country which creates a demand for cheap UEEE compared to new ones, thereby creating a flourishing market for UEEE.
- A flourishing refurbishing sector dominated by active technicians that have the ability to fix many technical defects in UEEE at a reasonable cost. This motivates the importer to import both functioning and nonfunctioning UEEE. Again, the activities and competence of the refurbishing sector motivate many buyers to engage in such transactions. Very high percentages of nonfunctioning imported UEEE are fixed successfully. Spare parts are also readily available from nonrepairable devices which are cannibalized. The cost of repairing the same equipment in the country of origin (developed country) is far higher and spare parts may only be sourced from new parts. These factors altogether, very often make it uneconomical to repair UEEE in many developed countries; hence such devices enter the waste steam.

14.3 E-waste management in Nigeria

In an ideal case, optimum resource efficiency and low environmental impacts can be reached when E-waste is collected and treated in state-of-the art facilities. However, imperfect disposal scenarios exist in Nigeria and this is the cause of the E-waste problems. The challenges facing E-waste management in Nigeria have been by discussed by Osibanjo and Nnorom. (2007) as well as Odeyingbo et al. (2017). These include:

1. Influx of UEEE with reduced life often mixed with E-waste.
2. Low collection rates of EoL EEE, because the final owners either stores EEE in drawers and cabinets and disposes at will.

3. Ignorance of the toxicity or hazardous nature of E-waste by the general population.
4. Sale of E-waste to scavengers by consumers rather than paying recycling fee.
5. Dearth of recycling infrastructure for the appropriate management of E-waste.
6. Disposal of E-waste through the normal household bins, often times getting to the open dumps before any scavenging can take place.
7. Flows of E-waste through the informal recyclers than through the few existing formal recyclers.
8. Difficulty in sourcing for funding to invest profitable E-waste recycling. The crude techniques adopted results loss of resources, energy wastages, and environmental pollution/human exposure to toxins.
9. Lax enforcement of E-waste legislation.
10. Nonimplementation of the EPR components of the E-waste regulation.

Given that Nigeria does not possess appropriate facilities and infrastructures to fully process the WEEE using state-of-the-art facilities, crude techniques are adopted in the informal sectors which cause avoidable risks to human health and the environment (Nnorom and Osibanjo, 2008). Furthermore, valuable resources including gold and copper are lost due to lack of infrastructure and inefficient processing methods while the recovered valuables are of low quality/purity.

14.3.1 E-waste management in the informal sector in Nigeria

In Nigeria, like in most developing countries, it is the informal sector that dominates the waste collection services, especially in areas where formal waste collection systems are nonexistent (Scheinberg, 2001). Besides buying from private households, activities of the scavengers are characterized by collecting EoL materials from dumpsites and backyards free of charge. Considering the financial benefits, some consumers collect and store large quantities of E-waste and sell to scavengers. The size, type, quantity, and quality of the EoL devices all influence the price paid by the scavengers. Generally, most scavengers look out for certain E-waste categories or components—due to the material composition and recoverable resources.

E-waste management components are a combination of steps and actions taken in the management and treatment of E-waste. This includes activities such as collection, sorting, reuse, refurbishing, repairing, and recycling and these can be broken down into three thematic steps:

- Collection
- Preprocessing (including sorting, dismantling, and mechanical treatment)
- End-processing (including refining and disposal)

Generally, each of these steps are managed by specialized operators. The efficiency of each of the steps has great influence on the entire recycling output.

14.3.1.1 Collection

The collection of EoL WEEE is a key aspect of an E-waste management component. Collection procedures also involve sorting and transporting the collected materials. The efficiency of a collection mechanism determines the amount of

material that is available for recovery and that are channeled toward recycling, and the amount that is lost in the process of storage and/or uncontrolled disposal.

At the moment, organized scrap collection point for E-waste is rare in Nigeria; however, effective and organized informal collectors exist. E-waste collection in many developing countries and emerging economies is organized in an informal door-to-door collection system, where collectors pay money to consumers to be allowed to pick up used and obsolete electronic devices, mostly metals-containing waste fractions (Odeyingbo, 2011). Such door-to-door collection systems, however, can only be, operated at low wages for the waste pickers or with subsidies from public or private sources (Manhart et al., 2011). Personnel moving round to pick such waste are called scrap collectors. The scrap collectors earn their daily livelihood from picking and collection of valuable waste which includes scrap metals, obsolete electrical electronic devices, and old cans. The nonvaluable E-waste components are dumped on the dumpsite, or simply burnt.

14.3.1.2 Sorting/dismantling

The collected EoL materials are transported to the various E-wastes dismantling cluster for the onward dismantling and sorting into various component parts by the E-waste workers based on material composition and the value attached to them. For instance, computer screens and TVs are manually dismantled, to recover metals such as iron, steel, copper, and aluminum. Recyclable and reusable components such as the printed wiring board (PWB) are removed while the remaining components especially plastics are destroyed by burning. Little or no attention is given to component parts containing hazardous materials such as batteries, condensers, and cathode ray tubes. Since there is no provision for the management of hazardous components, such are often disposed at open dumps. In a sustainable management scheme hazardous substances have to be removed and stored or treated safely while valuable components/materials need to be taken out for reuse or to be directed to efficient recovery processes. The conservation of resource especially in the area of reuse before recycling and proper recycling in itself could play a key role in environmental protection by avoiding the hazardous waste flow into the open dumps thereby reducing the risks associated with disposal.

