Chapter 5

Management of Electronic Waste in Africa

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ABSTRACT

The issue of WEEE (usually called e-waste) is of growing concern across the whole of Africa. Increases in the use of personal computers, mobile phones and other electrical and electronic equipment has caused a subsequent rise in the disposal of end of life products in a continent where infrastructure for the environmentally sound treatment is scarce. This chapter reviews the current situation across the continent of Africa investigating the impacts of the rise in WEEE. The issue of illegal importation and the demand for second hand items is considered. Data for Nigeria, Kenya and South Africa are considered as these countries are all taking concrete steps to address and embed environmentally sound management of WEEE in their legislation and practices. A number of legislative drivers such as the Basel and Bamako Conventions are outlined as these are key drivers for reducing the import and impacts of WEEE in Africa. It is widely acknowledged, in a number of studies, that improper management of WEEE has serious health and environmental impacts. The deleterious effects on people working in the sector are described along with the deterioration in the environment and potential long term concerns if current practices are not improved. The scale of the problem is not to be underestimated but there is hope for the future, with a range of initiatives and projects bringing about change. A number of potential solutions are described such as Best of Two Worlds, an OEM (Original Equipment Manufacturer) model for the future and industrial recycling solutions. Finally, concrete recommendations for the widespread adoption of environmentally sound management of WEEE across Africa are provided.

5.1 Introduction

The use of electrical and electronic equipment (EEE) is still low in Africa compared to other countries in the world, but it is growing at a staggering pace.[1] In the last decade for instance, the penetration rate of personal computers has increased by a factor of 10, while the number of mobile phone subscribers has increased by a factor of 100. Internet penetration in Africa as of 31 December 2017 was 35.2% compared to the world average of 54.4 percent.[2]

The penetration rate signifies that due to the intense trade of used EEE, people have better access to lower priced EEE. From this perspective, the import and trade of used EEE is in support of the UN Sustainable Development Goals as a means to foster the use of information and communications technology (ICT) for sustainable development.[3] This value is demonstrated by some global initiatives. At the World Summit on the Information Society held in Tunis in November 2005, delegates of 174 countries, including 50 African countries, agreed that ICT can support economic, social and cultural development and reaffirmed that "everyone can benefit from the opportunities ICTs can offer, by recalling that governments, as well as private sector, civil society and the United Nations and other international organizations, should work together to improve access to information and communication infrastructure and technologies […]".[1] However the illegal export of waste electrical and electronic equipment (WEEE) disguised as used EEE (UEEE) to Africa and other developing and transition countries, which lack the infrastructure and facilities for the environmentally sound management of

WEEE, is of international concern, more so as the transboundary movement of WEEE to developing countries is in contravention of the Basel Convention.[4]

There is a growing demand for UEEE in Nigeria and Africa. This is driven by the demands for second-hand electronic products for direct use, and also as secondary resources for refurbishment and dismantling providing a valuable income-generating opportunity for the local people.[5] There are many markets that specialise in the sale of second-hand electrical and electronic products, most famously Alaba International Market (Figure 5.1) and Computer Village, Ikeja, in Lagos. UEEE from Europe and the USA is perceived as being higher quality and more robust than items made specifically for the African market, which is lower quality and less reliable. There is also a common understanding that European, in particular UK, imports are more able to tolerate the frequent power interruptions and variations in supply that are common in Nigeria and sub Saharan Africa; hence those that can afford them have power generators at home or/and work.

[Figure 5.1 Alaba market near here]

When purchasing second-hand electronic products there is no consideration of whether the item is a waste or non-waste; the key question asked is whether the product is tested or untested. The same markets that sell UEEE also have highly specialised repair and refurbishment technicians, which a purchaser of an untested item would visit subsequent to their purchase to get it repaired and ensure full functionality. It should be noted, however, that

it is illegal to ship untested equipment from the EU, but this distinction is of little relevance to the market traders. A very high percentage of non-functioning imported UEEE are fixed successfully.[6] Imported UEEE is also sold to shop owners or distributors who then possibly repair non-functioning devices before they sell it at higher prices, compared to non-tested UEEE. However, repair technicians have reported that the lack of availability of spare parts is a barrier to increased reuse. Although a high proportion of component harvesting is undertaken to supply spares this does not address common failures, as the parts that fail most often will have limited availability.

It is much cheaper and easier to get UEEE repaired in Africa than in most European countries. The low costs of labour facilitates the time-intensive repair operation, and spare components can be harvested from the unrepairable items. The reuse and repurposing of complete EEE or components of EEE is common in developing countries (Figure 5.2).[7] Businesses are established for the sole purpose of refurbishing items, such as computers and mobile phones, which would be regarded as waste, and beyond repair in developed countries. However, the rapid evolution of technology is likely to impact on the availability of spare parts in the future and may negatively affect the ability to repair. There may also be, increasing, issues with newer versions of software being incompatible with older hardware. As more items of EEE become "smart" and connected to the internet there are also likely to be increasing concerns regarding data security which may impact on the repair and reuse markets. Nonetheless issue of classifying an item as a waste or non-waste is a critical issue under the 1989 Basel Convention's transboundary movement of waste which prohibits export of hazardous WEEE from developed

to developing countries as the importing countries receive both WEEE as well as the environmental and social externalities. The developing countries lack the capacity and technology for environmentally sound management of these wastes.

