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Informal e-waste management in Lagos, Nigeria – socio-economic impacts and feasibility of international recycling co-operations

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Final report of component 3 of the UNEP SBC E-waste Africa Project

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BASEL CONVENTION

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List of acronyms and abbreviations

ABS	Acrylonitrile Butadiene Styrene
BAN	Basel Action Network
BCCC	Basel Convention Co-ordinating Centre
CAPDAN	Computer and Allied Products Association of Nigeria
CAR	Climate Action Reserve
CDM	Clean Development Mechanism
CFC	Chlorofluorocarbon
CRT	Cathode Ray Tube
EEE	Electrical and Electronic Equipment
EPR	Extended Producer Responsibility
FMENV	Federal Ministry of Environment
GDP	Gross Domestic Product
GEF	Global Environment Facility
HFC	Hydrofluorocarbon
ICT	Information and Communication Technologies
ILO	International Labour Organization
LASEPA	Lagos State Environmental Protection Agency
LAWMA	Lagos Waste Management Authority
NARAP	Nigerian Association of Refrigeration and Air Conditioning Practitioners
NESREA	National Environmental Standards Regulations Enforcement Agency
NETAN	National Electronics Technician Association of Nigeria
NVMP	Dutch Association for the Disposal of Metal and Electrical Products
ODS	Ozone Depleting Substances
PBB	Polybrominated Biphenyls
PBDE	Polybrominated Diphenyl Ethers
PCB	Polychlorinated Biphenyls
PUR	Polyurethane
PVC	Polyvinyl Chloride
PWB	Printed Wiring Board
PROSA	Product Sustainability Assessment

RoHS	Restriction of Hazardous Substances Directive
SBC	Secretariat of the Basel Convention
S-LCA	Social Life Cycle Assessment
SMEs	Small and Medium Enterprises
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
VCS	Voluntary Carbon Standard
WEEE	Waste Electrical and Electronic Equipments
WSIS	World Summit on the Information Society

Exchange rate:

1000 Naira = US$ 6.72

Executive Summary

Lagos is the one of the world's largest cities and the economic centre of Nigeria. With its 17.5 million inhabitants and considerable economic growth rates in the last years, the local consumption of electrical and electronic equipment (EEE) reached high levels in absolute figures. While this growth is desirable from a development perspective and in particular regarding living standard and access to Information and Communication Technologies (ICTs), it also raises the question on sound end-of-life solutions which are not yet in place in the country.

In addition to the local consumption, Logos has developed into West Africa's main entry point for used and end-of-life electrical and electronic equipment. Although this equipment is mostly refurbished and sold to households and traders from Nigeria and other West and Central African countries, this sector generates significant amounts of e-waste, a problem that was first brought to public attention in 2005 with the film “The digital dump” by the NGO Basel Action Network (BAN).

In the course of the debate, the European Commission, the Governments of Norway and the United Kingdom, and the Dutch Association for the Disposal of Metal and Electrical Products (NVMP) financed the E-waste Africa Project, which is managed by the Secretariat of the Basel Convention (SBC). The project is a comprehensive programme of activities aiming at enhancing environmental governance of e-wastes and at creating favourable social and economic conditions for partnerships and small businesses in the recycling sector in Africa.

This study is integral part of the E-waste Africa Project and contains an in-depth socio-economic study on the functioning and the sustainability impacts of the informal EEE-refurbishing and e-waste recycling sector in Lagos, as well as a comparison of currently practiced and best available recycling technologies. By combining these types of analysis, the report derives “best applicable technologies” regarded suitable for the implementation in the Nigerian context. In addition, the report formulates recommendations to policy-makers, the Nigerian recycling industry and for pilot follow-up activities.

From a methodological perspective, the socio-economic study made use of the methodology provided by the UNEP/SETAC “Guidelines for Social Life Cycle Assessment of Products”. Additionally, some methodological gaps related to the use of indicators were filled using Öko-Institut's methodology PROSA (product sustainability assessment). For the purpose of this study, three key stakeholder categories were defined to assess the socio-economic impacts of the refurbishing and e-waste recycling sector in Lagos: workers, local communities, and society. The data was collected during 135 interviews conducted between May and December 2010.

Generally, refurbishing, collection, and recycling of used and end-of-life e-products takes place in and around certain business clusters. The most prominent of these clusters are Alaba Market and Ikeja Computer Village, which comprise 2,500 and 3,000 small businesses in the field of refurbishing and marketing of used electrical and electronic products. The so-called Westminster Market located close to the port is another hub for imported second-hand equipment, as well as Lawanson Market, a mid-sized second-hand market for used EEE.

The majority of refurbished products stem from imports via the ports of Lagos. The interim results from project component 2, the Nigerian e-Waste Country Assessment, show that 70% of all the imported used equipment is functional and is sold to consumers after testing. 70% of the non-functional share can be repaired within the major markets and is also sold to consumers. 9% of the total imports of used equipment is non-repairable and is directly passed on to collectors and recyclers.

The e-waste collection and recycling activities in Lagos are largely organised around the main sources of obsolete electrical and electronic products. Most of these activities are carried out by informal waste collectors (commonly referred to as ‘scavengers’) who move all around Lagos with handcarts collecting e-waste together with other metal-containing wastes. Mostly, these collectors buy such obsolete devices for small amounts of money from businesses or private households. In addition, there are also collectors that – due to financial limitations – cannot pay for metal-containing wastes and therefore focus on what is freely available, e.g. on roadside waste dumps. As the city of Lagos is too large to easily bring the collected materials to a central recycling site, this informal collection system makes use of many small- and medium-sized scrap metal yards, where metal-containing wastes are manually dismantled, sorted, stored and sold to traders. Fractions of no value to the workers are discarded or burned. The informal waste collectors compete with a quite efficient official waste collection organised by the Lagos State Waste Management Authority (LAWMA), which delivers the collected waste to three official dumpsites in Lagos. There, waste picker communities that live on or next to the dump sites take out all fractions of value, including e-waste. Here too, dismantled and assorted e-waste is sold to traders. Fractions of no value to the waste collectors are thrown back on the dumpsite. The e-waste recyclers operating in scrap metal yards, on dumpsites or in recycling sites around second-hand markets disassemble obsolete electrical and electronic equipment in order to liberate metals that can be sold to traders. In particular, the ambition focuses on steel, aluminium and copper. Often, cables and other plastic parts are incinerated to liberate copper. In addition, certain types of printed wiring boards (PWBs) are separated, collected, and sold to traders. Wet chemical leaching processes, often associated with the recovery of precious metals from PWBs, have not been observed in Lagos.

In terms of working conditions, there is a clear distinction between the refurbishing sector that buys and repairs/refurbishes used EEE and the collection and recycling business: As working in the refurbishing sector requires a certain level of technical skills, workers are normally paid between US$ 2.22 and 3.36 per day, which is mostly better than the average income of e-waste collectors and recyclers, who earn between US$ 0.22 and 3.36 per day. Although the differences seem to be of minor importance, a view on social security systems and job perspectives alter this valuation: While refurbishers usually receive a fixed salary, collectors and recyclers are usually self-employed, and therefore experience large day-to-day income fluctuations. Furthermore, persons working in the refurbishing sector often have the possibility to set-up their own small business, which often increases their daily income to around US$ 6.72 to 22.2. Here it is noteworthy that the sector has its own apprenticeship system, which produces around 2,000 alumni per year. Although apprentices often do not earn money during their education, they are usually provided with food and shelter and are granted a start-up budget after finishing training.

Health and safety issues also differ significantly between the sectors: In refurbishing, health and safety issues mainly stem from the risks of electric shocks, the inhalation of lead fumes from soldering operations and occasionally from the exposure to specific substances such as toner dust. In e-waste collection and recycling, health risks are manifold and encompass injuries from handling heavy devices, cuts and infections from sharp waste fractions, risks from participating in heavy road traffic (in collection) and exposure to hazardous substances during recycling operations (e.g. dioxins and furans during burning operations, heavy metals during CRT crushing operations). Although no site-specific data has been collected on workplace contamination, it can be assumed that soil, dust and air contain elaborated concentrations of toxic metals such as lead and cadmium, and halogenated chemicals such as phthalates and polybrominated diphenyl ethers (PBDEs).

In terms of working hours it is notable that all, refurbishers, collectors, and recyclers, work between 8.5 and 9.5 hours a day. Nevertheless, refurbishers usually do not work on Sundays and religious holidays, while collectors and recyclers usually work seven days a week, resulting into 255-285 working hours per month.

It is generally difficult to draw a clear distinction between e-waste collectors and recyclers: Most individuals carry out both activities in parallel. In addition, only few collectors / recyclers exclusively focus on e-waste. Most collectors and recyclers more generally address metal-containing waste types (e-waste, car parts, sheet steel…) and consider themselves being in the ‘scrap metal business’ rather than in the ‘e-waste business’. Therefore, it turned out to be very difficult to collect data on the size and economic importance of e-waste related activities in Lagos. The only general estimate supported by all stakeholders is that there are several thousands of informal scrap metal collectors and recyclers operating in Lagos that work partly or fully with e-waste.

Due to a high level of sector-organisation, data for the refurbishing sector is more reliable and leads to the following figures: Around 8,000 refurbishing enterprises operate in Lagos, giving work to an estimated number of 21,600 people. 35% of these jobs are filled with apprentices.

Despite all uncertainties, refurbishing, collection and recycling activities open significant employment opportunities in Lagos. While the refurbishing sector is mostly attractive for medium- and high-skilled workers, collection and recycling gives employment opportunities to a lower skilled workforce. In particular, informal collection and recycling of e-waste offer job and income opportunities for people from rural areas in the north of Nigeria. For these people, e-waste collection and recycling enables rapid access to cash money. For many collectors and recyclers this rapid-cash-flow is an important reason to engage in this sector, despite unfavourable working conditions. As e-waste collection and recycling does not require specific skills and investments, the sector is open to poor migrants from rural northern Nigeria, where people have little alternatives to small-scale agriculture. Here it was observed that a certain share of collectors and recyclers did not completely abandon their agricultural activities, but return to their villages and farms during the rainy season, when work intensity in agriculture is highest.

In contrast, most refurbishing activities require technical skills that cannot be performed by an untrained workforce. Here, employment opportunities mostly exist for university graduates with technical background or persons that went through the sector's apprenticeship system. The refurbishing sector in Lagos develops into a regional hub that does not only serve Lagos and Nigeria with second-hand products, but also exports to other West and Central African countries. In particular, the refurbishers from Alaba Market and Ikeja Computer Village have developed skills and quality levels that are regarded as unique in sub-Saharan Africa. This finding is supported by a World Bank analysis of cluster-based economic activities in Africa. According to the authors, Ikeja Computer Village is an overwhelmingly positive example for cluster-based economic development in sub-Saharan Africa.

In terms of contribution to the national economy, the refurbishing sector in Lagos generates US$ 50.8 million per year, which is equivalent to 0.015% of Nigeria's gross domestic product. Many refurbishing enterprises pay taxes and fees to the local government and to Lagos' State Government, and it was calculated on the basis of the interview results that these taxes sum up to US$ 419,000 annually.

In the second part of the study, the currently practiced and the best available recycling technologies were compared and analysed on the basis of their specific social, environmental and economic profile. Building on this assessment, 'best applicable technologies' suitable for the implementation in the Nigerian context were derived. The analysis was conducted for three key e-waste streams, namely desktop computers, cathode ray tube devices (CRT devices), and refrigerators and freezers, with the objective to use the results as model for the management of other product groups with similar characteristics.

In case of desktop computers, the comparison of the presently applied recycling technologies and the best applicable technologies reveals that there are untapped economic, environmental and social improvement potentials. These potentials can be realised by manual pre-treatment in Nigeria and export of the fractions bearing precious metals to pyrometallurgical refineries in Europe, Canada or Japan. In the Nigerian context, the best applicable recycling technologies for desktop computers can be sketched as follows:

- house-to-house collection of e-waste;
- manual pre-treatment, including deep dismantling down to the level of parts of sub-components;
- manual extraction and storage of neodymium magnets (wait for future markets);
- mechanical shredding or granulation of cables;
- further manual pre-treatment of low-grade copper fraction to reduce plastic content;
- refinery of steel and aluminium fraction in domestic plants;
- refinery of high-grade precious metals fraction in pyrometallurgical refineries abroad;
- refinery of copper and low-grade copper fraction in copper or steel-copper refineries abroad;
- controlled incineration / energy recovery of remaining plastic fraction in cement kilns.

Such an e-waste management system would lead to an export flow of heavy metals and organic pollutants from Nigeria to state-of-the-art facilities abroad, and to higher recovery rates of precious metals. Consequently, with these optimised recovery rates of silver, gold and palladium, a total of 5.23 kg CO_2e could be saved per desktop computer compared to primary mining of the same amount of metals. In economic terms, higher recovery rates of precious metals from the recycling of one desktop computer, as achieved in the proposed state-of-the-art technologies, would lead to an increase in the revenue from US$ 7.22 to US$ 13.63. Under usual conditions, these values can compensate the costs for manual pre-treatment, logistics, transport and refinery. The type of operations needed in Nigeria is largely independent from investments into machinery parks or infrastructure, and requires labour-intensive manual pre-processing that can be carried out by medium- and low-skilled workers.

In case of CRT devices, there are considerable environmental improvement potentials, especially in terms of managing the hazardous fractions like CRT glass, the internal phosphorous coating and plastics. In the Nigerian context, the best applicable recycling technologies for CRTs are proposed as follows:

- house-to-house collection of CRTs and careful handling in order not to damage the tubes;
- manual dismantling into main fractions;
- manual upgrading of printed wiring boards;
- compaction of tubes under a fume hood with attached filter system;
- refinery of steel and aluminium fraction in domestic plants;

- refinery of precious metal fraction in pyrometallurgical refineries abroad;
- refinery of copper fraction in copper refineries abroad;
- controlled incineration / energy recovery of remaining plastic fraction in cement kilns;
- careful use of glass culets in construction sector or disposal as hazardous waste;
- disposal of phosphorous dust as hazardous waste.

Theoretically, the improved management of circuit boards should increase the recycling revenue from US$ 7.67 to 9.84. However, this calculation does not include the costs for environmentally sound management of the CRT glass and disposal of the internal phosphorous coating. Considering the current oversupply of CRT glass, leading to a situation where providers of the glass have to bear costs of about US$ 160 per ton for its end-processing, the revenues from environmentally sound recycling of CRTs are lower than the revenues from the currently practiced recycling (declining from US$ 7.67 to 7.11) – not even taking into account the costs for sound disposal of the phosphorous dust and possible additional costs for the controlled incineration of plastics. Therefore, it is expected that profit-orientated enterprises will not engage in environmentally sound CRT recycling without the availability of additional financing systems and/or other safeguard mechanisms that ensure a proper handling of all fractions of CRT devices. Thus, any business model to implement environmentally sound CRT recycling can only be successful if laws and regulations provide a level playing field for all recycling activities. In addition, a financing system must insure economic sustainability. Environmentally sound CRT recycling could be supported by identifying suitable management options for critical fractions. This could include:

- identification and development of disposal sites for hazardous wastes;
- minimum quotas for co-incineration of hazardous wastes in cement kilns;
- further exploring the feasibility of using CRT glass in the construction sector.

In the case of refrigerators and freezers, the comparison of the presently applied recycling technologies and the best applicable technologies reveals that there are significant untapped environmental and economic improvement potentials. These potentials can be realised by the recovery of CFCs and HFCs from cooling circuits and foams and subsequent destruction of these Ozone Depleting Substances (ODS) in dedicated facilities. Additionally, the sound management of hazardous components and a better utilisation of the plastic fraction add to the benefits of sound refrigerator recycling. Economic benefits can be tapped if the CFC and HFC recovery and destruction are marketed using one of the existing emission reduction certification schemes, such as the Carbon Action Reserve (CAR) or the Voluntary Carbon Standard (VCS). In the Nigerian context, the best applicable recycling technologies for refrigerators and freezers can be sketched as follows:

- house-to-house collection of refrigerators and freezers and careful transport to prevent leakages of the cooling circuit;
- semi-automated extraction of CFCs from cooling circuits;
- automated recovery of CFCs from foams;
- refinery of steel and aluminium fraction in domestic plants;
- export of copper fraction;
- local recycling of polystyrene;
- marketing of PUR powder as oil binding agent;
- export and destruction of CFCs in certified facilities;
- controlled incineration / energy recovery of oil and remaining plastic fraction;
- controlled management of hazardous fraction.

From an environmental perspective, the best applicable technologies which enable a recovery of at least 90% of total CFCs contained in cooling circuits as well as in foams, would lead to a proper management of up to 2-7 t CO_2e per device. Together with better utilization of plastics, mainly polystyrene – a potential which is neglected in presently applied recycling technologies – revenues from CO_2 emission trading would yield significantly higher economic benefits. However, investment costs for setting up such facilities would range from around US$ 200,000 for basic machinery to recover CFCs from cooling circuits to several million US$ for comprehensive recovery facilities. On the other hand, management aspects related to export of CFCs as well as to certification and compliance within the framework of emission trading markets, would be quite complex. Thus, the informal refurbishing and recycling sector in Lagos might not be in the position to manage such a recycling system on its own. However, these players should still be engaged in the collection of obsolete refrigerators, their transport to the recycling facilities and the manual recycling steps. In this way, businesses would closely interlink with the current e-waste recycling structures and avoid competition in acquiring obsolete refrigerators. Due to the large stock of old fridges in Nigeria (6 million units older than 10 years), CFC recovery and destruction could make use of an economy of scale in Nigeria.

It is important to set the recycling management options described above against possible risks and unintended side-effects. Any future implementation strategy regarding sustainable e-waste management should take into account:

- dangers of negligence of non-valuable fractions, such as CRT glass, plastics etc.;
- problems related to changing composition of e-waste;
- variations in resource prices;
- dangers of indirect stimulation of illegal e-waste imports.