14.3.1.3 End-processing

Formal recycling centers are rare in Nigeria. Informal preprocessors collect materials from scrap collectors and local refurbishers. Some preprocessors at the same time are active as scavengers. The preprocessors disassemble E-waste and other wastes to extract valuable materials like copper, steel, entire printed wiring boards and other valuable components, and sell them directly to the end-processors, such as blacksmiths and aluminum smelters. The PWB and some other components are often sold to middle-men that export them to end processing units mostly in Asia.

There is no regard for safety or environmental protection in these activities and personal protective equipment are rarely used. The preprocessors work locally in

the residential neighbourhoods and their activities result in environmental pollution that pose health hazards. They engage, for example, in the open incineration of cables and other plastic parts in order to retrieve copper and other metals. There is lax enforcement of existing legislation, which makes this an open business—encouraging the operators to do everything possible to obtain valuable materials and earn income.

A summary of the activities of informal E-waste management in Nigeria are presented in Table 14.5.

In Nigeria, E-waste materials are treated using primitive mechanical tools such as hammers, chisels, screwdrivers, and bare hands to separate metallic materials from other materials such as plastics and glass. The common metals of interest include steel, aluminum, and copper. The printed wiring boards (PWBs) in of particular interest because of the larger amounts of precious metals they contain. Cables and wires are incinerated to liberate copper and other metals in open-air; PWBs are separated, collected, and sold to scrap traders, while other unsalvageable

Table 14.5 Activities of informal E-waste management.

Activities and conditions	Strength	Weakness
Preconditions of access	Low initial investment, no particular qualification required; entry and exit in the WEEE business are easy	No control or regulatory enforcement, unfair trading practices No data are kept and quantification is difficult
Jobs	Labor intensive, employment of local people Support for the local economic	It comes with exposure to health hazards
Dismantling	Manual operations, cost saving profitable business may be generated Effective manual dismantling of WEEE components	Lack of effective technology to prevent pollution. Loss of resources during treatment of more complex components such as PWBs
Skilled in identifying waste with high economic value	Sorting, effective collection with high collection rate, cleaning and altering physical shape to facilitate transport, highly skilled in upgrade and repair, dismantling and recovering material	Income is low, poor wages, no access to health services, and dependence on scrap dealers

Source: From Manhart, A., Osibanjo, O., Aderinto, A., Prakash, S., 2011. Informal e-waste management in Lagos, Nigeria—socio-economic impacts and feasibility of international recycling co-operations, Freiburg/Germany & Ibadan/Nigeria 2011; Scheinberg, A., 2001. Financial and economic issues in integrated sustainable waste management. Tools for decision-makers. Experiences from the Urban Waste Programme. The Netherlands: Waste http://www.waste.nl/page/525; Yoshida, A., Terazono, A., Ballesteros, F.C., Nguyen, D.-Q., Sukandar, S., Kojima, M., et al., 2016. E-waste recycling processes in Indonesia, the Philippines, and Vietnam: a case study of cathode ray tube TVs and monitors. Resour. Conserv. Recycl. 106, 48–58.

or invaluable fractions such as plastic and opened-up cable, are discarded by open-air burning or disposed at dumpsites and riverbanks. Field observation reveals that environmental protection is not usually considered nor enforced at any of the activities. These activities impact negatively on the ecology—affecting both the informal recyclers, persons working or living nearby, and the entire ecosystem. A summary of the impact of current management practices for E-waste in Nigeria are presented in Table 14.6.

The common E-waste recycling activities adopted in the Nigerian informal sector involves the dismantling of E-waste, the recovery of valuable components/parts (often sold to dealers that export same for processing) and the use of crude techniques in the recovery of precious metals. These activities of the informal E-waste handlers can be improved on especially in the following areas:

- Methods/techniques adopted—adopting eco-efficient methods that results in good recoveries with minimal impact on health and environment.
- The recoveries achieved with respect to quantities recovered and the purity.
- Protection of health and environment.
- Income of the operators.

When recycling of E-waste is maximized, it could serve as an incentive and source of revenue for the recycling business considering that E-waste contains only about 2.70% of pollutants and over 60% of valuable metals (Widmer et al., 2005) including steel, aluminum, and copper (EMPA, 2005) as well as precious metals (e.g. silver, gold, and palladium). The value of the materials recoverable from E-waste makes recycling activities economically interesting. This is an indication that there is great benefit and potential when E-waste is channeled toward routes that adopts best practices.

Table 14.7 sums up the strengths, weaknesses, opportunities, and threats (SWOT) related to E-waste management in Nigeria

14.3.2 Formal E-waste sector in Nigeria

Unlike the informal sector, operators in the formal E-waste sectors are legally registered EoL collection and processing/recycling service providers. Such organization must have permission from the relevant authority to collect, dismantle, and process E-waste following standards stipulated by the industry regulator after obtaining relevant operational licences. Formal E-waste recycling facilities are expected to adopt environmentally sound management options. Formal E-waste recyclers are expected to follow all practicable steps to ensure that all collected WEEE are managed in a manner which will protect human health and the environment.