[figure 5.2 Repair workshop near here]

The use of EEE varies between 4.6 kg (Liberia), 4.8 kg (Côte d'Ivoire), 6.3 kg (Benin), 41 kg (Ghana), and 44 kg (Nigeria) per inhabitant.[1] In 2010 Internet penetration in Africa was still relatively low; while the population of the continent equals to 13% of global population, only 5.6% of the population in Africa uses internet compared to the world average of 26.6%.[3] However, between 2000 and 2008, the number of users in Africa grew by a staggering 1,100% compared to the rest of the world's 332.6%. As noted above, internet penetration in Africa as of end-2017 was 35.2% compared to the world average of 54.4 percent. Africa is estimated to have one of the highest growth rates in internet usage.[3] This increase in the use of the internet has caused a rise in the number of personal computers, and so by association, a rise in waste. By 2030, the developing world is forecast to discard twice the number of personal computers annually as the developed world, some 600 million versus 300 million.[8]

Many countries have banned the import of waste but there is also an issue around second-hand working goods. Although some countries have banned, or restricted, the import of second-hand goods (such as Ghana banning heating and cooling devices, and Nigeria second-hand cathode ray tubes) there is still a demand for these goods. Many customers prefer to buy

second-hand well-known brands that are considered reliable; in particular, UK imports are considered able to cope with unreliable and fluctuating power supply. There is also a perception that some new imports from the Far East are made to a lower standard for Africa rather than for other global markets.

5.2 Sources of WEEE

5.2.1 Introduction

Some developed countries have been accused of exporting their WEEE to developing countries in the name of bridging the so-called ‘‘digital divide’’, and that in some cases these exports have been attempts to get rid of toxic wastes by dumping them in developing countries.[9,10,11] It is reported that most EEE exports to Africa are not pre-tested for functionality.[12] Consequently, it is not possible to assess whether these exports are legally defined as hazardous waste under the Basel Convention.[10] Studies have revealed that western African countries are importing large amounts of EEE, which include some second-hand items and some that is inoperable.[1]

The rise in awareness of the issues with WEEE and Africa can be traced back to the Basel Action Network’s Digital Dump .[10] Much of Africa’s WEEE enters through Nigeria where it is then transported through the Continent. The main sources of second-hand items were found to be Belgium, Finland, Germany, Israel, Italy, Japan, Korea, Netherlands, Norway, Singapore, UK and

USA.[10] The European Environment Agency estimates that up to 1.3 million tonnes of discarded EEE are exported from the EU annually mostly to Africa and Asia.[12]

Hence, managing WEEE has become a major challenge for governments and policy makers, and for the reasons discussed above, particularly in developing continents importing both used and new EEE.[13,14] Except for South Africa where an increase in material recovery activities has been reported, data on the recycling of WEEE in Africa is scarce.[13] In general, data regarding WEEE generation and management in Africa is poor, if available at all, and mainly relies on the studies and pilot projects by the Basel Convention Secretariat, and StEP (Solving the E-waste Problem), a United Nations-based membership organisation. The countries selected below are based on reported studies and pilot projects, providing an overview of the situation.

5.2.2 Nigeria

In the past decades, Nigeria's information and communications technology (which heavily relies on imported second-hand devices) witnessed major growth.[13] Nigeria is considered one of the fastest growing telecoms markets in the world with more than 170 million mobiles lines in 2019 and a teledensity (the number of fixed and mobile telephones per hundred inhabitants) of 115. It is estimated that 146 million Nigerians used mobile phones as of January 2018. About 120,000 fixed line telephone sets were reportedly abandoned and disposed or stockpiled in 2007.[14] In the same year, it was estimated that 8 million mobile phones and accessories were generated with a high probability that these materials would end up in open dumps or

landfills.[15] The high rate of repair and reuse of used mobile phones in Nigeria extends the life of the phones to about 7 years. However, it is estimated that mobile batteries and chargers are replaced twice a year, amounting to a total waste generation of approximately 3,000 tonnes and 9,500 tonnes respectively, for the period 2001–2006.[15]

Data regarding imports of WEEE into Africa has focussed on Nigeria, the subject of several studies. Nigeria dominates the region in the total amount of used and new EEE imports, total number of EEE in use and the subsequent total amount of WEEE generated.[1] An oft-quoted study of WEEE is that of the Basel Action Network (BAN) where 500 containers of WEEE were found to enter Nigeria every month, of which 75% was estimated to be non-functional (Figure 5.3).[10] In 2010 it was found that of 600,000 tonnes of used EEE, that were imported into Nigeria, 30% was non-functional. Subsequent studies found that 60-90% of waste was illegally traded or dumped.[16,17] It should be noted that an illegally traded item does not necessarily mean that it was not functional or repairable.

[Fig 5.3 – Container of e-waste, Lagos, Nigeria near here]

The most recent study of WEEE in Nigeria found most imported UEEE originated from ports in Germany (ca. 20%) followed by the UK (ca. 19.5%) and Belgium (ca. 9.4%).[18] The Netherlands (8.2%), Spain (7.4%) China (7.3%) and the USA (7.3%) are next in the ranking of main exporters, followed by Ireland (6.2%). Overall, these eight countries account for around 85% of UEEE imports into Nigeria. EU Member States were the origin of around 77% of UEEE imported into

Nigeria, despite legislation which prohibits export of WEEE to developing countries. Inspection of containers between 2015 and 2016 found that containers with imported UEEE represented around 0.7% of all containers of imported goods. 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, kitchenware, sports equipment, and other household items/furnishings.[18]

Nigeria is one of the leading countries in Africa (along with Ghana, South Africa, and Tanzania) importing second-hand electronics and WEEE from more industrialized countries. It is estimated that around 60,000 tonnes of UEEE was imported in containers to Nigeria per year through Lagos' two ports alone, not including imports over land routes from neighbouring countries. Most types of imported UEEE are at least partially functional but a fraction still remains non-functional, meaning that every year Nigeria may have imported around at least 15,700 tonnes of WEEE, mostly LCD-TVs containing mercury, refrigerators and air conditioners containing (H)CFCs. Most imported UEEE is falsely declared or even undeclared in import documents, the latter applying in particular to UEEE imports in containers with vehicles, and especially for roll-on/roll-off imported vehicles. These findings indicate that the stipulations of the Basel Convention, Nigerian import legislation, the transfrontier shipment regulations of the EU WEEE Directive, as well as the NESREA ban on CRT devices, are infringed on virtually a daily basis without regulatory consequences. Similarly, despite the ban, used refrigerators with (H)CFC leave the countries of export and are allowed into Nigeria.[18]