Especially the latter point is of crucial importance, as measures to increase revenues from e-waste recycling might also indirectly stimulate e-waste imports. This is not only a problem because these imports contravene the Basel Convention, but also due to the fact that even improved e-waste recycling will continue to have negative environmental impacts in Nigeria. Although such impacts can hardly be avoided for domestically produced e-waste, imported e-waste should not be tolerated in Nigeria at all. Here, it is a key challenge for decision-makers to draw a clear and applicable line between e-waste not authorized for import, and equipment intended for reuse and providing a basis for the businesses in Alaba Market and Ikeja Computer Village.

Based on assessments that have been carried out, the following recommendations can be derived for policy-makers and the Nigerian recycling industry:

- acknowledge and support the refurbishing clusters;
- incorporate the informal collection and recycling sector;
- deploy manual labour for pre-processing;
- support and maintain international recycling co-operations;
- focus on high quality recycling products;
- develop regulative framework;
- develop appropriate finance mechanisms;
- provide solutions for locally generated hazardous waste;
- regulate the import of used products.

In addition, it is recommended to launch pilot projects to develop environmentally sound e-waste recycling systems. In light of these pilot follow-up activities, the following recommendations are given:

- ensure strong relationships with key administrative bodies;
- conduct pilot operations in or close to existing recycling or refurbishing clusters;
- improve social standards;
- ensure rapid cash-flow;
- focus on all e-waste fractions.

1 Introduction

While the environmental problems from inappropriate recycling of e-waste have long been important topics for waste managers and policy makers in industrialised countries, it is only a few years ago, that international attention shifted towards the increasing e-waste problem in emerging economies and developing countries. For Nigeria, attention was particularly enhanced by the film “The digital dump” on e-waste imports and uncontrolled disposal in 2005 (Puckett 2005). The film produced by Basel Action Network (BAN) gave first insights into the rapidly increasing trade with used and obsolete electrical and electronic products from industrialised countries to port cities like Lagos in Nigeria. Subsequently, Nigerian scientists further investigated the environmental impacts resulting from this waste stream and published various articles covering this issue (Nnorom et al. 2007, Nnorom & Osibanjo 2008a, Nnorom & Osibanjo 2008b). The scientific debate was followed by an ongoing public and political discussion on how to deal with this problem, which has not only environmental, but also social and economic implications.

In Nigeria, the domestic consumption of electrical and electronic devices is increasing rapidly, which is leading to rapidly growing e-waste volumes. As indicated by the survey results of component 1 and 2 of the E-waste Africa Project, Nigeria’s e-waste generation is by far the highest in all West African countries. These volumes, along with the absence of environmentally sound management systems for this particular waste stream, have manifold impacts on the environment, local communities and the economic system in Nigeria. Although obsolete electric and electronic devices undergo some basic form of recycling in Nigeria, many e-waste fractions cannot be managed appropriately, which is resulting in the accumulation of large hazardous waste volumes in and around major refurbishing and recycling centres. Furthermore, some recycling practices – like the open burning of cables and plastic parts – cause severe emissions of pollutants such as heavy metals and dioxins. Additionally, electrical and electronic equipments contain a whole range of valuable metals like copper, palladium, gold, silver, indium and germanium that are lost if not recovered in an early stage of waste treatment. Although the current recycling practices mainly focus on the recovery of steel, aluminium and copper, they are quite inefficient for other metals. On a global perspective, this loss of scarce metals has to be compensated by intensified mining activities, which in turn have severe sustainability impacts in mining areas worldwide.

Apart from domestic consumption, the e-waste problem in Nigeria is aggravated by an ongoing stream of used and obsolete electrical and electronic equipment from industrialized countries entering Nigeria’s ports. Also here, Nigeria clearly sticks out of all other West African countries as import volumes are significantly higher than in all neighbouring countries, including Benin and Ghana. Although a certain portion of this imported equipment is refurbished in second-hand markets, many devices and components prove unsuitable for reuse and further add to the local e-waste generation.

On the other hand, the import and refurbishing of high quality second-hand goods is undeniably a major pathway to provide the country's population with electric and electronic equipment at affordable prices. As internationally agreed at the World Summit on the Information Society (WSIS) in 2005, all people and societies shall make use of information and communication technologies (ICTs) to bridge the digital divide and to stimulate development. Considering widespread poverty and, to a large extent, also low- und middle-income households in Nigeria, access to low cost second-hand equipments of ICTs gains enormous importance, a factor that cannot be ignored by policy-makers.

Additionally, collection, refurbishing and recycling of all types of electric and electronic products became an important economic activity providing income for many small, mostly informal enterprises operating in urban Nigeria. As regards large unemployment, it becomes clear that every reform of the sector requires a careful investigation of its impacts on businesses and employment.

Although end-of-life treatment operations of e-waste give rise to further employment and income opportunities for a large group of people, they are also associated with severe environmental and health hazards, hence diluting the overall potential and benefits to a large extent. Thus, the e-waste problem in countries like Nigeria needs a twofold approach:

- improvement of the local e-waste management capacities through incremental development of infrastructure for the environmentally sound management of e-waste and capacity building of the informal sector;
- better regulation of transboundary movements of used and obsolete EEE.

This study addresses the first demand and aims to elaborate improvement potentials through better recycling technologies[1]. Against this background, the analysis is not restricted to reducing environmental impacts, but also focuses on multiple socio-economic aspects and looks into feasible ways to integrate the informal e-waste recycling sector into possible business models so as to identify new market niches and to generate significant employment and income opportunities for the urban poor.

In order to take appropriate account of these aims, this document encompasses an in-depth socio-economic study on the functioning and the sustainability impacts of the refurbishing and e-waste recycling sector in Nigeria (chapters 3 and 4). In the second part of the study, the currently practiced recycling technologies are compared with best applicable recycling technologies[2]. Starting from these comparisons, the study explores feasible technologies

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1 In line with the analysis of the term „technology“ performed in Schluep et al. 2009, the term „technology“ in this report refers not only to „technical installations, but also to skills, processes and combinations thereof. In this respect, a systematic manual dismantling of an electronic device or a well elaborated chain of different processes is regarded as technology“. (Schluep et al. 2009)

2 In the context of this study, the term “best applicable technology“ is used instead of the commonly used term “best available technology (BAT)“. The term “best applicable technology“, referring to a technology, including

and business models that have the potential to improve the environmental, social and economic profile of the Nigerian refurbishing and e-waste recycling sector. This also includes business models that are based on international co-operations between the Nigerian recycling sector and recycling companies based outside Nigeria (chapter 5). From the findings, recommendations with a view to developing new market niches for the Nigerian e-waste recycling sector are formulated (chapter 6).

This approach is based on the consideration that the transformation from the current crude recycling technologies into a more sustainable e-waste management needs a nucleus that enables multiple benefits for all actors involved in e-waste management. In particular, benefits should be generated in the informal sector that controls large segments of the Nigerian collection, refurbishing and recycling activities and which will play a decisive role in implementing any future e-waste management systems. Starting with such nucleus recycling activities, the general acceptance of e-waste related policies and strategies could be enhanced. Furthermore, they could help to pave the way for a sound and coherent national e-waste strategy in Nigeria.

1.1 Background of the study

The project is funded by the European Commission, the Government of Norway, the Government of United Kingdom, and the Dutch Association for the Disposal of Metal and Electrical Products (NVMP). The field work, the desk studies and analysis was conducted by Öko-Institut e.V. and the Basel Convention Coordinating Centre for the African Region in Ibadan, Nigeria (BCCC-Nigeria).

The study is integral part of the E-waste Africa Project managed by the Secretariat of the Basel Convention (SBC) and constitutes Component 3 of the project. It is closely interlinked with the activities and results of the other project components. The E-waste Africa Project is composed of four components:

1. Under the first component, a fact-finding study on flows in used and end-of-life e-products imported into five West African countries by land and by sea, in particular from European countries, was carried out. The five African countries under investigation are Benin, Côte d'Ivoire, Ghana, Liberia, and Nigeria. Above, investigations were made at exporting ports in Europe.
2. Under this component, national assessments of used and end-of-life e-equipment and the preparation of national environmentally sound management plans were carried out in Côte d'Ivoire, Ghana, Benin and Nigeria. The country assessments encompass a description and an assessment of e-waste management practices in

skills and processes, suited best to the Nigerian context. In terms of conventional terminology "technology", "best applicable technology" might not be equivalent to "best available technology (BAT)".

the formal and the informal sector, including economic and social impacts, potential impact to human health and the environment, an assessment of needs to ensure environmentally sound management, and a detailed description of the legal and regulatory infrastructures in place. The results of the country assessments are shared with national multi-stakeholder groups composed of governmental officials, representatives from the recycling sector and the civil society, and will be used for the preparation of national e-waste management plans.

3. (This study): An in-depth socio-economic study on the functioning and the sustainability impacts of the e-waste sector in Nigeria was prepared. The focus is on both the positive and negative impacts, including the identification of meaningful improvement options in environmental, social and economic terms. Furthermore, the feasibility of international co-operations between African SMEs and European recycling companies are explored, taking into account the combination of their specific competitive advantages in e-waste disassembly and material recovery. From the findings, recommendations with a view to developing new market niches for the African e-waste recycling sector are formulated.

   A parallel study on these issues was already carried out in Ghana (Prakash & Manhart 2010). Although this project was formally no integral part of the E-Waste Africa Project, field work and outcomes were closely aligned with the E-Waste Africa activities.

4. An enforcement programme for African key importing countries, which are Benin, Egypt, Ghana, Nigeria and Tunisia, on the monitoring and control of transboundary movements of used and end-of-life e-equipment and on the prevention of illegal traffic was implemented. Moreover, a training curriculum aimed at port and customs authorities, governmental officials and accreditation authorities was developed by specialized institutions. The curriculum addresses tools for customs control, characterization and classification of used and end-of-life e-equipment, institutional coordination, regulatory framework development, and criteria for the environmentally sound management of used and end-of-life e-equipment.

   In the context of a collaborative effort, the project proposes measures for the prevention and control of exports from Europe to Africa of used and end-of-life e-products, and facilitates the training of enforcement officers from African countries in Europe. In addition to this, a scheme for exchanging information on end-of-life e-equipment between exporting and importing states was developed.

1.2 Objectives and methodological approach

The objective of this project is to study the feasibility of establishing environmentally sound materials recovery operations and of promoting environmentally sound management in a major informal e-waste recycling area, namely Lagos in Nigeria. In order to achieve this objective, two analytical parts were combined: In the first part, an in-depth socio-economic study, the functioning and the sustainability impacts of the e-waste sector in Lagos were elaborated (chapters 3 and 4). This survey is aimed to generate a better understanding of the size, functioning and socio-economic impacts of the sector and its various sub-sectors, and to create a sound information basis for further decision-making and also for the subsequent feasibility study. In the second part, a feasibility study was conducted that looks into ways to integrate the informal refurbishing and e-waste recycling sector into possible business models in order to identify new market niches and generate significant employment and income opportunities for the urban poor (chapter 5). In particular, this study aims to find solutions that enable environmental and social improvements at the same time. International co-operations between small and medium sized enterprises in Africa and recycling companies abroad are considered as one of the keys to such solutions.

The results of the two assessments form the basis for the subsequent recommendations (chapter 6).

1.2.1 Socio-economic assessment

The socio-economic study uses the methodology provided by the UNEP/ SETAC "Guidelines for Social Life Cycle Assessment of Products" commonly referred to as S-LCA guidelines. Additionally, some methodological gaps related to the use of indicators were filled using Öko-Institut's "PROSA – Product Sustainability Assessment" methodology. The S-LCA guidelines and PROSA provide a comprehensive list of indicators that enable an assessment of all positive and negative socio-economic impacts of a sector. Detailed descriptions of the methodologies are given in UNEP 2009 and Grießhammer et al. 2007.

The S-LCA guideline and PROSA sustainability toolkit follow the so-called "stakeholder approach". The stakeholder approach implies that different socio-economic indicators are allocated to pre-defined stakeholder categories. For the purpose of this study, three key stakeholder categories were defined to assess the socio-economic impacts of refurbishing and e-waste recycling in Nigeria: (1) Workers, (2) Local Communities, and (3) Society.

The following table illustrates the allocation of different socio-economic indicators to the above mentioned stakeholder categories.

Table 1 Allocation of socio-economic indicators to stakeholder categories

Stakeholder Categories	Workers	Local Communities	Society
Socio-economic Indicators	- Safe & healthy working conditions - Freedom of association and right to collective bargaining - Equality of opportunity and treatment and fair interaction - Forced labour - Child labour - Remuneration - Working hours - Employment security - Social security - Professional development - Job satisfaction	- Safe & healthy living conditions - Human rights - Indigenous rights - Community engagement - Socioeconomic opportunities	- Unjustifiable risks - Employment creation - Contribution to national economy - Contribution to national budget - Impacts on conflicts

To ensure that the indicator framework will be suited to be used in field assessment, the socio-economic indicators were fed into the so called S-LCA Assessment Sheet, which was used for data collection in Lagos, Nigeria. The complete S-LCA Assessment Sheet can be found in Annex I. The data collection was carried out in a concerted campaign between June and August 2010. Additionally, some information was collected during initial field visits in October 2009.

Data collection involved various techniques ranging from face-to-face interviews, group interviews, visual inspections, transect walk and interviews with key stakeholders.

In total, 135 interviews were conducted to generate information on socio-economic impacts of the refurbishing and e-waste recycling sector in Lagos. The interviews with collectors and recyclers were conducted primarily in the Alaba Market Recycling Community and the Ojota Scrap Market. The interviews with refurbishers were conducted at Alaba Market, Westminster Market and Lawanson Market (places indicated in map 1).

The product scope was kept in line with the scope of the project component 1 and 2 in order to ensure synergies. The project scope for the study was defined to include the following e-waste categories:

1. Large household appliances:
   - refrigerators (cooling and freezing),
   - air conditioners.
2. Small household appliances:
   - irons,
   - kettles.

3. IT and telecommunication equipment:
   - desktop & notebook computers,
   - CRT monitors & flat screen-monitors,
   - mobile phones.
4. Consumer equipment:
   - TVs,
   - radios (including hi-fi-systems).

1.2.2 Analysis and feasibility of recycling technologies

The section on the feasibility of international e-waste recycling co-operations between Nigeria and Europe is based on the analysis and comparison of the presently applied recycling technologies and other alternative recycling technologies and management paths. This is performed with a view to analyse the applicability of these recycling technologies in the Nigerian context on the basis of their specific environmental benefits and practical considerations. Furthermore, it was analysed, which recycling steps could be carried out locally within Nigeria and which steps have to make use of an international division of labour, namely the export of certain fractions or substances to state-of-the-art treatment facilities. This kind of exports are only considered where no other suitable processing in domestic plants seems possible or where investments and treatment volumes are required that would be clearly oversized for the current waste management structure and volumes.

On the basis of the best applicable recycling technologies, the economic, environmental and social improvement potentials are analysed and quantified as far as possible. With regards to social improvement potential, special emphasis is placed on health and safety issues related to the best applicable technologies, as well as to its estimated intensity of labour.

Drawing from this analysis, possible business models are sketched that could help to tap the described improvement potentials. Thereby, special emphasis is on the possible role of the informal sector and on defining strategies to include the informal sector in future e-waste implementation strategies instead of creating competition between a formalised and non-formalised recycling industry.

The analysis is conducted for three key product groups, namely desktop computers, CRT devices and refrigerators and freezers. The selection of product groups is based on the following criteria:

- The product group constitutes an important share of the total e-waste volume in Nigeria;
- The end-of-life phase is of particular environmental concern;
- Improved end-of-life management can serve as model for the management of other product groups with similar characteristics.

The results of this criteria analysis are presented at the beginning of each product group analysis in the section "relevance for Nigeria".

2 Definitions

The scope of this study, i.e. socio-economic assessment of the informal refurbishing and e-waste recycling sector in Nigeria, comprises the following stages: collection, refurbishing, recycling and final disposal, which are carried out by three stakeholder groups, namely collectors, refurbishers and recyclers. In order to avoid misunderstandings, the following sections comprise short definitions of these stakeholders:

2.1 Collectors

The term collector refers to those actors that carry out the collection of e-waste. It is important to note that collectors usually do not specifically and solely focus on e-waste, but usually on several types of waste in parallel. In Lagos, Nigeria, there are two main types of collectors: Official waste collectors that operate under the Lagos State Waste Management Authority (LAWMA) regime as well as under a specific e-waste collection system by Lagos State Environmental Protection Agency (LASEPA)[3] and informal collectors that conduct the business of waste collection on their own initiative. The latter type of collectors is often referred to as "scavengers".

While the official waste collectors move around by waste trucks, informal collectors typically make use of small handcarts that are pushed manually (see picture 1). Informal collectors that address e-waste are typically connected to the scrap metal business and therefore also collect other metals-containing types of wastes.

In regions with a high concentration of refurbishing enterprises, informal collectors might acquire relatively high shares of e-waste (e.g. > 50% of the collected waste). This share, however, is usually significantly lower in other regions such as residential areas or car repair clusters. There, other metal-containing wastes are usually dominant.

While some informal collectors merely focus on collection, the vast majority also engages in the recycling of the collected wastes (see chapter 2.3).

[3] The formal waste and e-waste collection is not within the scope of this study and is therefore not integrated in the socio-economic assessment of chapter 4.