Until recently, there was no formal E-waste recycling in Nigeria. The initiation and promulgation of an E-waste regulation instigated series of positive developments in the management of E-waste in Nigeria culminating in the establishment of the first E-waste recycling facility in Lagos, Nigeria.

The creation of a right balance of legislative driver and positive long-term business condition is essential for the sustenance of recycling business. These are the

Table 14.6 Impact of current E-waste management.

Impact	Action	Positive impact	Adverse impact
Social	• Picking, buying and selling of E-waste and other recyclable waste materials	• Provides jobs for scavengers • Contributes to social development through tax	• These activities can expose scavengers to toxic chemicals and microorganisms • They burn certain E-waste components, for example, cables to recover valuables thereby exposing themselves and the environment to a cocktail of toxins
Economic	• Money exchange for picking E-waste and selling E-waste component	• Source of income for families • Generates 62 Million Naira in tax annually	• Low income earning for scavengers • Risks from hauling the collected recyclables along the road using carts
Environment	• E-waste is disposed of with the household waste that goes to open dumps • Very low chance of separation	• EoL recyclable materials are collected and channeled into the recycling system thereby ensuring resource conservation • Veritable source of input for the informal sector	• Burning of cable component releases hazardous gases into the atmosphere while broken CRTs tubes will release lead and these are released into the air, water, and soil and may enter the food chain • Uncollected recyclables results in loss of of E-waste component for recyclers.
Health and safety	• A typical recovery method in informal sector for recovering copper from cables is to burn polyvinyl chloride in open air • Harmful chemicals are used to leach PWB to obtain precious metals	• None	• Cuts and infections from sharp waste fractions • Injuries from handling heavy devices • Exposure to hazardous substances during recycling operations, for example, dioxins and furans during burning operations, and heavy metals during CRT crushing operations • Chemicals released at waste dumpsites and during waste burning have negative effects on the environment and ecosystem

Source: From Heacock, M., Kelly, C.B., Asante, K.A., Birnbaum, L.S., Bergman, Å.L., Bruné, M.-N., et al., 2015. E-waste and harm to vulnerable populations: a growing global problem. Environ. Health Perspect. 124 (5), 550–555, https://doi.org/10.1289/ehp.1509699; Manhart, A., Osibanjo, O., Aderinto, A., Prakash, S., 2011. Informal e-waste management in Lagos, Nigeria—socio-economic impacts and feasibility of international recycling co-operations, Freiburg/Germany & Ibadan/Nigeria 2011; Velis, C., Mavropoulos, A., 2016. Unsound waste management and public health: the neglected link? Waste Manag. Res. 34 (4), 277–279.

Table 14.7 SWOT analysis of E-waste management in Nigeria.

Strength • Readily available skilled refurbishers with high potential for improved technological task to extend functional life of nonfunctional equipment • EoL devices and disposed E-waste can be refurbished or cannibalized and reused as parts. This creates more access to cheap UEEE	**Weakness** • Lack of awareness of the human and environmental impact of the activities of operators in the informal sector • Poor enforcement of legislation on E-waste management and implementation of EPR • Absence of infrastructure for the formal collection, storage, dismantling, and processing of E-waste • Absence of infrastructure (e.g., engineered landfills) for the disposal of the hazardous fraction from E-waste • Uncontrolled operation of informal sector resulting in deleterious effect to humans and the environment
Opportunity • Reform in the sector can result in green employment opportunities • Viable business opportunities for investors to finance sound recycling via emission reduction, trading scheme, that is, the clean development mechanism (CDM)	**Threat** • Toxic when discarded improperly • Informal activities result in the exposure of man and the environment to toxic and hazardous materials • High prices offered for E-waste diverted into reuse or cannibalization for recovery of parts for use in repairs could divert E-waste meant for recycling into the reuse route—thereby threatening the sustenance of a recycling business

Source: Adapted from Odeyingbo, O., 2011. Assessment of the flow and driving forces of used electrical and electronic equipment into and within Nigeria. Master Thesis. Environmental and Resource Management. BTU.

main discouraging limitation to business operation in developing countries, especially private business operators. For example, in Nigeria, the nonfunctional status of existing regulation is the major driver of the unsustainable E-waste management system by the informal sector. The continued uncontrolled or streamlined operation of the informal recycling activities could create competition for recycling between the formal and informal sector. The existence of formal E-waste recycling in Nigeria will result in a reduction of carbon footprint of waste management and assure effective recycling of E-waste. The activities of the first and only E-waste recycling facility in Nigeria is reviewed.

14.3.3 Hinckley E-waste management activities

Hinckley Recycling is a subsidiary of Hinckley Group, an established business with over seventeen (17) years of business in the ICT market in Nigeria. The company

has two facilities dealing with EoL electronics: (i) Ikeja Dedicated IT Refurbishing Unit—established in 2015 and dedicated to refurbishment, value recovery, and data destruction, and (ii) Hinckley Recycling—started recycling operations in 2017 for the safe and responsible collection and recycling of all E-waste streams.