UEEE is often described as second-hand goods, private goods, for charities and other declarations, because there are no procedures at Nigerian ports to check if they were used or end-of-life EEE, or in some cases the labelling of UEEE is manipulated (as used refrigerators classified as ‘‘not-containing CFCs’’) with new labels stuck over old ones to obscure the true contents. This highlights the risks associated with the import of UEEE when standards have not been established or enforced, and when almost all of the UEEE could be WEEE.[1]

Compliance with International law and National laws, where these exist, is poor.[18] Although the Nigerian Government has banned the import of CRT TVs, around 260 tonnes were found to be imported annually. The main sources were China (23%), USA (15%), UK and Spain (14% each), Italy (8%), Hong Kong and the Netherlands (4% each). These six countries accounted for about 80% of the total CRT imports. Inspection of containers showed that 80% of the imported containers carried clean UEEE, and only 40% of the imported UEEE was properly packaged. Nevertheless, around 80% of the devices were found undamaged during visual inspection.

The starting point for much WEEE is Apapa, a Nigerian container port.[10,19] The containers are then taken to other destinations, the most notable of which is Alaba, considered to be the largest EEE market in Africa. At Alaba there are over 2000 shops and stalls selling all types of EEE from irons to fridges, supported by repair facilities. BAN found a large quantity of the imported second-hand electronics were obsolete; the repairable equipment was moved to a large street market or other markets on the outskirts of Lagos. An estimated 15,000–45,000 tonnes of the computer hardware that are annually imported into Nigeria are reported as not

usable or repairable.[13] The functional lifespan of an item post-sale is unclear.[1] This so called "near-end-of-life" equipment can be another major source of WEEE imported into West African countries as functional equipment but turning into waste in a relatively short time.[1] The Basel Convention does not capture "near-end-of-life" equipment as a source of WEEE, which could be significant in some UEEE consignments. However, it is assumed that in 2010 between 50-85% of WEEE was domestically generated out of the consumption of new or used EEE of good quality, with a reasonable lifespan.

A UN University study on WEEE in Africa was also commissioned by the GEF project on Stockholm Convention national implementation plans in Africa.[20] The study shows that Nigeria domestically generates increasing amounts of WEEE, from around 170,000 tonnes in 2009 up to around 290,000 tonnes in 2017, corresponding to an increase of around 170% over this period. Small household appliances accounted for around 40% of WEEE, cooling and freezing equipment for another 21%, and large household appliances added around 6 percent. Thus, household appliances contributed around 67% to the total WEEE arising in Nigeria in 2017. Screens (18%) and small IT equipment (12%) were large contributors as well, while lamps had a share of around 3% in the total WEEE stream.

A regional project by the Secretariat of the Basel Convention in 2008-2012 was successful in enhancing the capacity of African countries to tackle the growing problem of WEEE, including development of national e-waste assessments in Benin, Côte d'Ivoire, Ghana, Liberia and Nigeria.[21] It is estimated that in 2010, some 540,000 tonnes of WEEE was collected through the

informal and formal collection systems.[16] However the material recovery rate (recycling and reuse) was estimated at around only 52% due to unsound overall management of waste.

5.2.3 Kenya

Electronic waste is now Kenya's fastest growing waste component, with over 17,000 tonnes generated annually.[21] An estimated 5,4000 tonnes of EEE comprising mobile phones and computers was put on the market in 2007.[9,22,23,24] In comparison 7,400 tonnes of WEEE were generated in the same year, comprising of mobile phones, computers, printers, TVs and refrigerators. A 200% growth in the importation of IT equipment was recorded in 2007.[24] It was reported that around 60% of the equipment donated to organisations such as schools was beyond repair.[24]

5.2.4 South Africa

WEEE is currently the fastest growing waste stream in South Africa.[25,26] An estimated 1.5 million computers enter the South African market every year. Another estimate puts the amount of EEE that entered the market in 2007 at 99,000 tonnes, comprising TVs, computers, printers, mobile phones and refrigerators.[23] In future, the volume of white goods is expected to surpass that of IT equipment as a percentage (by weight) of the waste stream.[27] In 2015 approximately 17,733 tonnes of WEEE was handled by 27 companies, the largest source of

inputs (45%) being from government departments. ICT and consumer electronics made up the largest contributing waste stream (79%).[28]

Accurate data regarding the type, rate and volume of WEEE being generated, in circulation and released for recycling is largely lacking in South Africa. In 2005 it was estimated that South Africa was generating between 1.12 - 2.1 million tonnes of WEEE annually.[29] StEP (see Section 5.2.1) suggested a much lower figure of 300,000 tonnes of which 18% was recycled, estimating that electronic waste in South Africa increases by 10% each year with each person generating around 6.6 kg of WEEE. In 2011 the Department of Environmental Affairs (DEA) estimated that South Africa generated approximately 64,045t of WEEE.[30] If an annual growth rate of 4% is applied to the DEA's estimates, total volumes produced in 2015 would be ca. 74,923 tonnes.[28]

5.2.5 Synthesis

Countries with high imports of used EEE, such as Ghana and Nigeria, generate the highest volumes of WEEE due to the direct import of non-functioning and non-repairable UEEE or WEEE, and the lower lifespan of functioning UEEE compared to new EEE.[1] However, a different narrative has emerged, with the WEEE issue in Africa being framed in terms of wealthy, developed, countries "dumping" their waste in developing countries. These latter countries do not have the necessary systems or infrastructure to deal with WEEE in an environmentally sound manner and therefore this waste is processed in conditions hazardous to workers and

the environment.[31] Evidence from a variety of sources suggests that the bulk of WEEE imports are not waste but are instead working or repairable equipment.[31]

It should be noted that while in the UK and other developed countries repair is considered expensive proportional to the replacement cost of an item, in developing countries the reverse is the case. Domestic sources contribute significant volumes of electronic discards in developing countries and trade from developed to developing nations represents a modest portion of WEEE flows relative to flows within these regions. At its peak in 1996, trade from territories designated under the Basel Convention as Annex VII (composed of the Organization for Economic Cooperation and Development (OECD), the European Community (EC) and Lichtenstein) to non-Annex VII territories (all other signatories) accounted for just over 35% of total trade. By 2012 trade from Annex VII to non-Annex VII territories accounted for less than 1% of total trade.[31]

5.3 Collection and Management of WEEE

In typical African countries such as Nigeria and Ghana, WEEE collection is by and large not well organized.[32] Most WEEE is collected from the workshops of refurbishers and/or repairers by the informal sector or mined by scavengers (otherwise called urban miners) from dumpsites after co-disposal with municipal wastes. This attitude in developing countries could be due primarily to lack of awareness and ignorance of the harmful effects of improper disposal of WEEE, the absence of “government will” on take-back incentives, and lack of collection points.