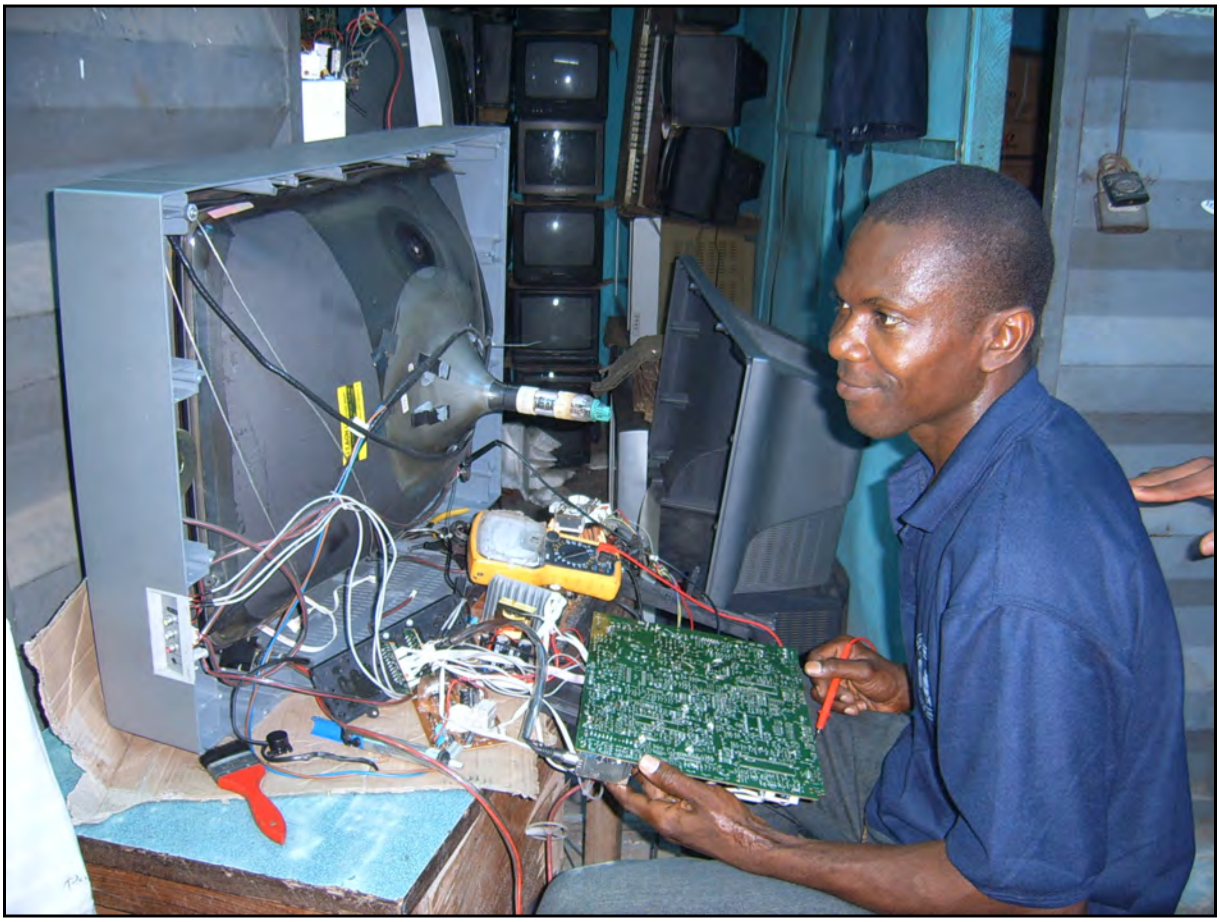
Picture 1 Informal e-waste collector in Alaba Market

2.2 Refurbishers

Refurbishers or repairers transform old and/or non-functioning electric and electronic equipment into second-hand and functioning equipment either by replacing or repairing defective components and/or by performing cleaning and repair activities in order to make the second hand equipment appealing to the customers. Although sometimes a distinction is made between refurbishers and repairers, the dividing line between the two groups cannot be drawn exactly. In this study, both groups taken together are generally referred to as refurbishers.

In addition to refurbishing and repair operations, most refurbishers also engage in marketing and sales of the refurbished products. For the scope of this study, this activity is included in the profile of refurbishers.

Each refurbisher in Lagos typically focuses on a distinct group of products such as cooling and freezing equipment, air-conditioners, small household equipment, TVs, computers or mobile phones.



Picture 2 Refurbisher of TVs in Alaba Market

2.3 Recyclers

Recyclers in Nigeria disassemble obsolete e-waste to recover metals, such as aluminium, copper and steel. While some recyclers are specialised on e-waste recycling, others engage in the recycling of various types of metal-containing wastes in parallel. Some recyclers also engage in the open incineration of cables and other plastic parts in order to liberate copper and other metals. Wet chemical leaching processes, often associated with the recovery of precious metals from printed wiring boards (PWB) have not been observed in Nigeria. However, PWBs collected in Nigeria are traded and exported, mostly to Asian destinations.

In few cases, recyclers deal directly with end-processing units, such as remelters and refineries, selling them the recovered metals. In many cases, middle-men are responsible for collecting the recovered fractions from the recyclers, and bringing them to end processing units. As already mentioned in chapter 2.1, many recyclers are also active in the collection of waste.

Generally, recyclers produce quite a significant amount of wastes, as the devices contain many fractions that are of no economic value in Nigeria. These fractions are usually disposed of or burned in an uncontrolled manner in or around recycling clusters.

Picture 3 Recyclers of the Alaba Market Recycling Community

3 E-waste management in Lagos, Nigeria – an overview

According to the Lagos State Government data, the city features above 17.5 million inhabitants making it one of the biggest cities – and the fastest growing – in the world (Lagos State Government 2007). It is the economically most important city of Nigeria and has a regional importance also for other West African countries as many internationally operating companies have affiliates or headquarters in Lagos. With its two ports, Lagos also plays a major role for international trade as many goods originating in or destined for West Africa are channelled through Tincan Island Port or Apapa Port.

This role as major population and business centre and hub for goods is also reflected in the amounts of e-waste generated and recycled within Lagos.

3.1 Import of new, used and obsolete equipment

From the analysis of export data from European countries, it becomes obvious that Nigeria is the primary destination for refrigerators, electrical machines, data processing equipment and televisions shipped to West Africa. Most of these imports are channelled through the city of Lagos as it represents the biggest West African market for new and used electric and electronic equipment. Although the analysed data does not allow any differentiation between new, used and obsolete equipment, all expert opinions suggest that an important share of these goods are second-hand and partly not functioning. In addition to these shipments packed in containers, used and obsolete e-equipment is also imported together with cars and trucks destined for re-use in West Africa[4]. Since Nigeria is the biggest importer of used trucks in West Africa, this trade, too, causes significant volumes of imports.

The imported equipment is mostly passed on to retailers which in turn sell the equipment to private and corporate consumers. Used and obsolete e-products are passed on to the refurbishing sector, which is organised in four major markets in Lagos. In addition, some traders from other Nigerian cities also purchase imported equipment from Lagos to be directly transported to other markets outside of Lagos.

The results from project component 1 and 2 (Ogungbuyi et al. 2011) and the work carried out by Odeyingbo (2011) show that 70% of all the imported used equipment is functional and sold to consumers after testing. 70% of the non-functional share can be repaired within the major markets and is also sold to consumers. 9% of the total imports of used equipment is non-repairable and is directly passed on to collectors and recyclers.

[4] As the fright charges are calculated on the basis of the export volume, cars and trucks for export are often loaded with other goods for export.

3.2 Refurbishing of used and obsolete equipment

The refurbishing sector in Lagos is organised in four major markets, which all have special characteristics and a certain role within the business of trading and refurbishing of used and obsolete electrical and electronic equipment:

3.2.1 Alaba Market

Alaba International Market was founded in 1978. Today, it is the largest market for used and new electric and electronic goods in Africa, where all major international brands and allied products are offered for sale. The market occupies a land area of approximately 2 km x 1 km in the southwest of Lagos (see Map 1). In view of the fact that all electronics products from communications, broadcasting, computers, televisions, videos, home appliances, refrigerators, video games to generators, satellite systems, general goods etc are available in this market, buyers from as far as Ghana, Niger, Chad, Togo, Benin Republic, East Africa etc. throng this market to make their purchases. In Nigeria, retailers from almost all major cities come to Alaba International Market to buy electronics and allied products. As many people come to Alaba Market during public holidays to do their purchases, most businesses in the market do not observe public holidays but rather use these peak seasons for business.

Picture 4 Shops in Alaba Market offering refurbished irons

Other ancillary products and/or services to be found in this market include financial services such as banking, mortgage banking, microfinance, stock broking, investment consulting, etc. Moreover, there are office service facilities such as photocopy shops, telephone booths, cyber cafés, secretarial service centres etc.

Nigeria Police station is not far from the market, providing additional security for buyers and sellers so that they can trade and do business in a secure and safe environment.

1 = Westminster Market | *2 = Alaba Market* | *3 = Lawanson Market*
4 = Ikeja Computer Village | *5 = Ojota Scrap Market* | *6 = Solous Dumpsite*
7 = Olusosun Dumpsite

Map 1 The city of Lagos indicating the main refurbishing and recycling clusters for used and obsolete electrical and electronic equipment

The market features more than 2,500 shops doing refurbishing and offering used electrical and electronic products for sale. Most of these devices are imported second-hand products and are either sourced from Westminster Market (see section 3.2.2) or directly from one of the two Lagos ports. In the latter case, trucks carry whole containers filled with used equipment into the market, where the untested devices are sold to refurbishing businesses.

The enterprises operating in Alaba Market are organised in the International Market Association Alaba, which is maintaining an office located on the market grounds, and which is representing the market in decision-making processes affecting the market businesses.

3.2.2 Westminster Market

Compared to Alaba Market, Westminster Market is much smaller, but occupies a strategically important area close to Tincan Island Port in Apapa, a major hub for imported products. Originally, only a warehouse to store imported goods stood in this place, which, under the Structural Adjustment Programme of the General Ibrahim Babangida regime between 1985 and 1993, gradually developed into a “real” market. During that time, the devaluation of the Naira made importation business less lucrative, and the warehouse at Westminster started to rent out space to people who still had the nerve to engage in the import business.

To run a business in the market, the importer must first apply for admission. Only if, his application includes his importation documents such as bill of lading and customs papers, the importer will be given a space to offload and sell.

There are approximately 300 shops in Westminster Market selling all kinds of used electrical and electronic devices such as computers, mobile phones, printers, TVs, tape recorders, CD players, kettles, irons, video-CDs, and computer games.

Westminster Market exclusively deals with used electric and electronic products imported through the Tincan Island port. Although off-loading and selling are the major business activities, testing and repair are also carried out. Customers encompass individuals and companies that buy for their own consumption, as well as resellers from other second-hand markets such as Alaba and Ikeja Computer Village.

Unlike Alaba market, Westminster respects public holidays. The market has an international standard security system in place. There are more than 30 security guards manning the place. In addition, the market maintains good working relationship with Nigeria police and the Nigerian Navy, both located close to the market. These two agencies have been of immense help to the market as they have not yet had any case of burglary in the complex. There is even a technical committee of directors in place. Also, water hydrant pipes are placed all around the complex in case of any fire outbreak. Westminster Market is insured against fire and burglary.

3.2.3 Ikeja Computer Village

Ikeja Computer Market – popularly known as Ikeja Computer Village – commenced in the mid-1990s in a residential area with a high density of law offices. In 1995/'96, the market opened businesses in the sales of new computers, mobile phones, printers and communication equipment. Around the year 2000, the market, aside from the sales of new computer and computer equipment, commenced the sales of used computers, printers and communication equipment. Presently, the market is very active in the sales of second-hand products, both in wholesale and retail. The market also deals in the refurbishment and repair operations.

Picture 5 Shops offering refurbished computers and monitors in Ikeja Computer Village

Ikeja Computer Village, with a size of about 1.1 km^2, is no longer completely residential but occupies well over 3,000 businesses in new computers, mobile phones, printers and communication equipment. The market serves as an outlet for Lagos and Nigeria as well as the neighbouring West African countries.

The enterprises operating in Ikeja Computer Market are organised in the Computer and Allied Products Association of Nigeria (CAPDAN), which maintains an office on the site.

The Ikeja Computer Market is repeatedly subject to local disputes over the use of the area. As the market is located in an originally residential area, there are voices that call for a closure or relocation of the market. Additionally, unsound recycling, disposal and burning activities of e-waste within and around the market have fuelled this discussion. In response to this dispute, the market authorities have banned some of these practices like burning of plastics and cables. Additionally, arrangements were made with the Lagos State Waste Management Authority (LWAMA) that set up waste bins all around the market. Now, all wastes generated within the market can be discarded into these bins, where they are picked up by regular waste trucks.

3.2.4 Lawanson Market

Lawanson Market is known for trading in used electrical accessories and appliances such as refrigerators, deep freezers, and air conditioners. Additionally, other appliances like televisions, DVD players, home theatres, electric cookers, irons, blenders, and juice extractors are traded, too. These goods are sold to retailers who again sell the products in small quantities to final consumers who come from all parts of Nigeria and even neighbouring countries. Most of the goods were originally imported from European countries, especially from Germany.

The main road divides the market into two administrative parts: the left axis is Mushin L.G.A. while the right axis is Surulere L.G.A. The market is bounded on the two sides by the Lawanson and Pako bus terminals. The majority of the businesses are shops attached to the residential buildings. Others maintain a proper shop located off the road. The market is composed of more than 350 businesses on the two sides.

In addition to these markets, there are many small shops distributed across the city of Lagos that also engage in the repair, refurbishing and sale of used electric and electronic products. These shops either source from one of the markets described above, or they receive equipment for repair from their customers. Generally, it is estimated that this loose network of shops number up to 2,000.

3.3 Collection and recycling of e-waste

The e-waste collection and recycling activities in Lagos are largely organised around the main sources of obsolete electrical and electronic products.

First of all, informal waste collectors (also referred to as ‘scavengers’) move all around Lagos with handcarts to collect e-waste together with other metals-containing wastes. Mostly, these collectors buy such waste devices for small amounts of money from businesses or private households. The collection prices for obsolete and non-repairable equipment vary greatly but range around 50 Naira (US$ 0.34) for one CRT monitor and 100 Naira (US$ 0.67) for one fridge or one desktop PC (without monitor and peripherals).

In addition, there are also collectors that – due to severe financial limitations – cannot pay for metal-containing wastes and therefore focus on what is freely available, e.g. on roadside waste dumps.

As the city of Lagos is too large to easily bring the collected materials to a central recycling site, this informal collection system makes use of many small- and medium-sized scrap metal yards, where metal-containing wastes are manually dismantled, assorted, stored and sold to traders. Fractions of no value to the workers are discarded on irregular dumpsites or burned. One example for this type of scrap metal yards is the Ojota Scrap Market described in section 3.3.1.

As the informal waste collectors compete with a quite efficient official waste collection organised by the Lagos State Waste Management Authority (LAWMA), a certain share of the e-waste generated in households and businesses is delivered to the three official dumpsites in Lagos. There, waste picker communities that live on or next to the dump sites take out all fractions of value, including e-waste. Here too, dismantled and sorted e-waste is sold to traders. Fractions of no value to the waste collectors are thrown back on the dumpsite. Sections 3.3.2 and 3.3.3 comprise short descriptions of these dump sites.

Another major source of e-waste are the markets described in section 3.2. As most businesses operating in these markets are engaged in refurbishing and repair activities, quite significant amounts of e-waste are generated as by-products. While some of the enterprises directly engage in the e-waste recycling business themselves, most of them pass on their waste to collectors who bring it to recycling sites within or close to the markets. These recycling communities are described exemplarily in section 3.3.4.

The e-waste recyclers operating in scrap metal yards, on dumpsites or in recycling sites around second-hand markets disassemble obsolete electrical and electronic equipment in order to liberate metals that can be sold to traders. In particular, the ambition focuses on steel, aluminium and copper. Often, cables and other plastic parts are incinerated to liberate copper. In addition, certain types of printed wiring boards (PWBs) are separated, collected, and sold to traders[5]. Wet chemical leaching processes, often associated with the recovery of precious metals from printed wiring boards (PWB), have not been observed in Lagos. In July 2010, the prices for scrap were as follows:

- Steel: 15 Naira/kg (0.10 US$/kg)
- Aluminium: 150 Naira/kg (1.01 US$/kg)

5 Usually, only the so called “high-grade printed circuit boards” are collected and exported. These boards mainly stem from computers and other IT-equipment and feature quite high concentrations of precious metals. In Lagos, this type of printed circuit boards are termed “green panel”, as the board material is mostly coloured green.

- Copper: 400–600 Naira/kg (2.69–4.03 US$/kg)
- PWBs: 300 Naira/kg (2.02 US$/kg)

In the following sections, some e-waste recycling clusters are described. Due to the decentralised structure of the e-waste collection and recycling in Lagos, the description of sites is by no means complete.

3.3.1 The Ojota Scrap Market

The Ojota Scrap Market is not just a market for scrap materials, but also a centre for dismantling and sorting activities. The scrap metal market is located in Lagos-Ikeja on the gentle slopes of a valley. The market is located under and next to a major bridge. There are numerous small enterprises in the market that dismantle and sort all types of wastes. Focus is on scrap metal, but glass, plastics, and shoes are also collected and sorted. On the upper parts of the slopes, some few businesses in simple houses run low investment machinery to shredder steel. On the middle part of the slope, there are many little shacks where scrap metal is dismantled and sorted manually. Steel scrap is piled up in large quantities outdoors. There are also some simple houses and shops that sell goods for the daily needs of the recycling community.

Picture 6 Section of the Ojota Scrap Market

The lower part of the slope borders on a swampy and bushy land next to a little creek. This lower section is used to dispose and incinerate waste. In particular, there are some places where cables are burned routinely. Although the businesses in Ojota Scrap Market do not exclusively focus on e-waste, almost all businesses engage in e-waste collection and/or dismantling and sorting to a certain extent. The Ojota Scrap Market and its surroundings are inhabited by approximately 1,000 collectors and recyclers, mostly originated from northern Nigeria.

3.3.2 The Soluos Dump Sites

The Soluos dump site is one of the three official landfills serving Lagos State. It is situated in the north-western outskirts of Lagos. There are three dump-sites in this location, named Soluos I, Soluos II and Soluos III. Soluos I is already filled up, whereas Soluos II and III, with sizes of 7.8 and 5 hectares respectively. The two sites have average life spans of five years (the number of years that it will take the dump sites to be filled up). Each of these sites receives an average of about 2,250 m^3 of waste everyday.