The company facility in Ojota, Lagos, is the first government approved E-waste recycling facility in Nigeria. It took the company 5 years of rigorous environmental tests, assessments, clearance, and accreditation stages, locally and internationally to acquire all necessary certifications to assure that the company is equipped to responsibly treat all E-waste streams capturing the 10 waste electrical and electronic equipment (WEEE) categories from the Nigerian environment. The company complies with National and International regulations for the recycling and disposal of E-waste. All E-waste processed by Hinckley is issued with a certificate of destruction recognized by NESREA and Lagos States Environmental Protection Agency (LASEPA), ensuring its business is legally compliant with the Harmful Waste (Special Criminal Provisions) Act Cap HI, 2004 & the National Environmental (Electrical/Electronic Sector) Regulations S.I No 23 of 2011. All the Company's operations are conducted in an environmental friendly manner, with adherence to the Basel Convention and ensuring that its business is contributing to reducing carbon footprint as well as recycling E-waste responsibly.

The collect and recycle services (CARS) of the company is targeted at organizations that have obsolete or unwanted equipment and expect an efficient and economical solution that delivers compliance to data security and environmental legislation. Under the CARS, Hinckley recovers redundant electronic items, securely destroying all confidential and protected data and manages the recycling of WEEE—in most cases exceeding the reuse, recycling, and recovery of targets. The company policy requires that all EoL equipment delivered to them are tracked and reported, to guarantee the clients that EoL devices are treated in a legally compliant manner and through a quality assured safe and environmentally responsible process (http://www.hinckley.com.ng/recycling/).

14.3.3.1 Refurbishment activities

Hinckley has an operational facility at Ikeja for refurbishment, value recovery, and data destruction, which is a separate entity from the recycling operations. In 2010, Hinckley exceeded 10% by weight of items reclaimed for reuse from what was previously classified as waste electrical and electronic equipment (WEEE)—exceeding targets in the draft Recast WEEE Directive (http://www.hinckley.com.ng/recycling/). Additionally in 2012, Hinckley processed over 2,000 items, refurbishing and selling the majority for reuse. Hinckley's Recycling Services Department also recovers repairable items and components from the waste items for refurbishment and reuse. Hinckley is Nigeria's leading repair and remarketing of used ICT products and they repair over 1000 items per month.

The company considers this service as a desirable route that many organizations can choose for equipment that merely requires a "refresh" in the product life cycle: refurbish existing equipment and redeploy such back into the organization.

Hinckley provides a range of solutions that enable an organization to have equipment collected from one location, refurbished, upgraded if required, reconfigured, and then redeployed to the same or another designated site.

14.3.3.2 Recycling operations

Hinckley accepts and recycles devices within the 10 WEEE categories. The Hinckley Recycling facility at Ojota is a multi-E-waste stream processing facility with capacity for 20,000 tons of E-waste per annum. The company's newly acquired facility has been inspected and approved for recycling by the regulatory bodies. The Ojota facility receives both hazardous and nonhazardous waste streams. Presented in Table 14.8 is the company's classification of fractions/components from E-waste.

Hinckley's process is transparent and is audited as material are tracked through the entire company processing from collection to the destination of the secondary material. (Company report). Some of the machines used in the processing are shown in Fig. 14.5.

Being a semiindustrialized processing facility, Hinckley ensures that all E-waste are processed into minute material fractions for further processing by the downstream sector. All hazardous components are treated safely and processed at state-of-the-art facilities worldwide. Hazardous components such as refrigerants are collected using the machine shown in Fig. 14.6. The approach adopted in processing specific components/materials of E-waste are presented in Table 14.9.

Formalizing the informal E-waste sector via training is essential in bringing the much needed change to assure protection of human health and the eco-system. In 2018, Hinckley commenced series of training programs for operators in the informal E-waste sector in Nigeria to update them on better E-waste management practices and keep then abreast of the environmental and health implications of their operations. The firm commenced the series with a week-long training of members of the

Table 14.8 Hinckley recycle classification of hazardous and nonhazardous E-waste components.

Nonhazardous fractions	Hazardous fractions
Aluminum	Lithium ion batteries
Iron/steel	Capacitors
Copper	Lead-acid batteries
Bronze/Brass	Nickel-cadmium batteries
Stainless steel	Other batteries
Mixed ferrous metals	LCD screens
Mixed nonferrous metals	CFL (e.g., scanner bulbs)
Mixed plastic	Toner cartridges
ABS plastic	CRT leaded glass
Glass	Phosphorous powder
Printed circuit boards (PCB)	Brominated plastic

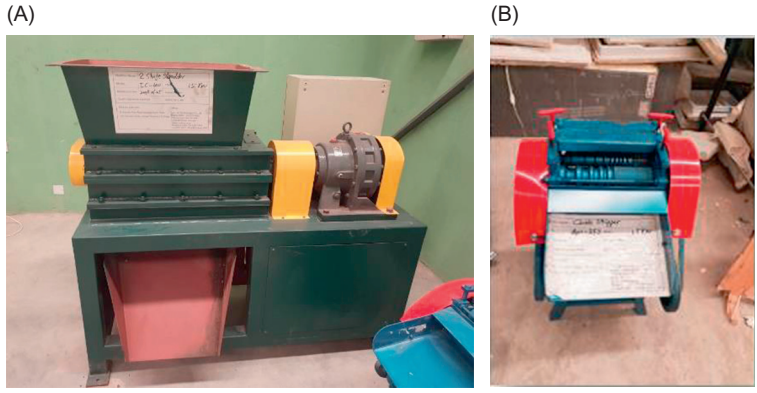

Figure 14.5 E-waste processing machines: (A) two-drum shredder and (B) cable striper.