5.3.1 Collection of WEEE

In many developing countries, WEEE is managed through various 'low end' management alternatives such as product reuse, conventional disposal in open dumpsites, open burning and crude "backyard" recycling.[3,10,12,32] Establishing environmentally sound treatment systems in developing countries is essential to reduce the impacts from rapidly increasing quantities of WEEE.[5] End-of-life is not the only aspect that needs to be taken into account; effective collection of WEEE is essential to the success of any management method (see Figure 5.4).

[Figure 5.4 collected WEEE near here]

In developed countries there is, or is being developed, strict legislation and enforcement, separate collection, and treatment systems specifically designed for WEEE treatment. In developing countries relevant legislation and enforcement is rare, and unregulated repair and reuse, together with dangerous recycling practices and informal sector activities dominate.[9] The absence of infrastructure for the appropriate collection and recycling of WEEE and legislation dealing specifically with WEEE are some of the challenges facing Africa.[25]

5.3.2 Management of WEEE

Relative to developed countries, in developing countries the top of the waste hierarchy is prioritised, with a clear focus on waste reduction, repair, reuse and refurbishment. Reuse of items is environmentally more favourable than recycling, and should be encouraged to reduce WEEE generation and encourage sustainability.[7] However, recycling, treatment and disposal are undertaken with significant environmental and health consequences. Collection rates, in the majority undertaken by the informal sector, vary among the countries and reach up to 95% in the case of Ghana. Almost all of the collected material reaches the informal recycling sector.[1]

The impacts at all stages need addressing – no safe guarding measures are put in place or observed by waste pickers or collectors as well as during WEEE sorting/dismantling and separation of fractions. Consequently, human exposure to toxic contaminants in WEEE fractions occurs, along with environmental contamination.

The recycling activities currently observed across Africa target WEEE containing valuable material being collected and treated by both formal and informal operators. Consequently, only WEEE of value is collected (for example mobile phones, smart devices, etc.) due to the high content of precious metals, such as gold, in their material fractions. Other WEEE that does not have overall positive value is either not collected or has valuable parts removed and the remainder dumped (in the case of the informal recycling sector) or, in the case of the formal recycling sector, stored pending consolidation for shipment to appropriate treatment facilities or smelters in developed countries. WEEE that holds less value or that may incur a cost to treat is vulnerable to improper handling and management.

If not properly treated with adequate safeguards and measures in place, WEEE can have negative impacts on both human health and the environment. WEEE contains toxic heavy metals such as lead, mercury and cadmium, and endocrine disrupting chemicals such as persistent organic pollutants (such as polybrominated diphenyl ethers, PBDEs) to which humans may be exposed and which may be released into the environment.[33] However, sustainable treatment of WEEE avoids these negative impacts. The appropriate handling of WEEE can both prevent serious health and environmental damage and also recover valuable materials, especially metals.

The recycling chain for WEEE is classified into three main steps:[34,35,36]

- Collection and logistic systems,
- Sorting/dismantling and pre-processing (including sorting, dismantling and mechanical treatment), and
- End processing including marketing of the secondary raw materials, treatment/recycling plants and technologies.

All three steps should operate and interact in a holistic manner to achieve the overall recycling objectives. Sustainable WEEE recycling aims to treat the hazardous fractions in an environmentally sound manner, maximize the recovery of valuable materials, create eco-efficient and sustainable businesses, and consider social impact and local context.

Informal WEEE recycling includes dismantling end-of-life electronics to retrieve valuable elements with primitive techniques, without or with very little technology or consideration of the hazardous components, allowing the emission of, and exposure to, dangerous chemicals.[36] Formal WEEE recycling facilities, common in developed countries, use specifically designed equipment to safely dismantle electronics while protecting workers from adverse health effects. However, these centres are very expensive to build and run and are rare in less developed countries.[7,37] Therefore in much of Africa processing activities are crude and dangerous, especially in the informal sector:[32,38,39]

- Informal sector collection – including scavenging at dump sites
- Forcing open CRTs with hammers, exposing the toxic phosphorous dust
- Open burning of circuit boards to melt the lead solder hence breathing toxic lead fumes
- Burning wires to melt the plastics to recover copper wire
- Open nitric acid baths for separating metals
- Dumping pure acids and dissolved heavy metals into the soils, drains and rivers thereby polluting the environment.
- Dismantling for spare parts for repair and refurbishment
- Disposal of residual and hazardous waste by burning and dumpsites (see Figure 5.5)

[Figure 5.5 WEEE at dumpsite near here]

In many African countries collection is carried out by the self-employed or by cooperatives engaged in either door-to-door collection or in scavenging of mixed waste on dumpsites.[40]

WEEE is manually dismantled by workers or scavengers, many of whom are children and teenagers. Workers have no protective gear and inadequate tools to dismantle and to break the products apart in order to salvage scrap metals, using tools such as hammers, chisels, and screw drivers.[12,15,37,41] Plastics are chipped and melted without the necessary protective ventilation. Burning to smoulder plastic off cables is the cheapest means known of recovering their copper and therefore is one of the most common crude recycling practices, despite legislation to prevent these practices.[42] These primitive techniques may appear efficient to untrained and less well equipped recyclers, but they do not ensure environmental protection or occupational safety. Indeed these rudimentary methods may lead to the recovery of materials that are only worth a fraction of the total potential economic return.[12] It has been suggested that most WEEE pollution in Africa is from burning insulation from wires and cables. Even for the resold usable products there is still concern regarding their fate at end-of-life.[42] The remaining waste, including plastic and cables, is either burned or dumped in unprotected sites.