Picture 7 The waste picker community on the Solous Dump Site

The Solous Dump Site is occupied by a waste picker community comprising about 350 to 400 individuals, mostly from the northern parts of Nigeria. The community has simple shacks constructed on the Solous I dump site to store belongings and for shelter. The people live from picking out recyclable waste that is brought to the dump site by the official waste collection scheme. In particular, the community sorts out shoes, plastics, glass and scrap metals, which are sold to traders. They also collect and dismantle the e-waste brought to the landfill.

3.3.3 The Olusosun Dumpsite

The Olusosun dumpsite was established in 1992. It is reputed as one of Africa's largest dumpsite comprising an area of around 42 hectares. 2,400 metric tonnes, equalling 40% of the waste of the city of Lagos, are brought to the dumpsite every day.

Roughly 1,000 simple homes have been built on Olusosun – the residents, mainly informal collectors and recyclers, collect and process scrap from the dumpsite and sell it to dealers. After disputes with neighbouring communities in 2010 (The Nation 2010), LAWMA regulated the stay of informal collectors and recyclers in order to prevent these people from sleeping on the dumpsite (P.M. News Nigeria 2010).

There are several chains of businesses on Olusosun. One section of the site is devoted to sorting out bits and pieces of refuse, focussing on all, plastics, metals, glass and other materials. The useful plastics are thoroughly washed up and packed in bags to be sold to the highest bidder, while the damaged pieces are neatly folded to be grinded into small bits. The crushed plastics are also packaged into bags, ready to be sold off to would-be buyers.

As the municipal waste stream of the city of Lagos contains significant amounts of e-waste, e-waste is also collected, dismantled and sold by the community.

3.3.4 The Alaba Market Recycling Community

As Alaba Market (described in section 3.2.1) is the biggest refurbishing cluster in West Africa, it also produces a lot of waste. This waste mainly comes from devices and components that cannot be repaired or that were used as a supply of spare parts. The metal-containing waste fractions are sold to a network of informal collectors who move around the market. The waste is brought to small scrap metal yards in and around the market. There, the waste is dismantled and sorted either by the collectors themselves, or by scrap metal workers exclusively focussing on dismantling and sorting. At this stage, cables are burned in open fires to free the copper from its insulation. The produced scrap fractions – steel, copper, aluminium and printed circuit boards – are sold to local traders that organise storage and transport to refineries. Currently, there are six such traders operating in and around Alaba Market, each employing around 30 workers on a permanent basis. Additionally, each trader is supplied by an average of 200 collectors. Also here, the scrap metal business does not exclusively focus on e-waste but also on other metal-containing wastes. Nevertheless, the share of e-waste is particularly high in the Alaba Market recycling community. Almost all people engaged in the scrap metal business are from the northern parts of Nigeria.

4 Results of socio-economic assessment

4.1 Impacts on workers

4.1.1 Safe and healthy working conditions

Informal e-waste collection, refurbishing and recycling in Lagos are each associated with specific health and safety risks for the involved workers.

During informal collection, these risks primarily stem from handling heavy and broken devices and the physical strain of pushing handcarts over large distances. Although not reported during the interview campaign, risks might also stem from participating in heavy road traffic.

In the refurbishing sector, many workers are engaged in hand soldering using lead containing solder paste. As most workers bow over the solder gun for quite long time periods per day, and as many refurbishers work in small, poorly ventilated workspaces, many refurbishers are exposed to lead fumes over long-time intervals (see Picture 8).

Picture 8 Refurbisher working with a solder gun in Alaba Market

Many refurbishers claimed that the solder fumes cause itchy eyes. Few refurbishers claimed that they suffer from muscle pain after long days of work. Although not yet documented, it seems likely that lead-borne diseases can occur amongst refurbishers. Additionally, refurbishers often report minor injuries from electric shocks during repair operations and small burnings from solder guns. Toner dust is a specific health risk in businesses engaging in the repair and refurbishing of photocopiers and laser printers. Toner dust can easily be inhaled and is reported to cause respiratory diseases, skin and eye irritation, chronic cough and coryza, as well as many other unspecific diseases like fatigue, pains, and fever (Öko-Test 2001). Although not classified as carcinogenic, there is evidence that toner dust might cause cancer (BAuA 2009). In some refurbishing businesses, it was observed that in many parts of the workspace toner dust accumulated up to layers of several millimetres.

A more general health problem are the generators used for electricity supply: As frequent blackouts make public electricity supply unattractive for refurbishing businesses, most refurbishers use one or more generators, which are mostly placed just next to the business. Especially in the large second-hand markets (see chapter 3.2), this leads to a high density of running generators causing exhaust gas and noise emissions. It is almost unavoidable that some generators are placed next to the entrance of a workspace.

In the recycling of e-waste, health and safety risks are manifold. Most recyclers report injuries on hands and feet from sharp waste fractions. In particular, people that engage in the recycling of CRTs report cuts and other injuries from breaking the tubes. During this operation, a certain amount of the cadmium-containing internal phosphorous coating is released as dust that can partly be inhaled by the workers. Further health risks are associated with the open incineration of cables to recover copper and the burning of plastic parts to reduce waste volumes, which is associated with significant emissions of persistent organic pollutants (POPs) such as dioxins and furans. Although there are no data for contamination levels of the working environment, it is known from similar recycling clusters in other countries that soil, dust and air can feature high concentrations of toxic metals such as lead and cadmium, and halogenated chemicals such as phthalates[6] and polybrominated diphenyl ethers (PBDEs)[7] (Brigden et al. 2008; Sepúlveda et al. 2010). While exposure to lead fumes or dust is known to cause multiple disorders including neurological, cardiovascular and gastrointestinal diseases (Haefliger et al. 2009), exposure to cadmium fumes or dust leads to malfunctioning of kidneys (Hellstrom et al. 2001) and the respiratory system (WHO 1992), and possibly to lung cancer (DHSS 2005). On the other hand, even in Europe, workers in electronics recycling facilities have higher blood levels of PBDEs than other workers (Brigden et al. 2008; Sjödin et al. 2003; Sjödin et al. 2001). Consequently, it is assumed that in the absence of protective gear and other workplace standards, the levels of

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6 Used as plasticizers or softeners in plastics, especially PVC.

7 Used as a flame retardant in plastic components of electronic equipment.

PBDEs in the blood of the recycling workers in Nigeria are much higher. Exposures to PBDEs have been known to cause endocrine disruptive properties (Legler & Brouwer 2003) and neurobehavioral disturbances in animals, such as abnormal brain development (Qu et al. 2007; Kuriyama et al. 2005).

For the waste picker community on Olusosun Dumpsite, it is known that the general health situation amongst waste workers (collectors and recyclers) is alarmingly poor. In a survey carried out on the dumpsite, the majority of workers reported to suffer from eye irritation, difficulty in breathing, cough and fatigue. In addition, diseases like malaria, typhoid, pneumonia, dysentery, cholera and fatigue are common (Oyelola et al. 2009).

4.1.2 Freedom of association and right to collective bargaining

Nigeria ratified the ILO fundamental conventions C87 on Freedom of Association and Protection of the Right to Organise Convention and C98 on Right to Organise and Collective Bargaining both in 1960.[8] Informal e-waste collection and recycling in Lagos is organised in networks of self-employed individuals. These structures do not feature any formalized workers' participation mechanisms. The Scrap Metal Dealers Association of Nigeria, however, represents an unknown share of the Lagos e-waste collectors and recyclers, and can exert some influence on policy making processes affecting the sector's businesses and workers.

The refurbishing businesses operating in one of the major second-hand markets exclusively registered with the relevant Market Associations, which – besides other tasks – also represent the refurbishers' interests on the political level. Apart from that, refurbishers of refrigerators and air conditioners are also organised in the Nigerian Association of Refrigeration and Air Conditioning Practitioners (NARAP). Other refurbishers are organised in the National Electronics Technician Association of Nigeria (NETAN). Nevertheless, these associations mostly represent the interests of the workshop owners, meaning that employees and apprentices have no independent body or association to support their demands.

4.1.3 Equality of opportunity and treatment and fair interaction

Nigeria ratified ILO fundamental conventions C100 on Equal Remuneration in 1974, and C111 on Discrimination (Employment and Occupation) in 2002.

The refurbishing sector in Lagos, Nigeria is clearly dominated by male workers. There are hardly any women working in refurbishing and repair operations itself. However, women sometimes work in sales and bookkeeping.

E-waste collection and recycling, too, are clearly dominated by males. The only sections in which women make up a significant share of the workforce are the waste picker communities

[8] Source: ILO Website: http://www.ilo.org/ilolex/english/convdisp1.htm

on the official Lagos dumpsites (see chapter 3.3), where the share of females is estimated to be around 30% of the workforce (Oyelola et al. 2009). The collection and recycling activities mostly attract workers from the northern part of Nigeria. Thus, people from the same region are generally preferred when it comes to providing new income opportunities.

There is little information available on hierarchies or disciplinary practices. Anyway, systematic discriminatory practices could not be observed, probably due to the high share of self-employment in these sectors. Nevertheless, unsound disciplinary or discriminatory practices cannot be excluded generally. In particular, it can be assumed that the common practice of having only oral contracts between employer and employee may sometimes give rise to disputes and situations that may lead to unfair interaction.

4.1.4 Forced labour

There are no reports on forced labour within the refurbishing and e-waste recycling industry in Nigeria. Nigeria ratified the ILO fundamental conventions C29 on Forced Labour, and C105 on Abolition of Forced Labour both in 1960.

4.1.5 Child labour

Nigeria ratified the ILO fundamental convention C182 on Worst Forms of Child Labour in 2002. The other ILO convention related to child labour, i.e. C138 on Minimum Age, was also ratified by Nigeria in 2002.

Under the convention C138, the general minimum age for admission to employment or work is 15 years (13 for light work). Additionally, there is the possibility of setting the general minimum age at 14 (12 for light work) in regions where the economy and educational facilities are insufficiently developed. Furthermore, the minimum age for hazardous work has been set at 18 years (16 years under the condition that "*the health, safety and morals of the young persons concerned are fully protected and that the young persons have received adequate specific instruction or vocational training in the relevant branch of activity*" – Article 3, paragraph 3).

However, Article 3, paragraph 1 of the convention C138 specifically states that "*the minimum age for admission to any type of employment or work which by its nature or the circumstances in which it is carried out is likely to jeopardise the health, safety or morals of young persons shall not be less than 18 years*". Considering severe health hazards associated with e-waste recycling activities, as also described in the section "Safe and healthy working conditions" (4.1.1) of this report, inappropriate e-waste recycling activities carried out without adequate instruction, training and sensitization, would be classified as hazardous work.

Furthermore, under the ILO Worst Forms of Child Labour Convention No. 182, the term "child" applies to all persons under the age of 18. The worst forms of child labour comprise all kinds of slavery or practices similar to slavery, such as sale and trafficking of children, debt bondage, forced or compulsory labour, use, procuring or offering of a child for prostitution, drug trafficking etc. Article 3, paragraph 4 includes "*work which, by its nature or the circumstances in which it is carried out, is likely to harm the health, safety or morals of children*".

There is little solid data on the extent of child labour in Nigeria or in the refurbishing and e-waste collection and recycling business in particular. Nevertheless, field data and observations suggest that child labour is not a major issue in the refurbishing sector, while it is more common in e-waste collection and recycling. It is reported that most children working in this sector are mostly aged 12 and above.

4.1.6 Remuneration

Due to the informal nature of the e-waste recycling sector in Nigeria, official figures on the income of the workers are not available. Therefore, the monthly income of each stakeholder group was calculated on the basis of the information provided during the interviews. In most cases, the interview partners were active in both, collection and recycling. Therefore, the income data do not allow for differentiation between these two types of activities.

Since most of the collectors and recyclers are self-employed, their income is correlated with the amount of collected and dismantled scrap volumes. The monthly income for collectors and recyclers ranges from 1,000 Naira to 15,000 Naira (US$ 6.70 to 100). Generally, it can be observed that those collectors that have enough financial resources to pay for obsolete devices and components have a significant higher income than collectors that solely have access to freely available waste. While the first group earns between 7,500 and 15,000 Naira a month (US$ 50 to 100), the latter group has a monthly income as low as 1,000 to 2,000 Naira (US$ 6.70 to 13.40). These income figures actually reflect the profit margin generated by collectors and recyclers at the end of the month, i.e. the investment for buying obsolete equipments and the rent for handcarts deducted from the money earned from reselling the recycling products.

In the refurbishing sector, three major types of income-groups can be differentiated: Workshop owners, employees and apprentices. While workshop owners often achieve a net-income in a range of 30,000 to 100,000 Naira (US$ 200 to 670) per month, employees usually receive a monthly salary ranging between 10,000 and 15,000 Naira (US$ 67 to 100). Apprentices usually do not receive any salary at all and are mostly only granted some money to care for food and transport. Nevertheless, apprentices usually receive some capital at the end of their two- to five-year-long learning period. This capital – often in a range between 300,000 and 1,000,000 Naira (US$ 2,000 to 6,700) – is meant to start an own business. Generally, it can be observed that people and enterprises engaging in the refurbishing, repair and sale of more complex products such as TVs, computers and mobile phones have higher incomes than those focussing on quite simple electric products such as irons and water heaters.

The income data suggest that collectors and recyclers focusing on freely available waste represent the most vulnerable group in terms of low income, as the average daily income is somewhere between US$ 0.22 and 0.45 (see table 2). In addition, apprentices in the refurbishing sector also have extremely low salaries. Nevertheless, the situation of these people is significantly different from other groups, as the apprenticeship usually marks the beginning of a career that will lead to higher income activities in the future.

Table 2 Daily income range for the people engaged in collection, recycling and refurbishing of e-waste in Lagos, Nigeria *(Source: Own calculations)*

Sector		**Daily income [Naira]**	**Daily income [US$]**
Collection & recycling	Door-to-door collectors	250–500	1.68–3.36
	Collectors addressing freely available wastes	33–67	0.22–0.45
Refurbishing	Workshop owners	1,000–3,300	6.72–22.2
	Employees	330–500	2.22–3.36
	Apprentices	0–300	0–2.0

Collectors and recyclers focusing on waste from door-to-door collection achieve incomes that are comparable to those of employees in the refurbishing sector. If not shared with other family members, these incomes enable a living above the internationally defined poverty line of US$ 1.25 per day. However, if shared with family members, the incomes are not sufficient to enable a living above the absolute poverty line[9].

It has to be underlined that the above mentioned data and interpretations are solely based on calculated incomes as a result of productive economic activity. Indirect costs or externalities, as for instance the inability to work in certain periods of illnesses or occurring costs related to the treatment of health related problems, which are common in the refurbishing and e-waste recycling sector, have not been considered.

4.1.7 Working hours

There are several conventions of the International Labour Organization (ILO) that deal with the issue of working hours, overtime, overtime compensation and rest periods:

- C1 – Hours of Work (Industry) Convention, 1919
- C14 – Weekly Rest (Industry) Convention, 1921
- C30 – Hours of Work (Commerce and Offices) Convention, 1930
- C106 – Weekly Rest (Commerce and Offices) Convention, 1957

The conventions demand that workers shall not, on a regular basis, be required to work in excess of 48 hours per week and that they shall be allowed at least one day off for every 7-day-period on average. Overtime shall be voluntary, shall not exceed 12 hours per week,

[9] In Nigeria, the average total fertility rate is 4.82. Hence, many families have more than four children.

shall not be demanded on a regular basis and shall always be compensated at a premium rate, generally one and one-quarter times the regular rate. Nigeria has not ratified any of these conventions.

Due to the informal nature of the e-waste recycling sector in Nigeria, most of the workers do not have a fixed working time in terms of hours per day or per week. Nevertheless, collectors and recyclers mostly work from 8am to 5 or 6pm every day, including public holidays and weekends. For religious reasons, some collectors and recyclers take some time off once per week (on Fridays or Sundays).

Generally, e-waste collection and recycling activities are not organised in strict production lines, so that individual workers may arrange working hours and rest periods to their specific needs (Manhart 2007). These rest periods or breaks rarely exceed 30 minutes per day, which – together with the daily working time – implies 255 to 285 work hours per month. Collectors and recyclers reported to take one or more days off occasionally in cases of health or family related matters albeit without getting paid for those specific days. Although the ILO conventions listed above are not applicable in Nigeria, the working hours in e-waste collection and recycling clearly exceed the limits drawn by these conventions.

Refurbishers, too, usually start work at 8am and finish around 5 or 6pm, with a lunch brake of about 30 minutes. In contrast to collectors and recyclers, almost all refurbishers take Sunday off and also do not work on important religious holidays such as Christmas. In terms of other official holidays, there are significant differences between the second-hand markets: While Westminster Market closes on public holidays, Alaba Market and Ikeja Computer Village stay open, as on these days, the markets attract an above average number of customers.

Therefore, monthly working hours for refurbishers can be assumed to lie somewhere between 210 to 240 hours. The following table summarizes the findings on the working hours:

Table 3 Working hours for the people engaged in refurbishing and e-waste collection and recycling business in Lagos *(Source: Own calculations)*

	Collectors & Recyclers	**Refurbishers**
Working hours per day	8.5 – 9.5	8.5 – 9.5
Working hours per month	255 – 285	210 – 240

4.1.8 Employment security

Most workers in the collection, recycling and refurbishing sector are self-employed and thus do not have any kind of written or oral labour contract. Employment is common only in the refurbishing sector, were many enterprises have between one and five employees, including apprentices. Although oral labour contracts are predominant, some few employees work on the basis of written contracts. In addition, there are some few larger recyclers that employ staff on a permanent basis. Also here, oral contracts are dominant.

The employment turn-over in collection and recycling is unknown. General observations based on the age of the encountered workers, however, suggest that few collectors and recyclers are able to stay in business for more than ten years. The main reasons for this relatively short career are thought to be health hazards (see section 4.1.1) and low income (see section 4.1.6).