Figure 14.6 Refrigerant recovery machine.

Association of Vendors of Used Computers and Allied Products, which is a body of the informal operators that have about 500 active members within Lagos. The training was followed by physical examination and laboratory testing of some of the scavengers for exposure to harmful chemicals from E-waste processing (Punch, 2018).

14.3.3.3 Challenges

In Nigeria, it is common to find scavengers, waste collectors, and smelters posing as "recyclers" by going house-to-house collecting E-waste for a fee. Such collectors divert E-waste into the informal recycling since they do not have facilities to recover precious elements and manage the hazardous fractions in an environmentally sound manner. These individual constitute a challenge to the proper management of E-waste rerouting E-waste into the informal sector while acting as the "new recyclers in town." This and the nonimplementation of extended producer responsibility constitute huge challenges to formal recycling in Nigeria.

Table 14.9 E-waste processing approach for specific components/materials.

Components	Material	Classification	Recycling process	End product (downstream)
Refrigerant	Gas	Gas is hazardous	Gas will be safely extracted using RRM-650. The gas will be stored and reused	Recycled gas for reuse
Compressor	Copper, steel, motor, and oil (lubricant)	Used oil is hazardous	Copper will be extracted and transferred locally at approved smelters. Oil is extracted and stored for reuse	Copper ingots
Condenser	Steel and copper	Nonhazardous	Metals and plastics will be extracted and transferred locally at approved smelters	Steel and copper ingots
Condenser fan	Plastic, steel, and motor	Nonhazardous	Metals and plastics will be extracted and transferred locally at approved facilities	Copper and plastic
Evaporator	Copper/steel/ aluminum	Nonhazardous	Metals and plastics will be extracted and transferred locally at approved smelters	Copper/steel/aluminum ingots
Filter/Dryer	Iron and silica gel	Nonhazardous	Silica gel is processed from KDF (Copper and Zinc)	KDF
Accumulator	Iron and gas	Gas is hazardous	Gas will be safely extracted using RRM-650. The gas will be stored and reused	Iron ingots
Body	Foam and plastic	Hazardous	Dismantled and bailed for local downstream production purpose	Mixed foam and plastic; use in building material
Divider	Iron, glass, and plastic	Nonhazardous	Material will be extracted and transferred locally at approved facilities	Recycled glass, iron ingots, plastic furniture

Hinckley has to deal with the low E-waste awareness as well as inadequate finance. There is no level playing field in this sector as Hinckley is unable to offer households or organizations same or comparable amounts as they receive from the scavengers due to the processing and treatment costs incurred for responsible recycling. Unfortunately, the situation is so bad that companies with environmental ISO standards, who uphold global sustainability, HSE, and environmental policies are unable to look away from the financial gains the informal sector avails them. This value system is one Hinckley battles with on a day-to-day basis.

14.4 Comparative analysis of E-waste treatment in developed versus developing countries

Today in industrialized countries, E-waste is processed separately from other waste streams owing to its material composition and appliance size (Krauchi et al., 2005). Many OECD (Organization for Economic Co-operation and Development) countries have developed management systems based on realities of the system boundary and legislation (OECD, 2014). The European Union WEEE (2002/96/EC) and RoHS (2002/95/EC) Directives, revolutionized E-waste management by setting collection, and recycling/recovery targets and restricting the use of hazardous materials in the manufacture of electronic products. In Europe, both the new and old WEEE directives set targets for collection, recycling, and recovery rates. The old WEEE Directive set a target collection rate of four kilograms per capita from 2006 to 2016, whereas WEEE 11 (effective from 2016) has set a 45% collection rate of the average weight of electrical and electronic devices that were placed on the market in the previous 3 years. Such ambitious legal framework does however not exist in Nigeria at the moment.

Switzerland has a legislation in force that ensures WEEE are managed effectively. The management is based on EPR with a clear definition, roles, and responsibilities of all the stakeholders involved (Sinha-Khetriwal et al., 2005). The Swiss Foundation for Waste Management (S.EN.S) is a nonprofit organization assigned to recover selected WEEE on behalf of manufacturers, importers, and retailers. It commenced its operation in 1990 with the responsibility of recycling refrigerators and freezers. In addition to the activities of Swiss foundation for waste management (S.EN.S), the Swiss Association for Information, Communication and Organisation Technology (SWICO) recycling guarantee was created by the association of manufacturers and importers of office electronics and IT equipment in Switzerland in 1993. SWISCO was initially collecting office electronics and IT equipment. It operational coverage however expanded to include other WEEE such as mobile phones, consumer electronics, telephone switchboard systems, as well as dental equipment (Hischier et al., 2005; Streicher-Porte et al., 2005). Both systems are well established, offering complete take back and recycling systems financed by an advanced recycling fee (ARF) (Hischier et al., 2005). These fees are paid by the distributors,

the retailers, and finally to the consumers, who pay an ARF with the purchase of any EEE (Streicher-Porte et al., 2005).