5.4. Environmental and Health Impacts

5.4.1 Overview

WEEE consists of a complex mixture of chemicals that during formal recycling are subject to strict controls and standards. During informal recycling there is the potential for these chemicals to be released as contaminants into soil, air and water.[40] Contaminants in WEEE are

released in highly heterogeneous mixtures, whose composition varies according to WEEE types and age, as well as handling and processing.[43] Depending on the nature of the handling and processing, the contaminants can take a number of forms; particulates, gas, vapours, aerosols, solid residues left after a smelting or leaching process, liquids (spent acid or waste water) or semi-liquids (sludge from leaching solutions).[43] Commonly generated contaminants that cause concern include:[32]

- Heavy metals such as lead, cadmium; mercury and nickel; persistent and bioaccumulative organic substances such as brominated flame retardants (BFRs); PCBs and polychlorinated dibenzodioxins that are in the WEEE and are released during processing such as crushing, shredding and burning.
- Persistent organic pollutants (POPs) that are generated as a result of processing activities, such as burning, for example PCBs.
- Acids and cyanides emitted by chemicals such as the acids from batteries.

In Nigeria it is estimated that the informal recycling sector annually disposes of an estimated 52,000 tonnes of brominated plastics, 4,000 tonnes of lead, 80 tonnes of cadmium and 0.3 tonnes of mercury by burning or dumping.[18] A further 80,000 tonnes of plastics are burnt in the open, generating pollutants such as polychlorinated dibenzodioxins and furans.

5.4.2 Environmental Impacts

Despite a number of global and regional initiatives, shipments of WEEE to developing countries continue unabated and are having significant environmental and health impacts.[41] Environmental monitoring in Nigeria and Ghana provides evidence of major environmental impacts resulting from improper collection, crude dismantling, material recovery and final disposal through the release of hazardous substances such as heavy metals as well as POPs into the environment.[32,44] Samples of soil, ash, and sediment from these waste sites reveal the presence of a wide variety of hazardous substances such as lead, cadmium, phthalates, and polychlorinated dibenzodioxins, causing exposure to these substances with respect to both workers and residents of surrounding communities as the toxins are disbursed into the air and leach into groundwater.[41]

In Ghana the Environmental Protection Agency estimated that 140,000 tonnes of imported electrical equipment and related wastes between 2009 and 2014 contributed to polybrominated diphenylethers (PBDEs).[45] Contrary to Article 6 (1) d (i) and (ii) of the Stockholm Convention, appropriate measures for handling and disposal of POPs in WEEE are lacking in Ghana and other African countries.[45]

5.4.3 Health impacts

Informal WEEE recycling has long been accepted as a source of environmental pollution but the health risks are only just being understood. WEEE-related health risk is an emerging issue for critically exposed populations in developing countries.[43]

Sources of exposure to WEEE can be classified into three sectors: informal recycling, formal recycling, and exposure to hazardous WEEE compounds remaining in the environment (ie, environmental exposure).[37] In addition, because of the high levels of environmental, food, and water contamination, residents living near WEEE recycling areas are also at risk of environmental exposure.[37] Although at reduced risk, residents are much greater in number – for example over 70,000 people are estimated to live on, or near, Agbogbloshie, the WEEE site in Ghana.

Agbogbloshie in Accra, Ghana is the second largest WEEE processing area in West Africa, Alaba international market in Lagos being the largest in the sub-region. Alaba market soils are heavily contaminated by heavy metals at concentrations several-fold higher than the EU exposure limits for lead, copper, nickel, chromium, etc. The Agbogbloshie site is notorious for crude WEEE recycling activities entailing uncontrolled open burning of cables to recover copper wire (see Figure 5.6), and crude dismantling of WEEE circuit boards by informal sector workers, without any protective safety measures, to recover aluminium and silver. In addition to the workers, pollution also affects neighboring communities and patrons of the Agbogbloshie food market.

[Figure 5.6 Burning cables to recover copper, Agbogbloshie, Ghana near here]

Exposure to the hazardous components of WEEE is most likely to arise through inhalation, ingestion, and dermal contact.[37] In addition to direct exposure, there are a number of other ways in which people come into contact with damaging chemicals. Exposure can come as a result of contact with the WEEE materials and contaminated soil, dust, air, water, and through food sources.[37,43] Children are particularly at risk due to potential exposure while breastfeeding, increased hand to mouth behaviours, developing physiology, potential exposure to contamination on parents clothes, or if activities are taking place in the home.[37] In Ghana it was noted that PCB concentrations in breastmilk exceeded guideline values.[45]

The evidence suggests an association between WEEE exposure and changes in thyroid function, in cellular function and expression, in temperament and behaviour and in adverse neonatal outcomes.[33,37,46,47,48,49]

Despite the volumes of WEEE recycled informally, the prevalence of work-related injuries among WEEE workers in Africa is largely unknown. A study assessed for the first time the prevalence, patterns and factors associated with occupational injuries among WEEE workers in the informal sector in Nigeria and symbolic of the African continent.[50] A high injury prevalence of 38% and 68% over 1-2 weeks and 6 months respectively, was found. The most common injuries were cuts (59%) mainly caused by sharp objects (77%), with the majority (82%) of the injuries occurring on hands and fingers. Despite the high occurrence of injury, only 18% of the workers use personal protective equipment. Fifty one percent of those users suffered at least one injury over a 1-2 week period and 88% got at least one injury in a 6 month period. The

factors associated with injury in 1-2 weeks were job designation and the geographical location, while the factors associated with injury over 6 months were job designation, geographical location and age.