This situation seems to be less pronounced in the refurbishing sector, where many workshop owners can be found that work in their business for more than ten years. Turnover rates amongst employees vary greatly: While some repairers are employed on a long-term basis, some enterprises hire repairers only for a short-term period.

Generally, the employment perspectives for workers in refurbishing, collection and e-waste recycling can be assumed to be positive due to the following reasons:

- The EEE and e-waste volume in Nigeria is growing steadily.
- Labour intensity continues to be high in the refurbishing and informal e-waste recycling structures.

However, there are recent discussions to ban certain refurbishing and recycling activities from some markets (Vanguard 2010) so that employment security might deteriorate and become more uncertain in some cases.

4.1.9 Social security

As most workers in collection and recycling of e-waste are self-employed and operate on an informal basis, they are not subject to any form of social security system like health and unemployment insurance, or old age pensions schemes. The same holds true for most workers in the refurbishing sector. Nevertheless, employees – including apprentices – are often supported by their employers in the case of illness. Among other things, some employers bear the costs for medication and paid or unpaid rest periods. Nevertheless, this support is on a purely voluntary basis and is not granted in every business.

4.1.10 Professional development

In collection and recycling, no kind of professional development exists. All related activities can be taken up after short and informal introductions so that no real training is required. In addition, collection- and recycling-related training programmes on topics like health and safety or marketing do not exist on a regular basis in Lagos.

In the refurbishing sector, professional development in the form of apprenticeships is very common. Generally, one or more apprentices stay with one refurbishing enterprise for two to five years to learn the technical skills required for the business. During this period, apprentices usually do not earn any money, but are sometimes granted food and accommodation. After the apprenticeship, the apprentices sometimes receive a start-up fund from their boss to start their own enterprises. Generally, the terms and conditions of an apprenticeship are not uniform and are hardly ever documented in a written contract. Therefore, conditions and effectiveness of the apprenticeship vary greatly and strongly depend on the commitment of the apprentice's boss.

4.1.11 Job satisfaction

Surveys related to job satisfaction are generally based on subjective opinions of the workers which, even in similar working conditions, can vary significantly. It was, however, observed that the vast majority of interviewees from the refurbishing sector were satisfied with their job. In particular, many workshop owners, employees and apprentices consider their job as “prestigious” and “high-tech”. In addition, most people claimed that their income would be sufficient to cater for all basic needs. Even apprentices who do not have any regular income yet, are mostly positive about their career perspectives and are looking forward to start their own business. Nevertheless, some apprentices complained about not being paid and that they are hardly able to cover their basic needs.

E-waste collectors and workers are less positive about their jobs and mostly claim that the activities they perform are not satisfactory. Nevertheless, most collectors and recyclers still consider themselves lucky to have at least one basic source of income.

4.2 Impacts on local communities

4.2.1 Safe and healthy living conditions

There are no scientific studies on health and safety impacts of refurbishing, e-waste collection and recycling in Lagos. There are, however, numerous studies from other countries addressing the environmental and health impacts of informal e-waste recycling practices, quite similar to those found in the Lagos recycling clusters. These studies were mostly carried out in India and China and were well summarised by Sepúlveda et al. (2010). In addition, scientific surveys were made in Ghana, which were published by Brigden et al. (2008).

These studies all came to the result that informal recycling activities such as dismantling, open burning of wires and plastics, and uncontrolled disposal lead to the emission of significant levels of heavy metals and persistent organic pollutants to soil, water systems and air. Typical pathways of pollutants can be summarised as follows:

- Dismantling: Emission of heavy metals and flame retardants (PBDEs) with fine particles (dust) to the atmosphere. The particles either re-deposit near the emission source, or are transported over medium or long distances, depending on size and weather conditions. Most of the dust sooner or later enters the water and soil system or reacts with the biota.
- Burning of cables and plastic parts: Emission of ashes and fumes containing heavy metals and PBDEs, which are partly transported over medium and long distances and partly deposit as bottom ash. Also here, most of the fly ash sooner or later enters the water and soil system or reacts with the biota. In addition, uncontrolled burning leads to the formation of other pollutants such as dioxins and furans, which are among the most hazardous anthropogenic pollutants. As calculated by Fasko et al. (2010), the uncontrolled burning of cables in five West African countries (Nigeria, Benin, Ghana, Côte d'Ivoire and Liberia) is a major source of these pollutants and roughly equals to approximately 10-20% of the total dioxin emissions to air in Europe[10].
- Disposal: Hazardous compounds such as heavy metals and PBDEs are leach into the water and soil system. The rate of these leaching processes over time depends on type and particle size of the waste and its exposure to weathering (rainfall, moisture and temperature regime).

[10] EU15 + Norway + Switzerland

Picture 9 Uncontrolled dumping of e-waste (mostly waste from fridges) near Ojota Scrap Market

In several informal e-waste recycling sites, these pathways resulted in significant concentrations of pollutants in air, soil and water in and around recycling sites: In Agbogbloshie and Koforidua, two major e-waste recycling sites in Ghana, the concentrations of copper, lead, zinc and tin were found to be in the magnitude of over one hundred times typical background levels. In particular, the concentrations of lead in soil and ash samples collected in these sites were found to be as high as 5,510 mg/kg dry weight (Brigden et al. 2008). Comparable lead concentrations are also reported from bottom ash samples taken in Indian recycling sites with intensive cable burning activities (3,560-6,450 mg/kg dry weight), dust from Indian e-waste separation workshops (150-8,815 mg/kg dry weight), dust from streets near e-waste recycling facilities in India (31-1,300 mg/kg dry weight) and dust from houses of e-waste recyclers in China (719-4,110 mg/kg dry weight). These values mostly exceed typical natural background levels for soils and industrial sites (35 and 500 mg/kg dry weight) (Sepúlveda et al. 2010).

In addition, Sepúlveda et al. (2010) demonstrated that levels of PBDEs, too, are significantly elevated in and around recycling sites in China and India. Furthermore they stated that even exposure to pollutants in connection with long-range transport can be measured in practice.

According to the authors, these findings clearly indicate that informal e-waste recycling practices cause serious detrimental effects on humans and the environment. Besides direct exposure of workers, this also includes risks of secondary exposure for remote areas.

Exposure to lead dust or fumes leads to the underdevelopment of brain in children, hence causing intellectual impairment (Haefliger et al. 2009; Brigden et al. 2008). Apart from that, lead is known to cause a wide range of disorders, such as “damage to the nervous system and blood system, impacts on the kidneys and on reproduction” (Brigden et al. 2008).

Similarly, negative health impacts of flame retardants, such as PBDEs, could also occur, not only through direct exposure, but also through food contamination (Harrad et al. 2004). In China, for example, high levels of PBDEs in the blood of local residents living in the proximity of e-waste recycling activities (Bi et al. 2007) have been reported. PBDEs have been known to cause abnormal brain development in animals (Eriksson et al. 2002), endocrine disruptive properties (Legler & Brouwer 2003) and anomalies in the immune system (Birnbaum & Staskal 2004).

Taking these findings into account, it becomes obvious that the informal e-waste recycling in Lagos does not only pose health risks to those people working in this sector (see section 4.1.1), but also to people living near the recycling sites. In addition, it can be assumed that the emission of pollutants contributes to enhancing the urban background pollution level in Lagos and that it therefore might increase general health risks of the Lagos population.

4.2.2 Human rights

There are no reports on the violation of human rights in the neighbourhood of refurbishing or e-waste recycling sites that were linked to the activities of the people involved in these businesses[11].

4.2.3 Indigenous rights

There are no indications on the violation of indigenous rights associated with the refurbishing, collection and recycling of e-waste in Lagos.

4.2.4 Community engagement

Mechanisms for the participation of local communities both in terms of being informed about the consequences of refurbishing and e-waste recycling activities, and in terms of being able to influence decisions to be made which may affect the local environment, human health and well-being, are not in place. Although there are market associations for refurbishers of refrigerators and air conditioners as well as for informal collectors and recyclers in all bigger

[11] Although severe health and safety hazards for workers and neighbouring communities may be regarded as violations of human rights, in this study these topics are covered in the sections “Safe and healthy working conditions” (4.1.1) and “Safe and healthy living conditions” (4.2.1).

refurbishing markets and sector associations (see section 4.1.2), these organisations primarily represent the interests of its members and usually do not maintain constant dialog with neighbouring communities.

4.2.5 Socio-economic opportunities

As described in the sections “Remuneration” and “Job satisfaction” and later in the section “Employment creation”, refurbishing, collection and recycling open up significant employment opportunities in Lagos. While the refurbishing sector is mostly attractive for medium- and high-skilled workers, the collection and recycling gives employment opportunities to a low-skilled workforce. In particular, informal collection and recycling of e-waste offer job and income opportunities for people from rural areas in the north of Nigeria. For these people, e-waste collection and recycling enables rapid and regular access to cash money, as the revenues from one day’s work immediately materialise when the recycling products are sold to one of the local middle-men. For many collectors and recyclers, this rapid-cash-flow is an important reason to engage in this sector despite unfavourable working conditions. Informal collection and recycling of e-waste and other types of wastes is one of the few economic activities that can be started without any formal or informal training and without any significant investments into machinery or facilities. Therefore, it is a sector that is principally open to poor migrants from rural northern Nigeria, where people have little alternatives to small-scale agriculture. Here it was observed that a certain share of collectors and recyclers did not completely abandon their agricultural activities, but return to their villages and farms during the rainy season which is the most work-intensive period in agriculture.

In contrast, most refurbishing activities require certain levels of technical skills that cannot be performed by an untrained workforce. Here, employment opportunities mostly exist for university graduates with technical background (e.g. computer science) or persons that went through the apprenticeship system described in section 4.1.10. The refurbishing sector in Lagos develops into a regional hub that does not only serve Lagos and Nigeria with second-hand products, but also exports them to other West and Central African countries. In particular, the refurbishers from Alaba Market and Ikeja Computer Village have developed skills and quality levels that are regarded as unique in sub-Saharan Africa. This was not only expressed by interviewees from these two markets, but also from businessmen from Ghana and Benin who regularly purchase refurbished products in Lagos. Although the refurbishing sector mostly works under informal conditions, it still holds the potential to form a nucleus for further technical and economic developments. This assertion is supported by a World Bank analysis of cluster-based economic activities in Africa (Abiola 2008, World Bank 2009). These studies emphasise the positive economic development of Ikeja Computer Village[12]

[12] In the World Bank study, Ikeja Computer Village is termed “Otigba Computer Village” after the main access road to the market.

and stress its particular strengths which are the widespread inter-firm co-operation, the high educational level of the workforce and the co-operation with the local authorities. According to the authors, Ikeja Computer Village is an overwhelmingly positive example for a cluster-based economic development in the sub-Saharan Africa.

4.3 Impacts on society

4.3.1 Unjustifiable risks

The informal refurbishing, e-waste collection and recycling sectors in Lagos are not under the suspicion of directly generating unjustifiable risks for the whole Nigerian society. Nevertheless, severe pollution from the current practices in recycling, disposal and incineration of residues is a significant long-term risk. Especially in terms of heavy metal contamination of soil and groundwater, and emissions of persistent organic pollutants (see section 4.2.1), the e-waste recycling sector is a considerable burden for the future development of the contaminated sites.

4.3.2 Employment creation

Due to the size of Lagos and the informal and intransparent nature of the waste collection and recycling system, it was not possible to come to a sound quantitative assessment of the employment creation in e-waste collection and recycling. This attempt was also complicated by the fact that most e-waste collectors and recyclers do not solely address e-waste, but work in parallel on various metal-containing waste types. This means that the collectors do not consider themselves as ‘e-waste workers’, but as ‘scrap metal workers’ instead. Therefore, it is almost impossible to count or estimate the number of persons that either solely or amongst other materials collect and recycle e-waste. Nevertheless, the Scrap Metal Dealers Association claims to have 5,000 members in Lagos. Here it is important to note, that scrap metal dealers are often not directly engaged in collection and recycling operations themselves but act as a link between the collectors and recyclers on the one side and volume markets or refineries on the other. Generally, it can be assumed that there are by far more informal collectors and recyclers than dealers. Therefore, it can be assumed that – despite all uncertainties – there are several thousands of informal scrap metal collectors and recyclers operating in Lagos that work partly or solely with e-waste.

The refurbishing sector in Lagos is organised in the framework of the major markets as described in chapter 3.2. Altogether, these markets feature about 6,000 repair and sale businesses. In addition, there are an estimated number of 2,000 shops distributed across the city of Lagos that also repair and sell used electrical and electronic equipment. The interview campaign revealed that on average 2.7 people work in one refurbishing enterprise, in other words, that the estimated total number of people working in the refurbishing of used and obsolete electrical and electronic products in Lagos is 21,600. 35% or 7,500 of these workers are apprentices. Considering the duration of the apprenticeship that normally takes between 2 and 5 years (average 3.5 years), this means that every year more than 2,000 youths complete their professional training in this sector.

4.3.3 Contribution to the national economy

Due to the informal nature of vast parts of the refurbishing and e-waste recycling sector in Nigeria, this contribution is not reflected in the national GDP[13].

Nevertheless, the collected data allow an estimation of the Lagos refurbishing sector's contribution to the national economy. As calculated in Table 4, the sector generates US$ 50.8 million per year, which is equivalent to 0.015% of Nigeria's GDP.

Due to insufficient data, the contribution of e-waste collection and recycling could not be quantified.

Table 4 The refurbishing sector's contribution to the national economy *(Source: Own calculations)*

	Number in Lagos	Average monthly income [Naira]	Total annual income [million Naira]	Total annual income [million US$]
Workshop owners	8000	65,000	6240	41.9
Employees	6040	12,500	906	6.1
Apprentices	7560	4,500	408	2.7
Total			**7554**	**50.8**

4.3.4 Contribution to the national budget

Most shops and workshops located in the major refurbishing clusters are subject to various types of taxes to be paid to the local government and to Lagos State Government. These taxes include company tax, income tax and a fee for trade permits. Depending on the company size, these taxes range from 100 Naira to 8,700 Naira (US$ 0.67 - 58) per month, with an average value of 650 Naira (US$ 4.37). Taking into account the size of the refurbishing sector in Lagos, this means that the annual tax generation can be estimated at 62 Million Naira (US$ 419,000).

In contrast, most collectors and recyclers do not pay any form of tax or fee at all. This is due to the vastly informal nature of the sector and the fact that most collection and small scale recycling activities do not depend on a permanent installation or workshop, which would have to be registered with the local administration. Nevertheless, recyclers that work in a

[13] GDP of Nigeria – US$ 339 billion (estimated in 2009) (CIA 2010)

permanent location in one of the scrap markets (see chapter 3.3) usually do pay taxes to the local government in the same range as the refurbishing workshops in the second-hand markets.

4.3.5 Impacts on conflicts

It is well known that a rapid increase in demand for raw materials used in electronic products gives rise to conflicts over resources worldwide (Manhart 2009; Manhart 2007). The e-waste recycling industry could actually play an important role in reducing such risks of conflict, i.e. the higher the recovery rate of metals in e-waste, the lower the pressure on primary mining sites, such as those of gold, palladium, cobalt and tin. Here, it is noteworthy that the current recycling practices and technologies in Lagos are not optimised in terms of resource recovery rates and fall significantly below its full potential (see chapter 5.1).

On a local level, the activities within and around refurbishing and recycling centres sometimes give rise to disputes over the use of the property or the activities' impacts on the neighbouring communities. As an example, communities around the Olusosun Dump Site recently complained about the rising number of waste pickers and recyclers living on the dump site and using the public facilities of the nearby quarters (The Nation 2010). As a result, the presence of informal collectors and recyclers on the dump site was regulated by the Lagos Waste Management Authority (LAWMA) in order to prevent people from sleeping on the dump site (P.M. News Nigeria 2010).

Furthermore, there is an ongoing debate on the use of land currently occupied by Ikeja Computer Village. As the Ikeja Computer Market is located in a residential area, the rapid expansion of the market also had side effects on the local population and other businesses. Amongst others, the burning of wastes – including plastics from electric and electronic devices – by refurbishers and recyclers offended many local citizens that partly called for a relocation of the market. As a response, the local authorities banned all burning practices in and around Ikeja Computer Village. Now, a large portion of the waste generated in Ikeja Computer Village is collected in central places and daily picked up by the Lagos Waste Management Authority (LAWMA). Nevertheless, dispute still continues, as collectors and recyclers continue to use sections of the markets for their operations.

5 Analysis of present and best applicable recycling technologies

The results of the socio-economic assessment show that the currently practiced form of e-waste collection and recycling in Lagos has both, severe negative impacts such as health impacts on workers and neighbouring communities, as well as positive impacts in terms of employment creation and significant contribution to the national economy. This differentiated picture of the current situation leads to the conclusion that a ban on the current practices – without offering alternative employment opportunities – would have severe unintended side-effects, especially on the people and communities that today make their living from this waste stream. Furthermore, some of the root causes of the problem, the domestic generation of e-waste in Nigeria and the demand for affordable second-hand equipment, would remain unchanged by a ban of certain recycling practices[14]. A ban would therefore not entirely solve the problem but would only lead to a shift thereof.

For this reason, this section looks into feasible ways to upgrade the currently practiced e-waste recycling in Nigeria with a view to reduce environmental impacts, to maintain and generate employment opportunities and to improve social standards within this sector.

5.1 Recycling of desktop computers[15]

5.1.1 Relevance for Nigeria

Desktop computers are widely used in West African countries. In contrast to notebooks, desktops are affordable at moderate prices. Used desktops are sold at prices ranging from US$ 35 per device for a basic set-up to US$ 100 for a desktop with a more modern processor like Pentium IV.

The end-of-life management of desktop computers is of high importance as they contain a broad variety of hazardous substances such as heavy metals and persistent organic pollutant. The EU-Directive 2002/95 on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) led to a reduction of the use of cadmium, lead, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) in devices produced for the European market after June 2006. Nevertheless, electronic equipment like computers still contains various other hazardous substances that have not been addressed by this legislation (Groß et al. 2008).