However, this is not the case in the developing countries. The backlog demand of EEE in developing countries as well as the lack of national regulation on management of E-waste and/or lax enforcement of existing laws promotes the growth of informal economy that deals with E-waste (Osibanjo and Nnorom, 2007; Ni and Zeng, 2009).

It is difficult to have an effective and sustainable formal E-waste collection system without an effective financial mechanism combined with legislation. In Nigeria, the informal collectors in most cases buy E-waste from the consumers while only a few consumers hand over their E-waste free of charge. It is rare for a consumer to pay for the disposal of E-waste.

Inappropriate methods are used in the management of E-waste in the developing countries, including disposal with municipal waste, disposal into surface water bodies and the use of "unsound" techniques in the "crude recycling" of selected components of E-waste to recover valuable materials such as copper, silver, and gold (BAN, 2002; 2005). The crude techniques adopted in material recovery from E-waste include open burning, cathode ray tube cracking and dumping, circuit board recycling, plastic fragmentation and melting, and dumping various waste residues (Ni and Zeng, 2009). These activities are wrecking environmental havoc in the developing countries and various studies have reported severe environmental and health implications of such activities (Fu et al., 2008; Wong et al., 2007). The conventional waste management approach is that waste generation, collection and disposal systems are planned independently. However, experience has shown that all these are very closely interlinked and each component can influence the other. This situation also corroborates the situation in E-waste flow network, where active interaction exists between the various components in the flow network.

The complexity of E- waste management in Nigeria could be demonstrated by the amount of interconnections between the various components which affects each other. The reality of the interaction of the component is represented by the interaction between the operators in the flow network which includes actors involved in retail, refurbishment, consumption, repair, disposal, dismantle, export of dismantled scraps, or local recycle. For instance, the E-waste collection and recycling activities in Lagos are carried out by informal waste collectors (commonly referred to as "scavengers") who move round the city collecting E-waste together with other metal-containing wastes. Mostly, these collectors buy such obsolete devices for small amounts of money from individuals, businesses, or private households. There are also collectors who cannot afford to buy these obsolete devices because of financial constraint hence they focus on what is freely available, for example, at open dumps. Dismantled and assorted E-wastes are sold to traders while nonvaluable fractions are thrown back on the dumpsite. The E-waste recyclers disassemble obsolete electrical and electronic equipment in order to liberate metals that can be sold for economic gain. Some metals of interest include steel, aluminum, and copper. Cable wires are incinerated to liberate copper, printed wiring boards (PWBs) are separated, collected, and sold to traders. Invaluable fractions are discarded

mostly by burning and discarding on dumpsites. The various stages are closely related and executed.

This trend in the management of end of life materials of E-waste in Nigeria leads to a high accumulation of residual materials which are difficult to manage due to lack of appropriate management scheme that can take care of both valuable E-waste component and the nonvaluable ones. It is evident that an appropriate E-waste management system would require a financial scheme to sustain the system. The nonexistence of an appropriate management scheme that integrates E-waste finance still creates a research gap necessary for empirical studies.

At the moment, enterprises and individuals engaging in E-waste management cannot effectively manage the collected EoL materials in environmentally sound methods without the availability of additional financing systems and/or other safeguard mechanisms that ensure a proper handling of all fractions of EoL WEEE especially the CRTs containing device. The work of Manhart et al. (2011) revealed that an average E-waste collector and recycler in Nigeria earns between US$ 0.22 and US$ 3.36 per day. This earned income is below the internationally defined poverty line of US$ 1.25 for majority of these operators especially those with dependants. These financial returns cannot secure the operators a decent living. The quantity and quality of the collected WEEE under consideration determines the overall management approach adopted because of the different monetary values attached to the various components and also the competition between informal business and formal system.

An ideal management system, within the formal sector, is expected to observe all the environmental and occupational regulations attached to their activities while taking care of both valuable and nonvaluable components. This is expected to increase the operational cost of activities, whereas the informal sector generally does not obey many of the set rules which give them cost advantage over the formal operators. The nonenforcement of the existing E-waste regulation is assumed to be one of the major drivers of the unsustainable E-waste management system in Nigeria.

14.5 Proposing a sound E-waste management strategy in Nigeria

Studies have shown that pollution from E-waste processing using crude methods has the potential to cause damage both to the environment and human health through the contamination of air, soil, water, and sediment. Studies of blood, breast milk, and hair of workers and people residing within E-waste treatment sites have reported elevated levels of heavy metals levels (Zhao et al., 2007, 2008; Li et al., 2017).

14.5.1 Financing E-waste management

The financing mechanism of E-waste take-back system activities and allocation of economic responsibilities, along the EoL material flow network has proven to be

challenging in many developing and developed countries with existing take-back schemes or countries discussing potential take-back scheme (UNEP, 2014; StEP, 2009). An effective financial scheme will involve financial responsibility to the key stakeholders throughout the flow network. An appropriate system would require a financial system which takes care of both valuable and nonvaluable fraction in such a way that the value of recyclables should be able to offset the processing cost with a profit margin after handling the nonvaluable, hazardous components.