5.5 Socio-Economic Impact of WEEE Management

The five West African countries (Liberia, Cote d'Ivoire, Benin, Ghana and Nigeria) that were part of the large electronic waste Africa project, "Where are WEEE in Africa?", are classified as countries with low human development.[1] Factors such as unemployment, high illiteracy levels, impoverishment amongst large sectors of the populace, lack of access of the populace to electricity, water, housing, adequate sanitation facilities (such as toilets and landfills) and transportation, as well as poor healthcare facilities, are seen to be common to these countries, although economic conditions differ to some extent. When investigating the economic conditions of workers in the WEEE collection and recycling sector, daily revenues were found to vary greatly from between US$ 0.22 (below the international poverty line) and US$ 9.50.[1] This income has, in most cases, to be shared with other family members and is only earned on economically active days and not during periods of sickness or other emergencies. It is estimated that, for example in Alaba, every working person is supporting up to 20 other family members. In the refurbishing sector, salaries are higher and range between US$ 2.20 and US$ 22 per day, reflecting the higher skills levels required. However, the highest incomes are achieved by workshop owners, while employees typically earn less than US$ 4.00 per day.[1]

In countries such as Nigeria, Ghana and Cote d'Ivoire the repair and refurbishing sectors are well organised with apprentices and training widely adopted. These sectors are focused on used equipment either from imports or from domestic sources such as businesses and households. In both Accra (Ghana) and Lagos (Nigeria), the refurbishing sector generates income for more than 30,000 people.[1] The refurbishing sector in Africa often operates partly under formal conditions as many of the enterprises that serve this sector are registered with the local authorities and pay taxes to local and regional administrations. The recycling and collection schemes are often not formalised to any significant extent and are not registered.

Experience demonstrates that simply prohibiting or competing with the informal collectors and informal recyclers is not an effective solution.[51] New formal WEEE recycling systems should take existing informal sectors into account. Integration and involvement of the informal sector into formal wastes management activities can yield economic and social benefits.[38,52] Ignoring the informal sector can result in unsustainable interventions: an abrupt abolishment of the current informal system would be counterproductive.[39]

The management of WEEE collection requires a local solution in the markets where the waste is generated. While the sound dismantling of WEEE, pre-treatment of fractions and end-processing of easily recyclable fractions (for example ferrous metals) can be performed locally, the effective recovery of precious metals from complex WEEE depends on access to global market specialists, for example Umicore who operate a smelter to recover precious metals from circuit boards (see Chapter 9).

5.6 Governance Issues in WEEE Management

The illegal WEEE trade is a shared concern of both exporting and receiving countries.[43] There is a need for international cooperation and coordination, including harmonized customs controls, along with better enforcement, and monitoring of domestic and international laws and regulations. In general, African countries have had poor regulatory frameworks and poor policing of the industry, resulting in lack of information and data regarding WEEE flows and activities. While these countries benefit from some of the international treaties signed, they still do not have the capacity and infrastructure to ensure the impacts are felt at all levels.[7]

Where the principle of Extended Producer Responsibility (EPR) is applied (see Chapters X and Y) a financial safety net is created by producers and importers financing the collection and treatment of WEEE, including the material fractions of negative value that need to be landfilled or stockpiled awaiting treatment. This approach creates a market demand for these otherwise undesirable and potentially valueless materials. Implementation of EPR in the developing countries has become necessary in the light of the present high level of transboundary movement of WEEE into these countries and the lack of basic or state-of-the-art recycling and waste disposal facilities. Change in attitude by governments, appropriate legislation dealing specifically with WEEE, control of waste dumping, implementation of EPR and transfer of technology on sound recycling of WEEE are the key issues in effective management of these wastes in developing countries.[13] In Africa EPR has not been widely implemented, with the

exception of South Africa (2008), Kenya(2010) and Nigeria (2011).[1] It should be noted that implementation and enforcement do not go hand in hand.

To deal with the increasing problem of WEEE two Multilateral Environmental Agreements (MEAs), the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (1989), and the Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes within Africa (1991) were developed. These agreements classify WEEE as hazardous waste and have provisions for addressing the environmentally sound management of these wastes. The most important and comprehensive international tool that impacts on WEEE is the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal.[12,42] The Basel Convention was intended to stop developed countries passing hazardous waste to those countries that lacked the capacity to deal with it in an environmentally sound manner. Although these two agreements have similar objectives in controlling the import of WEEE into Africa, there is a marked diversion in their scope and approach. The Bamako Convention has not received the necessary attention and development to position it as an effective regional MEA in dealing with WEEE management.[53]

The Basel Convention has three main aims:[54]

(i) The reduction of hazardous waste generation and the promotion of environmentally sound management of hazardous wastes, wherever the place of disposal;

(ii) The restriction of transboundary movements of hazardous wastes except where it is perceived to be in accordance with the principles of environmentally sound management; and

(iii) A regulatory system applying to cases where transboundary movements are permissible.

The Bamako Convention (1991) places a complete ban on all imports of hazardous waste into Africa and does not allow importation of hazardous waste for "any reason ***into*** Africa".[55] It sees such activities as illegal and a criminal act. Hazardous wastes, according to the Convention, should, as far as is compatible with environmentally sound and efficient management, be disposed in the State where they were generated. An African country that lacks safe disposal facilities for the toxic wastes it generates faces three choices: disposing of the wastes locally and, presumably, unsafely (which is not recommended); halting waste generation; shipping the wastes elsewhere, preferably somewhere with safe disposal facilities.[56]

About 50% of African countries have ratified Bamako Convention while Ghana and Nigeria, the major destination countries, are yet to ratify the Convention. Virtually all the countries that have ratified the Basel and Bamako Conventions have not transposed these Conventions into domestic legislation, weakening the control of transboundary movement of WEEE at the ports of entry. It is encouraging that Nigeria and Ghana are two of the few countries in the African region that have established national WEEE control regulations in 2011, prohibiting WEEE

imports, with distinction between waste and non-waste being part of the regulatory requirements at the border/ports.