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[14] Another root cause, the import of obsolete equipments not suitable for reuse, must be considered additionally. In contrast to the other root-causes, there is a broad consensus that such imports require strong regulative action such as a complete ban of all e-waste imports.

[15] In this study, the term "desktop computer" is used for the computing device only and does not include monitors or peripherals such as computer mouse or keyboards.

With regard to the desktop computers sold on the Nigerian second-hand markets, it is estimated that the majority of devices was produced before 1st July 2006, i.e. the implementation date of the RoHS-Directive. This assumption is supported by material tests on used computers in 2009. The test findings revealed that lead levels in printed wiring boards exceed the European RoHS threshold by the factor of 90 (Osibanjo 2009).

Hazardous substances are mostly contained in printed wiring boards, electronic components and plastic parts. Generally, all plastics used in computers contain flame retardants, with mostly hazardous characteristics. Additionally, the PVC of cables becomes a substance of concern when the cables are heated or burned (formation of dioxins).

Other electronic devices like DVD-players, hi-fi- and stereo-systems and set-top-boxes feature similar material compositions so that solutions for desktop PCs can also be applied to these product groups.

5.1.2 Presently applied recycling technologies

The presently applied recycling technologies in Nigeria include the following steps:

- Collection by formal and informal waste collectors;
- Removal of functioning components for re-use (cables, memories, drives…);
- Manual dismantling to extract steel, aluminium, copper and printed circuit boards, and open incineration of cables and components to recover copper;
- Disposal of residues.

Additionally, fire is sometimes used to reduce the waste volumes on both controlled and uncontrolled dump sites.

The recovered metals are either sold to traders or directly to refinery units like the steel plant operated by Universal Steel in Ogba, Lagos, or the steel plants located on the road to Ojigo-Sagamu in Ogun-State (e.g. Phoenix Steel, African Foundry). While there are several aluminium remelters and electric steel plants, there is no copper refinery in Nigeria. Therefore, copper is exported to foreign copper plants. One prominent copper export route leads across the Nigerian-Benin border to Cotonou, where copper is shipped out of West Africa in large quantities. Agents of foreign traders visit scrap markets and recycling sites on a regular basis to purchase high-grade printed circuit boards such as motherboards or printed circuit boards from drives. These high-grade boards are locally called “green panel”, as they are commonly distinguished from low and medium grade boards on the bases of their green colour. Apparently, most traders export high-grade printed circuit boards to Asian destinations. Nevertheless, one trader was identified who exports printed circuit boards from Lagos to Germany.

Although plastics is usually disposed of or incinerated, there is one local company called Monaplex that occasionally accepts thermoplastics from e-waste in order to manufacture spare parts for cars.

Picture 10 Cable burning close to Ojota Scrap Market

5.1.3 Best applicable recycling technologies

For an environmentally sound recycling, waste desktop computers, at first, have to be collected from private households and businesses. Subsequently, they have to be dismantled and sorted according to their main fractions (pre-processing). Thereby, emphasis must be laid on the management of all fractions contained in desktop computers, as a pure focus on individual fractions would lead to an uncontrolled accumulation of hazardous material.

The output fractions then have to be passed on to refineries that are able to recover the materials at high quality and at high environmental standards (end-processing). Fractions that are not suitable for material recovery have to be managed in an environmentally sound manner.

Collection

The collection of obsolete electronics is a key aspect of an e-waste recycling system, as the collection mechanism determines the amount of e-waste channelled towards recycling and the amount that is lost in the process of storage and/or uncontrolled disposal.

Generally, there are various possible ways of organising collection systems: In many European countries, e-waste collection is organised in municipal collection points, where consumers are obliged to hand in their obsolete devices. Although the collection points can ensure a proper sorting of devices, these systems are strongly dependent on public awareness as the efforts for the transport to the collection point have to be made by the consumers themselves. This generally results in imperfect collection rates because many consumers rather avoid the effort of making a trip to the collection point and opt for more convenient ways of getting rid of their old devices. In the case of small and medium sized e-waste, this circumstance leads to quite low collection rates in Europe (Darby & Obara 2004; Huisman et al. 2007).

In contrast, e-waste collection in many developing countries and emerging economies is organised 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 together with other, mostly metals-containing waste fractions. In Lagos, collectors pay around 100 to 300 Naira (US$ 0.67 – US$ 2.0) for one obsolete desktop computer. In terms of collection rates, these collection systems are estimated to be far more efficient than centralised bring systems. 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.

Pre-processing

There is a wide range of different pre-processing technologies available, from shredding, crushing and various types of mechanical sorting to purely manual operations. Generally, these different types of pre-processing technologies can be classified into two major groups:

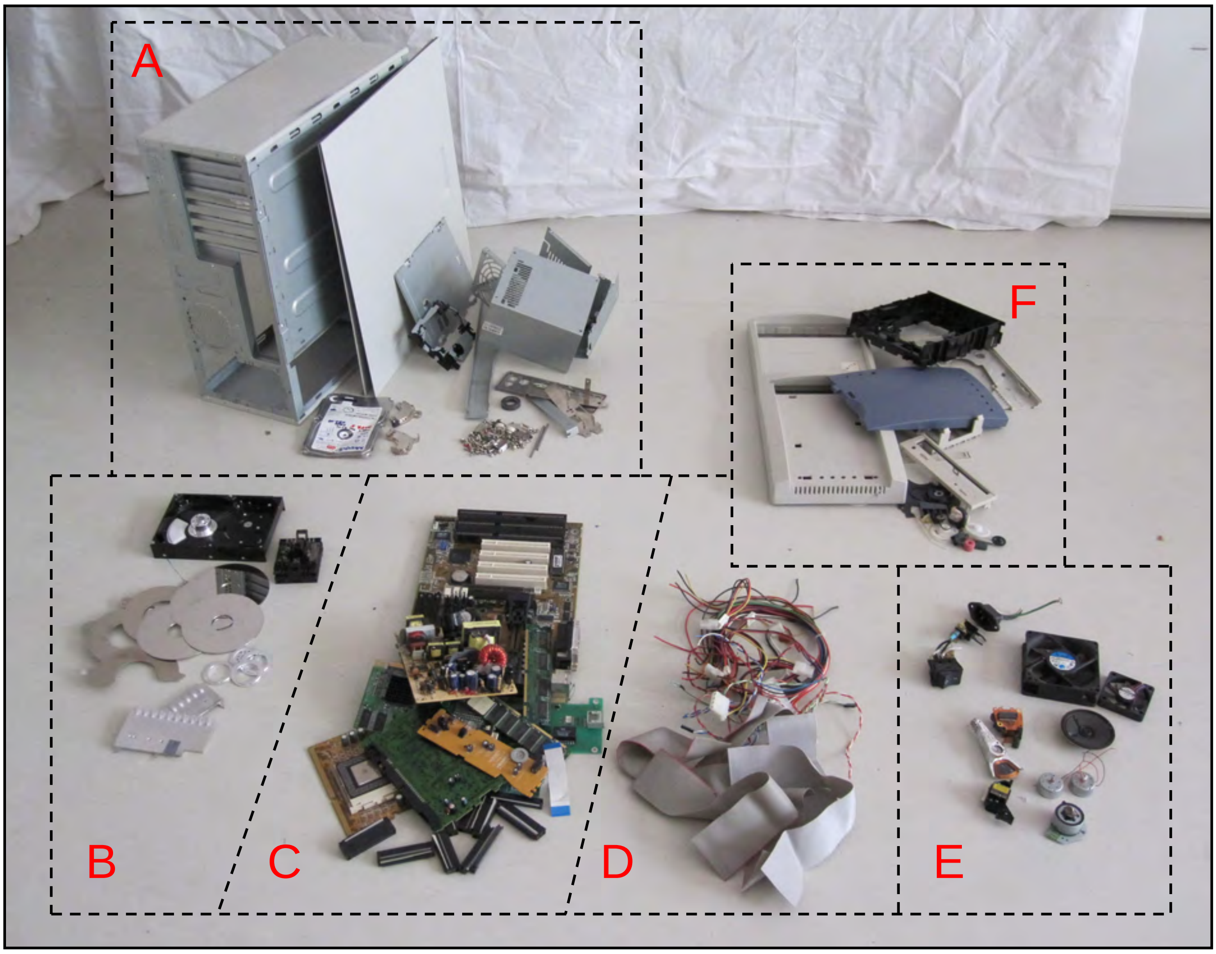
- mechanical shredding and sorting,
- manual dismantling and sorting.

There is a broad consensus that manual pre-processing has clear benefits in terms of material recovery if compared to mechanical pre-processing. One key problem of mechanical pre-processing is the fact that shredding and sorting does not achieve perfectly pure output fractions: As many e-waste fractions consist of various closely interwoven materials, mechanical shredding cannot liberate each material out of all its interconnections. In the subsequent sorting processes, this will inevitably lead to losses of certain materials ending-up in other output streams. Furthermore, each sorting technique relies on some distinct physical properties (e.g. density, magnetism, electric conductivity), which in reality are also influenced by other factors such as particle size and cohesion to other particles. So even with fully liberated input material, some particles will end up in the wrong output stream. Although these problems could partly be reduced by technical improvements, to some extent, resource losses are inevitable with these technologies (Hagelüken 2006). For precious metals, these losses are estimated at roughly 20%–58% (Hagelüken et al. 2005, Salhofer & Spitzbart 2009). As manual pre-processing technologies achieve output fractions of much higher quality, losses in the subsequent refinery processes can be minimised. Nevertheless, the depth of the manual dismantling is still of high importance for the total system yield: Salhofer & Spitzbart (2009) proved that dismantling of desktop computers down to the level of subcomponents such as the printed wiring boards of hard drives, power supplies, floppy and CD/DVD-drives achieves highest recovery rates.

Generally, it strongly depends on the socio-economic conditions whether manual pre-treatment is economically preferable to mechanical pre-treatment. Salhofer & Spitzbart (2009) conclude that – despite lower material recovery rates – mechanical pre-treatment operations are mostly economically preferable to manual pre-treatment under Central European conditions. Nevertheless, in regions with lower wage levels like China, it was proved that even in times of lower resource prices as in 2003, manual pre-treatment is clearly preferable from both an environmental and economic perspective (Gmünder 2007). Additionally, manual dismantling and sorting operations require only very low investment costs for simple tools and can be carried out by unskilled personnel. Compared to mechanical pre-treatment, manual pre-treatment is significantly more labour-intensive.

The output of the manual pre-processing operations encompasses the following fractions:

- steel scrap (cases, structural elements, screws…),
- aluminium scrap (heat sinks, structural components of drives, hard disks…),
- high-grade precious metals fraction (PWBs, contacts),
- copper cables,
- low-grade copper fraction (motors, drive readers, speakers …),
- plastics (cases, structural elements…).



A = Steel scrap ***B = Aluminium scrap*** ***C = High-grade precious metals fraction***
D = Copper cables ***E = Low-grade copper fraction*** ***F = Plastic fraction***

Picture 11 Manually dismantled and sorted desktop PC

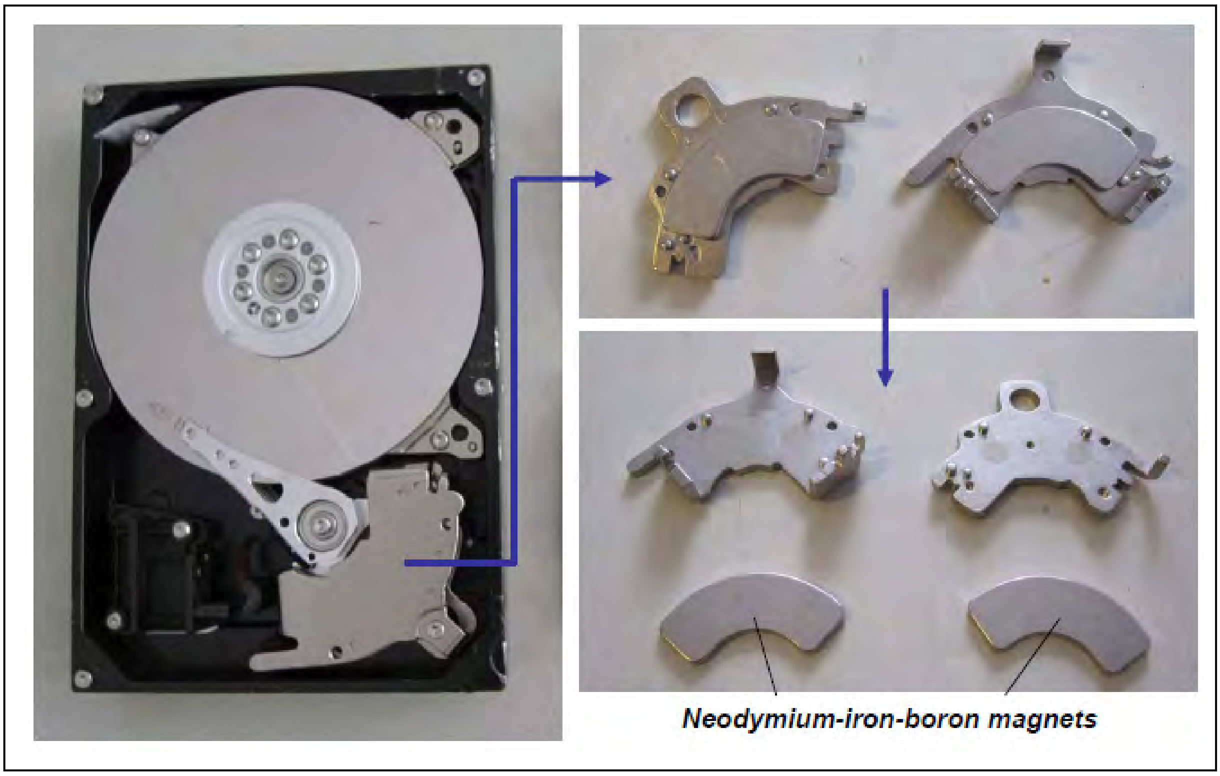
Nevertheless, even with intensive manual dismantling, some copper and precious metals-containing components like cables, small motors and reading/writing devices of drives need further pre-treatment. Although even these steps could be carried out manually, the economic output might not justify the high labour intensity. Therefore, this residual fraction could be passed on to mechanical pre-treatment facilities. Thereby it is of particular importance to identify alternative local treatment options for cables in order to eliminate the common practice of cable burning (see Picture 10). Generally, copper cables can either be stripped manually using knives and bench vices (to fix the cables), or automatically using a cable shredder or cable granulator. Both options have distinct strengths and weaknesses, which can be summarised as follows:

- Manual cable stripping is only suitable for thick cables. With thin cables, it is quite difficult to liberate all copper strings from the insulation.
- Manual stripping is very labour-intensive. As scrap yard workers in Lagos are used to the practice of burning, it might be difficult to convince them to deploy significantly more labour for comparable copper outputs.
- Automatic shredder and sorting machinery is capital-intensive and requires investments costs in a range of US$ 25,000 to 100,000 – depending on size and capacity of the installation[16]. Additionally, the machinery needs electricity (usually 400V at 50Hz) as power demands are in a range of 3 to 100kW.
- Unsound operation of shredders can lead to dust emissions and dioxin formation. This is especially the case, when the machinery runs hot.
- Both, manual cable stripping and mechanical shredding entail copper losses into the plastic fraction. This might require a subsequent sorting of the plastic fraction in a saltwater-bath (plastic floats, while copper sinks).

Taking these issues into account, it can be concluded that despite some disadvantages mechanical cable shredders should be deployed to provide alternatives to the common burning practice.

In addition to fractions listed above, it should be considered to collect the magnets contained in the hard disk drives separately, as they contain quite significant concentrations of neodymium (see Picture 12).

[16] Cable shredders / granulators are usually available with capacities ranging from 50kg/hr to 1000kg/hr.



Picture 12 Neodymium-iron-boron magnets of hard drives

Neodymium is a rare earth element that is needed for very strong neodymium-iron-boron magnets (NIB-magnets). These magnets are not only used in hard disk drives, but are increasingly utilised to build high-efficient wind power generators and motors for electric mobility (Angerer et al. 2009). As the demand for these two applications is rapidly increasing, the demand and price for neodymium is increasing, too. As the supply of primary neodymium comes to more than 95% from China (Angerer et al. 2009; Buchert et al. 2009), other countries fear scarcities, as neodymium is increasingly seen as a high-tech-metal which is vital for the development of so-called green technologies such as wind power and electric mobility (Schüler et. al 2011).

Although neodymium recycling is currently not carried out on an industrial scale[17], price development and projections[18] suggest that neodymium recycling will soon become attractive. As manual pre-treatment is currently the only feasible way to produce high quality

[17] This is mostly due to the lack of availability of high-quality neodymium scrap. Here, the key problem is the mechanical separation of neodymium magnets from the steel fraction. Because of its properties, neodymium magnets are strongly attached to steel parts and cannot be separated by mechanical pre-processing technologies. Therefore, with mechanical pre-treatment, neodymium goes entirely into the steel-fraction, where it is dissipated and lost for any further recovery.

[18] Projections suggest an increase in demand from 4,000 metric tonnes in 2006 to 28,000 tonnes in 2030 (Angerer et al. 2009).

neodymium-scrap, Nigerian recyclers could engage in this future niche market. However, it should be considered that there is not really a market for produced neodymium-scrap yet, so that benefits might only pay off in the future, once neodymium-recycling is further developed.

End-processing

The output fractions of the manual pre-treatment are passed on to end-processing operations. Ideally, such end-processing operations are able to combine efficient material recovery with high environmental standards.

The steel scrap is processed in electric arc furnaces that produce secondary steel products. There are various electric arc furnaces operating in and around Lagos region. Amongst others, Universal Steel maintains a furnace in Ogba, Lagos. In Ogun State, just outside the city of Lagos, there are several steel plants (e.g. Phoenix Steel, African Foundry) that source scrap steel from all over Lagos.

The aluminium scrap is passed on to aluminium remelters such as Tower Aluminium in Lagos. Additionally, there are various small remelters that use aluminium from various sources to produce local products such as pots.