The present E-waste management system in Nigeria cannot finance itself. One of the materials of high values in E-waste is gold and its concentration in PCs is estimated to be about 4 g. This value creates an incentive to recover gold from the PC. Unfortunately, when the gold-containing components are sold at lower values for recovery/refining abroad, the monetary benefit is drastically reduced. More so, the other material fraction in E-waste attracts low economic value, e.g., glass and plastics. This condition is responsible for the burning or dumping options in developing countries. The availability of recycling technology in Nigeria will assure enhanced profitability from the E-waste fractions currently exported. Funding is therefore necessary to drive sound management approach to E-waste.

In developing countries house-to-house collection of E-waste by the informal sector is believed to significantly achieve higher collection rates when compared to voluntary take-back systems in Europe (UNEP, 2014). This can be attributed to the fact that such procedures are convenient for the consumers and sometimes the money paid by the collectors is an economic incentive that encourages the consumer to participate (Odeyingbo, 2011).

Various studies have identified the need for a well-functioning local take-back and recycling scheme which involves development of effective collection strategies (not cherry picking), ensuring collection of both valuable and nonvaluable fractions which are channeled into appropriate recycling process and or treatment/disposal routes. To ensure an effective collection and appropriate treatment, an appropriate financial scheme that can achieve a win-win situation for all the stakeholders involved, conservation of resources through recycling, and reducing impact on the environment is crucial. Financing E-waste management system should be a system which aims at establishing institutional frameworks by initiating a suitable process that will accommodate negotiations, regarding responsibilities, and rules amongst relevant stakeholders at local, national, regional, and global level and how such system could be sustained in a long term and fair market condition for all.

14.5.2 Enforcement of E-waste regulation in Nigeria

Sequel to the high incidence and influx of shipments of hazardous waste and E-waste into Nigeria, the Government moved to address this transboundary movement. It is expected that the availability of policy and law could help develop a legal framework centered on the activities of the stakeholders to assure environmentally sound management of E-waste. Due to the documented evidence of E-waste dumping in Nigeria and the return of shipments of E-wastes to country of origin,

the government through the regulatory agency, NESREA initiated moves to control the in-flow of E-waste via legislation. In 2011, the government passed the National Environmental (Electrical/Electronic Sector) Regulation which banned the importation of E-waste and provided guidelines on environmentally sound management of E-waste. NESREA has the responsibility to enforce all environmental laws, regulation, guidelines including monitoring and control of E-waste. The agency wants to stop the importation of unserviceable UEEE coming into Nigeria. In recent times, NESREA together with the Nigeria Port Authority sent back some ships suspected to carry E-waste into Nigeria from Europe. The NESREA Regulation stipulates that all UEEE imported into Nigeria shall comply with the following provisions:

1. The item(s) shall be of comparative models of equipment in use.
2. It shall be fit for the purpose it was originally designed for.
3. It shall be fully functional as originally intended.
4. The outward/external appearance of the item shall not show any waste characteristics
5. It shall not be scrap.
6. The items shall be properly package for protection during transport, loading, and unloading.

Some of the regulatory requirements for the importation of UEEE into Nigeria are:

A. Where the holder of the equipment/products indicates intention to ship or is shipping UEEE and not WEEE, the following documentation shall be provided to back up the claim to NESREA:
   - **I.** A copy of the invoice and documentation relating to the sale and or transfer of ownership of the UEEE which states that the equipment is for direct reuse and fully functional.
   - **II.** Evidence of evaluation/testing, such as certificate of testing proof of functional capability on every item in the container/truck.
   - **III.** A declaration made by the holder who arranges the transport of the UEEE that none of the material or equipment within the consignment is waste.
   - **IV.** Evidence of sufficient packaging to protect it from damage during transportation, loading and unloading.

B. Prior to any transboundary movement of UEEE, the importer or the representative shall provide information to the appropriate authorities (NESREA and Nigerian Customs Service) providing compliance with this guidance.

C. For practical reasons of control, every carrier (e.g. shipping container, lorry, and truck) of UEEE shall be accompanied by
   - A Cargo Movement Requirement (CMR) document. The CMR is a proof of evaluation/testing and certificate containing testing information on each item, and
   - A Copy of permit to import.

D. Item that should not be imported into Nigeria.

E. Consequently, UEEE would normally be considered waste if:
   - **i.** The product is not complete and some essential parts are missing.
   - **ii.** Functionality or safety is impaired.
   - **iii.** The appearance is generally worn or damaged.
   - **iv.** The packaging is insufficient.

v. The item has among its constituent parts anything that is required to be discarded including refrigerators or air conditioners containing ozone depleting substances (ODS).
xvi. It is destined for disposal or recycling instead of reuse.
xvii. It is old or outdated destined to be cannibalized to gain spare part.

Despite the regulatory provision of the Basel Convention and the NESREA regulation, huge amounts of UEEEs and E-wastes still flows into Nigeria annually (Odeyingbo et al., 2017). It is therefore necessary to review existing legislations if necessary and ensure strict enforcement to assure sound E-waste management. It may also be necessary to review the type of permits or licenses issued to importers of UEEE to assure compliance to existing regulation—especially on the importation of only functional UEEEs.

14.5.3 Introduction of environmentally sound technology

The role of technology and appropriate skill cannot be over looked in the E-waste management system. The continuous training of personnel working in E-waste management sector and provision of basic infrastructure are crucial. The availability of techniques relating to personal protection, handling of hazardous products, first aid and combating fire and flames are essential for people working in this sector. The provision of appropriate technology would contribute in achieving the aim of an eco-friendly recycling business.