5.7 Effective Business Models for Sound Management of WEEE in Africa

5.7.1 The Basel Convention Project

The Secretariat of Basel Convention project, "Where are WEEE in Africa?", was designed to build local capacity to address the flow of EEE and WEEE destined for reuse in selected African countries.[1] In addition it contained activities to augment the sustainable management of resources through the recovery of materials in WEEE. This project was one of the biggest activities undertaken to strengthen the environmentally sound management of WEEE in Africa. The project goal was to enhance environmental governance for WEEE in selected African countries (Benin, Cote d'Ivoire, Egypt Ghana, Liberia, Nigeria, Tunisia). The project's four components were:

- A study on flows of used EEE and WEEE imported into Benin, Côte d'Ivoire, Ghana, Liberia and Nigeria, from European countries.
- National assessments and national environmentally sound management plans.
- A socio-economic study on the WEEE sector in Nigeria and a feasibility study of international cooperation between African SMEs and European recycling companies.
- Enforcement programmes in Benin, Egypt, Ghana, Nigeria and Tunisia to prevent illegal transboundary movements of WEEE.

This project provided the most comprehensive analysis to date of the situation for WEEE in Africa and has resulted in a number of subsequent actions and activities. In 2012 the First Pan-Africa WEEE Forum was held in Nairobi, Kenya. The following eight priority actions for implementation were identified for achieving environmentally sound management of WEEE:

- Baseline assessment
- Legal, policy and regulatory frameworks
- Imports and exports of UEEE and WEEE
- Enforcing international, regional and national law
- Design of a system for environmentally sound management of WEEE
- Financing environmentally sound management of WEEE
- Environmental and social-economic aspects of WEEE management
- Capacity-building and training

Although there have been talks of a ban on export of all EEE to Africa it is hard to see how this will solve the problem, and risks exacerbating the digital divide. A solution for the environmentally sound management of WEEE in Africa will not differentiate between imported or indigenous product but should give countries the opportunity to exploit the value of the resources in EEE. Solutions have been proposed and a number of activities are in play, a selection of which are outline below.

5.7.2 Best of Two Worlds

In developing countries, the formal WEEE recycling sector should be supported by a stricter legal framework to ensure its broader implementation and expansion, together with widespread adoption of best practice to drive environmentally sound management.[5,43] Any sustainable solution needs to recognise the role of the informal sector as even a total ban on import would still require the sector to deal with existing and domestic WEEE.[43,52] In addition this would cause a drop in income and therefore health and living conditions amongst the poor who are already struggling to survive.

Therefore a Best of Two Worlds (Bo2W) model has been developed by the multi-stakeholder StEP Initiative.[5,52] This approach advocates a division of tasks such that a more protected informal sector in developing countries would take part only in low risk tasks, while higher risk activities would take place in developed countries. The division would therefore be:

- Developing Countries – best pre-processing. Manual dismantling activities are more efficient and less costly for a higher yield of material liberation than the mechanical option.
- Developed countries – best end processing of complex fractions. State of the art treatment facilities to enable hazardous materials to be safely treated and valuable materials recovered.

This would enable developing countries to gain value from WEEE whilst ensuring that the risks are minimised, reducing the environmental, health and safety burdens in the developing country.[5]

5.7.3 A Producers' Model for the Future

Since 2011, the Electronic Waste Solutions Alliance for Africa (the Alliance), comprising a group of original equipment manufacturers (OEMs) namely Dell, HP, Microsoft (now including Nokia who were a founding member) and Philips, has been proactively working to implement a sustainable model for WEEE recycling supported by appropriate recycling regulations in Africa. The recycling model takes into account the value of WEEE at each step of the recovery process, and intends to create employment in the recycling sector while applying environmentally sound management techniques to minimize environmental pollution and health hazards commensurate with optimizing resource recovery. The model starts by incorporating the informal sector in the collection stage, which traditionally burns WEEE to recover valuable material (see above). Because WEEE collection and recycling is designed to be economically viable by turning waste into a resource, sustainability could be ensured by engendering profitability. The model has been designed to ensure the following:

- Collection of all material, whether of value or not, is governed by the solution
- Local dismantling of material can create jobs
- Local profit for metals that are not hazardous to recycle

- Access to the global market is maintained for appropriate recycling and treatment of WEEE material where specialist treatment is necessary and does not exist locally
- Enforcement of standards relating to health and safety, environmental protection etc.

The informal sector in Africa does collect WEEE effectively but tends to sell the material into the channel that “pays most”, introducing a high risk for unsound dismantling and treatment practices. The Alliance model aims for WEEE collected by informal workers to be directed towards licensed and sound recycling and treatment channels. Regarding the current practices of processing WEEE, it is evident that unsound practices are conducted in the informal sector due to lack of knowledge, lack of control but also lack of economic opportunities for the individuals. The Alliance model aims towards a sustainable solution that effectively and eco-efficiently manages WEEE by integrating informal sector collectors. Acknowledging that they require an economic incentive to do so, the model contains a collection incentive for the collector.

The Alliance has been working with the Government of Nigeria, National Environmental Standards and Regulations Enforcement Agency (NESREA) to support the development of the WEEE management system. To fulfill the expectations of the Nigerian WEEE regulation published in 2011, the Alliance has proposed a comprehensive EPR plan as the model to be adopted in country, including key principles and definitions, a detailed mapping of roles and responsibilities of each responsible party within the system, and a recommended governance model.

Alongside the EPR plan, the Alliance helped initiate the local "producer work group" comprising local manufacturers and importers of EEE who will need to formally establish the Producer Responsibility Organization (PRO) that will organize the day-to-day collection and recycling of WEEE (see Figure 5.7). In support of the local group the Alliance has appointed consulting firms Deloitte and Sofies to develop a detailed business plan. This plan includes an analysis of the preferred legal form the PRO should take and an assessment of costs and possible revenues during the first 12 months of the establishment of the PRO. This means that there is now a complete blue print available for the set-up and financing of the PRO by the local "producer work group". However, progress has been slow.