The high-grade precious metals fraction can be sold to two major types of end-processing enterprises: Pyrometallurgical and hydrometallurgical refineries. Thereby it has to be noted that pyrometallurgical refineries target a wide range of metals, while hydrometallurgical refineries exclusively focus on precious metals.

In terms of recovery rates of precious metals, pyrometallurgical refineries are preferable to hydrometallurgical refineries as the melting process affects all input materials, while the hydrometallurgical treatment only affects the surface layer of the feed material. Although the PWBs can be grinded to particle sizes that allow quite comprehensive treatment, these physical size reduction processes are also likely to generate precious metals losses. Additionally, interactions of chemicals also reduce the effectiveness of metal recovery (Schluep et al. 2009). From an environmental perspective, there is an ongoing debate on the sustainability of hydrometallurgical refineries: While some authors argue that they provide a low-cost solution for emerging economies (Cui & Zhang 2008), others stress the fact that hydrometallurgical processes have not yet published comprehensive flow sheets, and that the types of processes – using strong acids or caustic solutions – are associated with considerable risks for human and environmental health. A comprehensive overview on the critical issues of hydrometallurgical refineries is presented in Schluep et al. 2009.

The copper from cables and the low-grade copper fraction can be sold to secondary copper refineries. The low-grade copper fraction is especially attractive for secondary copper-steel smelters with a focus on processing mixed steel-copper scrap. Generally, it is beneficial to remove larger plastic parts to increase the fraction's purity.

The plastic fraction is mostly composed of ABS and Polycarbonates used for cases and structural components. Furthermore, thermosets like epoxy resin are used for PWBs and in coatings and housings of electronic components, switches and motors. PVC is used for cable insulations. All these plastic types have in common that they are permeated with flame retardants. Especially those plastic parts that – during the use-phase of the products – are exposed to heat usually feature high concentrations of flame retardants.

Generally, the thermosets from PWBs and electronic components are strongly interlinked with the copper and precious metals fraction and are used as fuel and reducing agent in the metal refining process. The thermoplastics (ABS and Polycarbonates) can theoretically be recycled into new products. Nevertheless, the contamination with flame retardants significantly reduces the options for secondary applications as these constituents, applying the established recycling methods, will be part of the new products. For consumer safety reasons, this is unacceptable for many applications. Furthermore, the secondary use of these materials will only postpone the end-of-life problem associated with hazardous flame retardants and might lead to the problem of cross-contamination. Especially if used in a wide range of applications, the subsequent situation of broadly dispersed flame retardants might be even worse than today, where plastics with flame retardants can easily be identified on the basis of their original function. Even secondary applications in new electric and electronic devices turned out to be largely infeasible, as the majority of new products are designed to comply with the European RoHS-Directive which is strongly limiting the use of the flame retardants PBB and PBDE. Although ongoing research projects aim to identify ways to depolymerise and clean thermoplastics from e-waste (Arends 2009), these techniques are not yet applicable on an industrial scale. Therefore, one option for the management of plastics from waste computers is energy recovery in power plants or cement kilns with sophisticated off-gas treatment. There are currently two cement kilns operating in and around Lagos, which are both operated by Lafarge. Alternatively, plastics could also be disposed off in engineered landfills for hazardous waste.

Interim conclusion

In the Nigerian context, the best applicable recycling technologies for desktop computers can be sketched as follows:

- House-to-house collection of e-waste;
- Manual pre-treatment, including manual dismantling up to the level of parts of sub-components;
- Manual extraction and storage of neodymium magnets (wait for future markets);
- Mechanical shredding or granulation of cables;
- Further manual pre-treatment of low-grade copper fraction to reduce plastic content;
- Refinery of steel and aluminium fraction in domestic plants;

- Refinery of high-grade precious metals fraction in pyrometallurgical refineries abroad;
- Refinery of copper and low-grade copper fraction in copper or steel-copper refineries abroad;
- Controlled incineration / energy recovery of remaining plastic fraction in cement kilns.

5.1.4 Economic incentives for environmentally sound recycling

The intrinsic material value of desktop computers is mainly based on two major groups of metals: The bulk metals copper, steel and aluminium and the precious metals represented by gold, silver and palladium (see Table 5).

Table 5 Material content, intrinsic and net values of an average desktop computer (without monitor and peripherals) at 2007 resource prices *(Sources: Gmünder 2007; USGS 2009a, b; CSR 2009; MP 2010)*

	Amount contained in a desktop computer [g/unit]	**Average material price 2007 [US$/t]**	**Intrinsic material value 2007 [US$/unit]**	**Estimated recovery rates with presently applied technology**	**Estimated recovery rates with best applicable technology**	**Net material value with presently applied technology [US$/unit]**	**Net material value with best applicable technology [US$/unit]**
Steel	6,737.50	253*	1.70	95%	95%	1.62	1.62
Plastics	1,579.55	310**	0.49	0%	0%	0	0
Aluminium	550.21	2,700	1.49	88%	78%	1.31	1.16
Copper	413.225	7,231	2.99	85%	98%	2.54	2.93
Zinc	25.94	3,400	0.09	0%***	0%***	0	0
Tin	19.57	19,800	0.39	0%	0%***	0	0
Antimony	18.58	5,660	0.11	0%	0%***	0	0
Nickel	12.70	37,200	0.47	0%***	0%***	0	0
Lead	6.59	2,730	0.02	0%	0%***	0	0
Neodymium	5.87	100,000****	0.59****	0%***	75%*****	0	0.44*****
Silver	1.70	550,000	0.94	0%	87%	0	0.81
Gold	0.26	22,400,000	5.82	30%	93%	1.75	5.42
Palladium	0.12	11,488,748	1.38	0%	91%	0	1.25
Chromium	0.02	2,010	0.00	0%***	0%***	0	0
Ceramics & others	366.04	-	-	-	-	-	-
Sum	**9737.87**		**15.88**			**7.22**	**13.63**

** Prices for iron & steel scrap ** Prices for mixed plastic *** Partly indirectly recovered together with other metals*

***** Material price as of November 2010 ***** Recovery rates not yet achieved on an industrial scale*

With the described best applicable recycling technologies (see section 5.1.3), up to 95% of steel and 88% of aluminium can be recovered. These figures are based on the assumption that thorough manual disassembling and sorting is a process able to recover 95% of the steel and 98% of aluminium of massive components like cases, frames and large heat sinks. As for printed wiring boards, it is estimated that only large aluminium parts (heat sinks) are removed prior to refining. Unlike in the presently applied recycling, smaller aluminium parts are not removed in order not to damage IC-components and to prevent precious metals losses. As aluminium is not recovered in the subsequent copper and precious metals refining processes, this leads to approximately 10% aluminium losses[19] (calculated with data from Gmünder 2007 and Salhofer & Spitzbart 2009).

Copper is used in cables, coils, contacts, motors (motors of fans, CD/DVD-drives and hard drives) and printed wiring boards. It is assumed that manual pre-treatment operations can recover 100% of the copper contained in cables. The copper contained in printed wiring boards and contacts is treated in high-tech refineries which can recover 100% of the copper contained in the input material. Copper contained in components like motors can only partly be recovered as these components need to undergo mechanical pre-processing which inevitable leads to some material losses. Therefore, the net recovery rate is estimated to be 98%.

Palladium, gold and silver are concentrated in printed wiring boards (motherboards, graphic cards, sound cards, modem cards and the boards of drives and power supply…) and contacts. Currently, these fractions are partly shipped to Asian destinations, presumably for hydrometallurgical recovery of gold. The efficiency of such gold recovery operations has been estimated to be between 6% and 30% (Keller 2006). Alternatively, these fractions can be fed into high-tech metallurgical refineries with recovery rates of 92% and more. Minor concentrations of precious metals can also be found in motors, hard discs and reading/writing devices. Prior to refining, these fractions, however, need further mechanical pre-treatment and sorting. In the course of these operations, losses of precious metals occur. Therefore, the total recovery rate for silver, gold and palladium with 87%, 93% and 91% respectively are somehow lower (calculated with data from Salhofer & Spitzbart 2009 and Umicore 2009).

The recovery rates of zinc, tin, antimony, nickel, lead and chromium are difficult to determine. While tin and lead are mainly used in solders, antimony is used as a flame retardant in plastic parts. Zinc, nickel and chromium are used in alloys. The tin, antimony, nickel and lead contained in PWBs are recovered as by-products in integrated smelters. The zinc, nickel and chromium of alloys are recovered together with the scrap aluminium, steel and copper to generate new products.

Currently, 100% of neodymium is indirectly recovered with steel. Nevertheless, this type of recovery constitutes a dissipative loss of neodymium, which is frequently regarded as

[19] The motherboard and the printed wiring boards of the drives and the power supply contain 40% of the aluminium in a desktop computer. It is estimated that removable heat sinks make up 50% of this aluminium fraction.

strategically important resource for green technologies such as electric mobility and wind power generation. Although neodymium recycling is still in its infancy, it is expected that recovery rates could be as high as 75% (Takeda et al. 2006). Here, it is important to highlight, that there is currently no established market for neodymium scrap. Recyclers engaging in this field have to build international networks with specialised enterprises, and might even have to wait until the market for secondary neodymium is gaining momentum.

The comparison between the net material values of the presently applied recycling technologies and the best applicable recycling technologies shows that revenue from recycling of one desktop computer could be increased from US$ 7.22 to 13.63. Nevertheless, these figures have only indicative character, as resource prices are in constant change. Furthermore, it has to be kept in mind that these revenues cannot be made by one individual recycler, but can only be achieved by a complex and well-organised recycling chain that includes precious metals refineries in Europe, Canada or Japan. Additionally, the figures only represent the potential sales revenues, not taking into account labour and transport costs, logistics, taxes and investment costs.

5.1.5 Environmental benefits

The proposed recycling system for desktop computers has significant advantages over the status quo in terms of management of hazardous substances. First of all, the precious metals-containing fraction (PWBs and contacts) would be treated in state-of-the-art smelters located in Europe, Japan or Canada, the proposed recycling system thus leading to an export flow of a waste fraction featuring high concentrations of heavy metals and organic pollutants (Hagelüken 2006). Furthermore, these smelters are all equipped with sophisticated off-gas treatment, so that also the net emissions of hazardous substances like dioxins would be significantly minimised.

Secondly, the proposed system would provide significant potentials in terms of resource efficiency. As indicated in section 5.1.4, the recovery rates of gold would rise from 30% to 93% and for silver and palladium to 87% and 91% respectively. Although these increases in efficiency would have slightly negative impacts on the recovery rate for aluminium, the net efficiency would be clearly beneficial. From an environmental perspective, this is of high importance, as the secondary production of metals has significantly less environmental impacts than the primary production (see Table 6). With optimised recovery rates of silver, gold and palladium, a total of 5.23 kg CO_2e could be saved per desktop computer if compared to the same amount of metals in primary mining.

Table 6 Energy demand and greenhouse gas emissions of primary and secondary metal production for one desktop computer (without monitor and peripherals) *(Source: Calculated with data from EcoInvent 2009 and Gmünder 2007)*

	Fe (steel)	Al	Cu	Ag	Au	Pd
Primary production						
CED [MJ/kg]	29.63	187.26	54.49	1,641.56	298,128.96	166,642.02
GWP [kg CO_2e/kg]	2.04	10.20	2.81	112.14	17,879.75	9,284.30
Secondary production						
CED [MJ/kg]	8.33	22.79	0.84*	119.31*	6,964.43*	3,647.91*
GWP [kg CO_2e/kg]	0.40	1.32	0.10*	14.31*	835.40*	437.57*
Amount per device [g]	6,737.50	550.21	413.23	1.70	0.26	0.12
Recovery potential [%]	95	78	98	87	93	91
Environmental impacts of secondary production from the recycling outputs of 1 desktop computer						
CED [MJ]	53.34	9.78	0.34	0.18	1.68	0.40
GWP [kg CO_2e]	2.54	0.57	0.04	0.02	0.20	0.05
Environmental impacts of primary production of the same amount of materials as from recycling of 1 desktop computer						
CED [MJ]	189.62	80.37	22.06	2.43	72.09	18.20
GWP [kg CO_2e]	13.07	4.38	1.14	0.17	4.32	1.01
Saving potential through recycling of 1 desktop computer [absolute]						
CED [MJ]	136.28	70.59	21.73	2.25	70.40	17.80
GWP [kg CO_2e]	10.53	3.81	1.10	0.14	4.12	0.97
Saving potential through recycling of 1 desktop computer [%]						
CED [%]	72	88	98	93	98	98
GWP [%]	81	87	96	87	95	95

CED = Cumulative Energy Demand, GWP = Global Warming Potential

** Secondary production from electronic and electric scrap recycling in pyrometallurgical refinery.*

Thirdly, the mechanical pre-processing of cables would significantly reduce the emissions of persistent organic pollutants as it would offer an alternative to the current practice of cable burning.

5.1.6 Health and safety issues and labour intensity

Although desktop computers contain quite a variety of hazardous substances, none of these substances is present in liquid or gas form. This circumstance makes the proper transport and pre-processing of waste desktop computers quite manageable compared to other e-waste types. The most important aspect to avoid human and environmental contamination is to minimise the generation of dust and to evade unsound management practices such as uncontrolled melting or burning operations. As the proposed recycling system primarily foresees manual collection and pre-treatment, but no melting or burning operations, the health and safety risks are manageable. Varin & Roinat (2008) provide a good overview on the recommended health and safety measures of manual pre-processing operations. The following paragraph is therefore entirely copied from this work:

> *"Even though manual dismantling operations generate few contaminants likely to be absorbed by the respiratory route, dismantling technicians are advised to wear masks. Contamination happens mostly indirectly, by ingestion of contaminants present on hands and cloths. Employees must therefore respect the following minimum safety instructions:*
>
> - *Wear protection suits, or regularly clean these suits by washing separately;*
> - *Do not eat, drink or smoke in the workshops;*
> - *Wash hands before meals and snacks;*
> - *Avoid nail biting and brush one's nails regularly;*
> - *Vacuum the premises to avoid dust accumulation."*

In addition, the mechanical pre-processing of cables requires special health and safety training to avoid injuries during operation. Furthermore, workers have to be trained to keep the machinery in an operation mode that prevents the emission of dust and the formation of dioxins.

If neodymium magnets are recovered and collected separately, the magnets should be heated to above 300°C for demagnetisation. Otherwise, there is a certain danger of injury due to the magnets' attractive force.

In terms of labour intensity, the proposed manual pre-processing is quite labour-intensive. The time requirements for workers have been measured by Gmünder (2007) in China and by Salhofer & Spitzbart (2009) in Germany. While in the Chinese case, 83 working hours were needed to disassemble 1 t of desktop computers,[20] the German case required 7.5 hours for the same amount. It has to be noted that in the Chinese case, however, workers used simple tools and only partly electric screwdrivers, being engaged in very intensive dismantling operations. In contrast, the German workers were equipped with electric tools throughout the operations and carried out a dismantling work, which was less intensive than that of their Chinese counterparts. Additionally, the German test used a batch of identical computers, so that workers did not face the challenge of different computer constructions, set-ups and screw types. For the Nigerian case, it is therefore more realistic to calculate with around 80 working hours per tonne or 50 minutes per device.

For the pre-processing of cables, only few workers are required to run and maintain the machinery. Nevertheless, labour intensity will increaser, if semi-automated sorting technologies such as saltwater baths are preferred to fully-automated sorting processes.

[20] 1 t of desktop computers roughly equals 100 devices.

5.1.7 Interim conclusion and possible business models

The comparison of the presently applied recycling technologies and the best applicable technologies reveals that there are significant untapped economic, environmental and social improvement potentials. These potentials can be realised by manual pre-treatment in Nigeria and by exporting the precious metals bearing fractions to one of the few pyrometallurgical refineries in Europe, Canada or Japan. As the value of the recoverable precious metals sums up to US$ 7.48 per desktop computer at 2007 resource prices, under usual conditions, these values can compensate for the costs for manual pre-treatment, logistics, transport and refinery[21].

From the type of operations needed in Nigeria, it is obvious that this business is largely independent of investments into machinery parks or infrastructure. The investment into comprehensive pre-processing machinery would, on the contrary, reduce the economic potentials of this approach and would also have negative impacts on employment creation.

Furthermore, the manual pre-processing operations can be run by medium and low-skilled workers. Therefore, the business is suitable to be implemented within the current informal recycling sector in Nigeria.

Nevertheless, the question whether the described potentials can be entirely realised in practice largely depends on the type of the business model and the links between Nigerian recyclers and large scale refineries. Therefore, different business models need to be analysed on the basis of their specific strengths and weaknesses. With regard to its feasibility, each business model must – as minimum requirements – fulfil the following functions:

- As part of the business model, it is necessary to establish and maintain contractual links between pre-processing operations in Nigeria and pyrometallurgical refineries in Europe, Canada or Japan. In addition, the business model needs at least one actor that is capable of handling administrative issues related to the transboundary shipment of e-waste. In the current situation, where e-waste recycling is dominated by unregistered informal enterprises, many local players might face severe difficulties in this regard.
- As most of the workers engaged in e-waste recycling in Nigeria have very limited financial reserves, the business model needs to ensure a steady and reliable cash flow necessary for the workforce involved. Thereby, the time lag between pre-processing of e-waste in Nigeria and the final marketing of the resources is critical. It is estimated that the time required for the collection of sufficient export volumes, the transport, the sampling and the refinery will sum up to several months. For a workforce that depends on rapid cash flow, this time span represents a severe obstacle.

[21] In the future, similar co-operations might also be feasible in the field of neodymium recycling.

- Besides paving the road for the export of certain e-waste fractions, the business model must also ensure a steady know-how transfer to the recycling sector in Nigeria. This know-how must cover issues such as information on values contained in the various e-waste fractions, the best treatment options for hazardous components, information on changing material compositions and measures to further increase the economic, environmental and social benefit of the recycling operations.