14.5.4 Effective extended producer responsibility implementation

Extended producer responsibility (EPR) is an environmental protection strategy aimed at decreasing total environmental impact from a product and its packaging, by ensuring that the producers of the product take responsibility for the entire lifecycle of their products especially in the take-back, recycling, and final disposal of their products, including its packaging. The primary responsibility of EPR lies with the producer, who makes designs and marketing decisions. In 2013, an EPR system was initiated by NESREA with the introduction and adoption of a draft Guidelines for Implementation of EPR for the Electrical and Electronic Sector (EES). The guidelines create an avenue to achieve a sustainable E-waste management status in Nigeria by implementing and enforcing the EES regulation of 2011. The core stakeholders targeted in the EPR guidelines includes producers/importers, manufacturers, and assemblers of EEE. The guideline incorporates the establishment of collection centers in collaboration with the original equipment manufacturers (OEMs). It further makes provision for the establishment of an EEE Registry, that is, an organization that maintains an inventory of recyclers/E-waste related companies and E-waste stocks nationwide, and this will be operated by third-parties and public−private partnerships, to achieve an effective EPR system in Nigeria. A synergy of both voluntary and mandatory approaches to E-waste should be encouraged and the EPR

concept should be reviewed to include other stakeholders, such as the consumers and government. In addition, the following will facilitate effective EPR in Nigeria:

- Establishment of WEEE registry/database.
- Proper regulation of the informal sector.
- Introduction of nonmonetary incentives that will encourage for consumers to return EoL goods for recycling or pay for the disposal of their waste.
- Creation of a financial model to fund environmentally sound recycling.
- Efficient record keeping that is easily retrieved to facilitate rational investment decisions.

One of the challenges to an effective EPR is the overlapping and lack of clarity in the roles and responsibilities of stakeholders—importers, collectors and recyclers, municipalities, consumers, and the producer responsibility organizations (PROs). Maybe, the earlier this is resolved in the Nigerian EPR, the more likely the EPR will impact positively on E-waste management in Nigeria. Also of importance is the illegal importation of UEEE by individuals and businesses that are not registered with the regulatory agencies. Recent findings showed that only 3% of the importers of UEEE are registered with the regulatory agencies in Nigeria (Odeyingbo et al., 2017). This implies that the vast majority of the importers cannot contribute to the EPR scheme and this will result in inadequate levels of finance to handle end-of-life costs.

Monitoring and control by the government agencies will ensure that stipulated conditions and target are met by operators. Monitoring is an important component in the E-waste management system because it ensures continuous improvement and maintaining compliance to the existing regulation and standards. Awareness creation among the stakeholders is necessary to rational investment decisions.

14.6 Conclusion

E-waste management represents the dark side of advances in the information communication technology (ICT) sector, which obviously has been instrumental to the transformation of virtually all aspect of human endeavors. The export of UEEE/WEEE generated in the developed countries to the developing countries may have some benefits but the negative impacts are so evident in the destination countries due to the absence of facilities/infrastructures that would facilitate environmentally sound management of E-waste and assure resource conservation. Low end techniques such as open burning and other crude E-waste management practices are adopted and these result in the emission of pollutants like dioxin, furan, and heavy metals. E-waste is unique as it contains both hazardous and valuable/precious metals.

The factors driving the inflow of UEEE and E-waste into Nigeria, the management approaches adopted as well as the challenges in achieving environmentally sound management of E-waste were discussed. Progress in the formal recycling sectors was reviewed while some of the approaches in achieving sound management practices were presented. The major challenges facing E-waste management in

Nigeria include inflow of E-waste, poor take-back/collection strategies that favors formal processing, and dearth of state-of-art technologies to recover resources from E-waste. Incentive-based policies that protect human health and the environment must be proactive and practical in this sector.

The PiP has shown that physical inspection of containers and vehicles conveying UEEE is critical in UEEE/E-waste inventories. The national adoption of this strategy will unravel the real flows of UEEE/E-waste and this is important in checking illegal E-waste trafficking. The importation of huge quantities of UEEE/E-waste into Nigeria, many of which are nonfunctional, aggravates the already bad situation. Considering the recent discoveries on the modes of importation and the functionality reported, it is pertinent that the existing regulation is enforced to ensure strict monitoring of UEEE and E-waste importations. The observation by the PiP that only 3% of the importers of UEEE are registered with the regulatory agency is worrisome. This shows that about 97% of active UEEE importers are into illegal activities and would most likely make no effort to adopt best practices and implement the NESREA regulation in their action. This could be a reason for the wrong declarations observed by the PiP.

The regulatory agencies should ensure that the existing laws are enforced especially with respect to implementation of EPR. Strict enforcement of the provisions of the E-waste regulation is essential to ensure the adoption of environmentally sound management options that guarantees protection of life and the eco-system. Awareness creation on the toxicity of some E-waste components and the health implications of informal recycling are essential to divert E-waste from the informal sector. Controlling the importation of UEEE to ensure that only tested and functional devices are imported as enshrined in the E-waste regulation will reduce the volumes if E-waste managed.

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