[Figure 5.7 E-Waste Solutions Alliance for Africa PRO near here]

The plan considers EEE waste as an opportunity to recover valuable materials, and seeks to harness a developing recycling infrastructure, encouraging industry growth and job creation in Nigeria and across Africa through an effective, viable and sustainable structure that operates to international standards and benchmarks. The plan takes care of all WEEE categories including non-valuable hazardous material fractions (currently being burned or landfilled) including CRT monitors, compact fluorescent lamps (CFL lamps) and refrigerator equipment as well as materials and fractions with value. Through an EPR mechanism integrated into the plan, producers acknowledge their responsibility to take care of their products (placed on Nigerian market) at the end of its lifecycle; this responsibility could include a financial obligation. The

plan recommends a multi-stakeholder approach where all actors in the value chain have an important role to play in their particular arena of action under their control, such as government, producers, academia, waste reclaimers, pickers, collectors, consumers and the WEEE recycling industry.

The benefits of the plan would be the establishment of a WEEE management system that addresses the current and future projected growth in EEE consumption, built on a more formal collection infrastructure adopting safer recycling practices and avoiding the release of sensitive materials into the environment. The private sector model will encourage better local utilization of recovered materials where feasible. The principle of EPR will ensure no increase in the cost of ownership of EEE (for example though visible fees) to consumers and end users, as the model allows for revenue to be generated from the intrinsic value of recovered materials. The cost of treating non-valuable fractions can be internalised by the producer.

5.7.4 Hinckley Recycling

A number of relatively new recycling facilities operating to high standards are being established across Africa. Hinckley Recycling is one of the longest-established. Founded in 1998, Hinckley has over 50 employees and operates across West Africa. Hinckley Recycling is the first registered WEEE recycler in Nigeria and works closely with the Ministry of Environment, NESREA and LASEPA, conforming to strict environmental recycling requirements and best practices. The company also works with donor agencies, most notably GIZ (Deutsche

Gesellschaft fur Internationale Zusammenarbeit) who hold workshops and training on the management of WEEE.

[Figure 5.8 Hinckley Recycling near here]

All WEEE processed by Hinckley Recycling is issued with a certificate of destruction, ensuring compliance with the Harmful Waste (Special Criminal Provisions) Act Cap HI, 2004 and the National Environmental (Electrical/Electronic Sector) Regulations S.I No 23 of 2011. Services on offer include collection and recycling; internal office recycling; data destruction; reuse and redeployment; value return services; charity donation; and employee purchase.

The example of Hinckley Recycling highlights a number of issues that are particular to operating a WEEE management facility in Sub-Saharan Africa:

Operating margins for the business are small, as it operates on small profits but high volume and so additional costs impact on the economic viability. Hinckley Recycling has protected its recycling business by diversifying into multiple revenue streams.

Power is a major issue in Nigeria. Hinckley Recycling is a semi-industrialized recycling facility which is heavily reliant on power tools, shredders and pallet scales. The power is unreliable and there can be power outages for days or fluctuating current which damages the equipment and impacts on overheads and productivity.

Infrastructure is another common issue. The road network is poor but transport is a vital part of the business. Poor road networks make accessibility for collections a challenge and damage the 5 tonne trucks that are used. The road network means that transport is slow and maintenance of trucks is time consuming and costly.

Security both internally and externally is of concern. The items that are processed are typically small with good value. Laptops, tablets and phones are all attractive items for staff and so they require additional security. External security issues relate to individuals/gangs aware of the contents of the warehouse, making it an attractive target. Security whilst in transit is a concern where trucks and drivers can become targets for armed robbers.

Legislation is typically slow to arrive and even slower to implement, while certain aspects of the law are not enforced effectively. Producers and consumers of electronics allow WEEE to be discarded with little fear of repercussions. A clear and viable policy on WEEE needs to be communicated to producers and users alike with fines issued to defaulters. The enforcement agencies also have a role in creating a level playing field for collectors and recyclers ensuring all stakeholders adhere to best practice, eliminating free riders from the system.

Awareness of the adverse impacts on humans and the environment is low. Hence there is little incentive to pay for the services Hinckley Recycling offer; as noted above, it is common to sell WEEE to the highest bidder, with little or no concern for the consequential impacts. The advent

of EPR should change this but it is a long journey and the business has to survive until proper producer responsibility is implemented and enforced.

5.8 Recommendations for Environmentally Sound Management of WEEE in Africa

The lack of infrastructure and appropriate regulatory framework, low public awareness, adverse socio-economic as well environmental and human health impacts arising from unsound management of WEEE are well known. Developing and implementing effective solutions that create green jobs and alleviate poverty without risk to human health and the environment should be undertaken by government in partnership with OEMs and other stakeholders. In particular:

- The Africa vision on environmentally sound management of WEEE and the call for a set of eight priority actions on WEEE in Africa (see Section 5.7.1) should be embodied in regional and national policies, strategies and action plans for effective implementation.
- Africa should take full advantage of the economic and entrepreneurship potentials of WEEE in an environmentally sustainable manner with implementation of the principle of EPR, including take back schemes backed by legislation, and exploration of so-called ''Urban Mining''.
- Consideration must be given to increasing access to spare parts to encourage greater reuse and repair, including the application of 3D printing.
- Exports of UEEE to Africa and other developing countries that are compliant with the Basel Convention Prior Informed Consent (PIC) procedure should not be banned but

controlled, as they provide opportunities for employment, poverty alleviation, creation of businesses, and promote North –South and South-South economic and technological cooperation while bridging the digital divide.

- Pilot projects should be implemented, covering sustainable collection, repair/refurbishment, dismantling, and recycling, with a capacity-building component for Africans, especially in the informal sector. These projects should be undertaken in partnership with OEMs with funding support from development partners.
- Capacity building should be provided to African countries and appropriate institutions to promote the environmentally sound management of WEEE in partnership with local expertise such as the Basel Convention Regional Centres (BCRCs) and Basel Convention Coordinating Centre for Africa (BCCC in Nigeria).

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