In addition, a business model that is sustainable in all dimensions, i.e. in economic, environmental and social terms, should be transparent with regard to its profit management. From a development perspective, it is, after all, very important that profits are distributed in a fair manner amongst recyclers and exporters, and that a certain share is reinvested into dismantling infrastructure, training, social security and the management of non-profitable e-waste fractions.

Based on these requirements, there are three types of possible business models:

Model 1: Indirect co-operation with one or more intermediaries

An easy way to overcome the limitations of the informal sector would be a business model that installs one or more intermediaries between the informal e-waste sector and the pyro-metallurgical refineries. Such intermediaries must be capable of fulfilling the requirements listed above. Thereby, they would act as formal link between the informal e-waste sector in Nigeria and the refining companies. Nevertheless, such a business model might be critical in situations where intermediaries have a monopoly position and can control the local prices for pre-processed e-waste. From other resource markets, it is known that many intermediaries dealing with informal sector activities use such monopoly positions to bring down prices and to maximise their own profit margins (Wagner et al. 2007). Furthermore, intermediaries are not necessarily interested in a comprehensive transfer of know-how as they themselves are not involved in e-waste pre-processing and therefore do not have to fear negative health and safety impacts themselves. Additionally, intermediaries might be tempted to focus on high-grade precious metals fractions only, while neglecting other hazardous fractions with lower intrinsic value. Although such 'cherry-picking' might be suitable in the initial phase to get the business model started, it has long-term side-effects as low-value and hazardous e-waste would further accumulate in Nigeria.

Model 2: Direct co-operation between small-scale recyclers and refineries

By establishing a direct link between small-scale recyclers in Nigeria and pyrometallurgical refineries, some of the drawbacks and risks associated with intermediaries could be avoided. Ideally, such direct links would be established on the basis of a cooperative or a community-based approach within the Nigerian e-waste sector. Such an approach should be capable of managing the formal and administrative business requirements. Moreover, it should care for a fair distribution of incomes. Nevertheless, such an approach would obviously require significant efforts to bring the e-waste sector in the position to link with international recycling partners. Amongst others, micro-finance schemes might be needed to enable basic types of upfront investments and to secure the cash flow to e-waste workers. Furthermore, the know-how transfer needs to be established and organised in a way that ensures benefits to all members of the cooperative.

Model 3: Co-operation between established scrap traders and refineries

The field survey in Lagos revealed that there are some local traders that organise the bulk trade with scrap metals from various sources including e-waste dismantling operations. These traders are registered with the local authorities, pay taxes and employ a certain number of workers. In addition, they are supplied by a network of informal collectors and recyclers. These traders have warehouses to store scrap materials and also maintain a network and logistics to export certain fractions, like copper, out of Nigeria.

These local traders could be linked to pyrometallurgical refineries and might be supported in order to increase the social and environmental performance in their operations and their supply chain. Although such a model would not directly improve the situation of small-scale collectors and recyclers, it could constitute a pragmatic implementation strategy with the advantage that no new business structure would have to be invented.

5.2 Recycling of CRT devices

5.2.1 Relevance for Nigeria

Cathode ray tubes (CRTs) are used as display screens in old TVs and computer monitors. These CRT devices are still widely used in Nigeria as they provide a cheap alternative to the modern flat screen panels. In contrast to Europe, there is still a large market for used CRTs and repair services for CRTs. Used CRT TVs are being sold for prices ranging from US$ 25 for a small device to above US$ 50 for large TV devices. Used computer monitors sell for US$ 15 to US$ 25.

The end-of-life management of CRTs is of high importance as they contain a broad variety of hazardous substances such as heavy metals and persistent organic pollutants. In addition to the flame retardants and heavy metals contained in printed wiring boards and plastics, the glass tube itself is of concern because of its high lead oxide content. Depending on the size of the CRT, the glass of one device contains between 0.5 and 4 kg of lead, which is the reasons why it is often regarded as the potentially most polluting of all electronic waste components (Nnorom et al. 2010). Barium oxide and strontium oxide are of additional concern. Although under usual conditions, the substances are bound in the glass matrix, crushing and weathering of CRT class leads to long-term emissions into soil and groundwater (ICER 2003), a process that is likely to be accelerated under tropical conditions such as in Nigeria. Additionally, the internal phosphorous coating of the front contains cadmium and other pollutants (ICER 2003). This coating is partly released as dust when CRTs are broken (see chapter 4).

5.2.2 Presently applied recycling technologies

The presently applied recycling technologies in Nigeria include the following steps:

- Collection by informal waste collectors,
- Removal of functioning components for re-use (cables, power supplies …),
- Removal of deflection and focusing coils (mostly by breaking off the neck glass),
- Manual dismantling to extract steel, aluminium and copper parts and open incineration of cables and components to recover copper,
- Uncontrolled crushing and disposal of CRT glass and residues.

The recovered metals are sold along with metal fraction of other e-waste recycling activities (see section 5.1.2).

5.2.3 Best applicable recycling technologies

Collection

The CRTs have to be collected and transported to pre-treatment operations. During transport and handling, it is important that the tubes remain undamaged to prevent emissions of the internal phosphorous coating and to ensure that all CRT glass is channelled into the proper end-of-life management.

Pre-processing

Pre-processing starts with the manual dismantling into the main components and fractions, namely steel, aluminium, printed wiring boards, cables, low-grade copper fraction, plastic fraction and glass-tube. Apart from the tube, all fractions can be managed along with those from the recycling of desktop computers (see section 5.1.3). Nevertheless, it has to be considered that TV and monitor boards have significantly lower precious metals contents than those from IT-equipment so that in their case, the costs for shipment and refinery might not be justified from an economic perspective. In order to overcome this problem, the boards can further be pre-treated by taking off steel and aluminium parts, and possibly some of the larger electronic parts like capacitors. This will relatively ‘upgrade’ the copper and precious metals content of the boards. Furthermore, the obtained steel and aluminium – which would be lost in the copper and precious metals refining process – can be sold to secondary steel and aluminium smelters.

The appropriate pre-treatment of the glass tube depends on the envisaged type of end-processing. In case the glass is recycled into new CRTs, the front glass needs to be separated from the funnel glass. This step is important as the compositions of the two types of glasses are significantly different: While the funnel glass contains an average of 13% of lead-oxide, the front glass is widely free from lead but contains 8% barium-oxide and 4% strontium-oxide (ICER 2003). The separation of the different glass types can either be done by semi-automated cutting or by automated shredder and sorting technologies. Generally, semi-automated technologies require lower investment costs and are more labour-intensive (Zumbuehl 2006). Nevertheless, it is difficult to treat large quantities of CRTs with these technologies.

If the glass is passed on to lead or copper smelters, the front and funnel glasses do not necessarily have to be separated. Nevertheless, most smelters prefer sorted CRT glass as this enables a better adjustment of the right feed-mix.

If the glass is used in the construction sector, no separation of front and funnel glass is needed. Nevertheless, high lead-oxide content might lead to long-term lead emissions which could be prevented by reducing the share of funnel glass.

In any case, the pressure in the tube needs to be equalised prior to further treatment in order to avoid implosion. This means that a small hole has to be punched into the tube to release the vacuum in a controlled manner. This hole can easily be made where the anode connection is attached to the tube. Then, the glass (separated or not) needs to be crushed and compacted. During this process, the internal phosphorous coating is partly emitted as dust, containing cadmium and other pollutants. Therefore, all crushing operations have to be carried out under a fume hood with an attached filter system to collect the dust.

The output of the pre-processing operations encompasses the following fractions:

- steel scrap (cases, structural elements, screws…),
- aluminium scrap (heat sinks, structural components of drives, hard disks…),
- precious metals fraction (PWBs),
- copper fraction (focusing and deflection coils, cables…),
- low-grade copper fraction (electronic parts, speakers…),
- plastics (cases, structural elements…),
- mixed or sorted CRT glass,
- phosphorous dust.

End-processing

All fractions, except CRT glass and phosphorous dust, can be managed together with those of desktop computer recycling (see section 5.1.3).

For CRT glass, there are various management options: The most preferable from an economic and environmental perspective is the recycling into new CRT glass (glass-to-glass recycling) (Kang & Schoenung 2005). Nevertheless, CRT production has almost come to an end, as today, the market for TVs and computer monitors is dominated by LCD and plasma technology. There is only one remaining CRT production facility in India that accepts secondary CRT glass of high quality. Nevertheless, this facility has an established supplier structure so that it is unlikely that new players will be able to enter this market.

The second established management option is the use of CRT glass in lead or copper smelters (glass-to-lead recycling). Thereby, the glass is used as flux agent and substitute for silica sand. The lead from the glass can partly be recovered in the process. The silica is moving into the slag phase. There are only few smelters that are technically designed in a way that they can process CRT glass. In 2003, there were three smelters accepting limited amounts of CRT glass in Europe. At that time, these capacities were not even sufficient to manage the end-of-life CRTs of Great Britain (ICER 2003). In the USA, there are only two smelters processing CRT glass (Kang & Schoenung 2005).

Another recycling option is mixing CRT cullet with concrete or asphalt to be used in the construction sector. This management option could be attractive for Nigeria as it could build upon existing industry structures. Nevertheless, this option still faces the problem of possible cross-contamination so that it must be proved from case to case that the hazardous substances incorporated in the building materials constitute no risk to human health and the environment.

Other recycling options encompass the production of foam glass, ceramic bodies and insulating glass fibre. Nevertheless, these applications are still in a development stage and have not yet resulted into a management option for end-of-life CRT glass (Andreola et al. 2007).

A common end-of-life management option for CRT glass is the transfer to hazardous waste disposals. The phosphorous dust also needs to be disposed as hazardous waste.

Interim conclusion

In the Nigerian context, the best applicable recycling technologies for CRTs can be sketched as follows:

- House-to-house collection of CRTs and careful handling in order not to damage the tubes;
- Manual dismantling into main fractions;
- Manual upgrading of printed wiring boards;
- Compaction of tubes under a fume hood with attached filter system;
- Refinery of steel and aluminium fraction in domestic plants;
- Refinery of precious metals fraction in pyrometallurgical refineries abroad;
- Refinery of copper fraction in copper refineries abroad;
- Controlled incineration / energy recovery of remaining plastic fraction in cement kilns;
- Careful use of glass culets in construction sector or disposal as hazardous waste;

- Disposal of phosphorous dust as hazardous waste.

5.2.4 Economic incentives for environmentally sound recycling

The main value carrier of CRTs is copper, which makes up more than 60% of the total intrinsic value (see Table 7). The majority of this copper is used for the focusing and deflection coils (see Picture 13). Therefore, these components are highly attractive for recyclers.

Picture 13 Focusing and deflecting coils of manually dismantled CRTs *(Source: Öko-Institut 2010)*

Table 7 Material content, intrinsic and net values of an average CRT TV at 2007 resource prices *(Sources: Eugster et al. 2007; Hagelücken 2006; USGS 2009a, b; CSR 2009)*

	Amount contained in a CRT TV [g/unit]	**Average material price 2007 [US$/t]**	**Intrinsic material value 2007 [US$/unit]**	**Estimated recovery rates with presently applied technology**	**Estimated recovery rates with best applicable technology**	**Net material value with presently applied technology [US$/unit]**	**Net material value with best applicable technology [US$/unit]**
Glass	17,043	0	0	0%	0%	0	0
Plastics	6,880	310**	2.13	0%	0%	0	0
Steel	2,990	253	0.76	95%	95%	0.72	0.72
Copper	900	7,231	6.51	85%	98%	5.53	6.38
Aluminium	598	2,700	1.61	88%	88%	1.42	1.42
Tin	31	19,800	0.62	0%	0%***	0	0
Lead	22*	2,730	0.06	0%	0%***	0	0
Nickel	6.7	37,200	0.25	0%***	0%***	0	0
Silver	0.62	550,000	0.34	0%	87%	0	0.30
Gold	0.04	22,400,000	0.85	0%	93%	0	0.79
Palladium	0.02	11,488,748	0.26	0%	91%	0	0.23
Ceramics & others	1,434	-	-	-	-	-	-
Sum	**29,900**		**13.38**			**7.67**	**9.84**

** Only lead contained in the TV-board ** Prices for mixed plastic *** Partly indirectly recovered together with other metals*

With thorough manual disassembling and sorting it is estimated that 95% of steel, 88% of aluminium and 85% of copper can be recovered. The copper recovery rate can be increased by refining the printed wiring boards in integrated smelters.

Palladium, gold and silver are concentrated in printed wiring boards and contacts. It is estimated that the recovery rate is equivalent to those of desktop computers (see section 5.1.4).

The recovery rates of tin, lead and nickel are difficult to determine. While tin and lead are mainly used in solders, nickel is used in alloys. The tin and lead contained in PWBs are recovered as by-products in integrated smelters. The nickel of alloys is recovered together with the scrap aluminium, steel and copper to generate new products.

The comparison between the net material values of the presently applied recycling technologies and the best applicable recycling technologies shows that revenue from recycling of one CRT TV could be increased from US$ 7.67 to 9.84. Nevertheless, this calculation does not include the costs for environmentally sound management of the CRT glass and the disposal of the internal phosphorous coating. As sketched in section 5.2.3, there is an oversupply of CRT glass, leading to a situation where providers of the glass have to pay for its environmentally sound end-processing. In the first half of 2010, the costs for co-processing in copper-smelters ranged between US$ 120 and 200 per ton (Wouters 2010). Assuming an average price of US$ 160 per ton, this would imply costs of approx. US$ 2.73 per device. This means that revenues from environmentally sound recycling of CRTs are lower than revenues from the currently practiced recycling (declining from US$ 7.67 to 7.11) – not even taking into account the costs for sound disposal of the phosphorous dust and possible costs for the controlled incineration of plastics. Even if another recommended management option for CRT glass is chosen, i.e. transfer to dumpsites for hazardous waste – this would imply costs, which would partly neutralise revenues from other fractions.

As already indicated in section 5.1.4, all revenue and cost figures are only indicative. It has to be kept in mind that the turnovers cannot be made by one individual recycler, but can only be achieved by a complex and well organised recycling chain that includes local Nigerian recyclers as well as transport agencies and refineries located in other countries. Additionally, the figures represent only the potential sales revenues, not taking into account labour and transport costs, nor logistics, taxes and investment costs.

5.2.5 Environmental benefits

The proposed recycling of CRTs would especially lead to a better management of hazardous substances. While pollutants contained in the printed wiring boards would be managed in smelters abroad, the organic pollutants in the plastic fraction would be widely destroyed in controlled incineration in cement kilns.

Controlled compaction of CRTs and the sound management of the trapped dust would reduce emission of cadmium.

The lead, barium and strontium contained in the CRT glass would also be better managed as the material would be better protected from weathering and mechanical impacts; pre-supposing proper disposal and/or proper use in construction material.

5.2.6 Health and safety issues and labour intensity

The exposure to cadmium-containing dust emissions through breaking, cutting and compacting operations of CRT glass is the main health and safety risk during CRT recycling. In addition, risks of injury from imploding tubes, glass splinters and the handling of heavy devices have to be considered.

In addition to the health and safety measure described in section 5.1.6, while dismantling and compacting CRTs, workers should wear respiration masks to avoid the inhalation of dust, safety glasses to protect the eyes from splinters, and further protective clothing like robust gloves, protective shoes and aprons. In any case, breaking, cutting and compaction operations of CRT glass should only be carried out under fume hoods with an airflow that fully evacuates the dust emission from the tubes. The outgoing airflow must be filtered in order to avoid heavy metal emissions to the surrounding area.

Although no precise data on the labour intensity of manual dismantling and compaction of CRTs is available, it is estimated that per unit labour requirements are lower than with desktop computers, as both, CRT TVs and CRT monitors, feature less sub-components for dismantling. It is assumed that the manual dismantling and compaction steps require about 30 minutes per device.

5.2.7 Interim conclusion and possible business models

The comparison of the presently applied recycling technologies with the best applicable technologies reveals that there are considerable environmental improvement potentials, especially in terms of managing the hazardous fractions like CRT glass, the internal phosphorous coating, and plastics. Nevertheless, the environmentally sound management of these fractions is costly and will at least partly compensate revenues from the net material value of CRT devices. Compared to the presently applied CRT recycling, the environmentally sound treatment path would raise clearly less revenues. Therefore, it cannot be expected that profit-orientated enterprises engage in environmentally sound CRT recycling without additional financing systems or other safeguard mechanisms that ensure a proper handling of all fractions of CRT products. In the current situation, it is much more profitable for both formal and informal businesses to conduct 'cherry picking' by focusing on the valuable fractions only and discarding the rest.

Therefore, any business model to implement environmentally sound CRT recycling can only compete against such cherry-picking recyclers, if laws and regulations provide a level playing field for all recyclers by outlining the recyclers' full responsibility for all waste fractions. Additionally, finance mechanisms should be established that compensate for the management of these deficit fractions. One possibility could be to apply extended producer responsibility (EPR) in Nigeria. This could either be done by charging a fee for any electric or electronic device imported to Nigeria, and to use that for the financing of environmentally sound end-of-life management. Or a producer organised recycling system could be installed, insuring financial sustainability of environmentally sound recycling operations.

Additionally, sound CRT recycling could be supported by identifying suitable management options for critical fractions. This could include:

- Identification and development of disposal sites for hazardous wastes;
- Minimum quotas for co-incineration of hazardous wastes in cement kilns;
- Further reviewing the feasibility of the use of CRT glass in the construction sector.

5.3 Recycling of refrigerators and freezers

5.3.1 Relevance for Nigeria

Refrigerators are commonly used in West African countries, both in private households and in shops and bars.

The end-of-life management of refrigerators and freezers is of considerable environmental importance as most devices manufactured before 1993 contain refrigerants and foam blowing agents with a high ozone depleting and greenhouse gas potential. Although the refrigerants and foaming agents are not directly hazardous to human health, the potential greenhouse gas emissions from crude recycling or untreated disposal are very high (see Table 8). As the typical life-span of cooling and freezing appliances is between 14 and 17 years in Europe (Rüdenauer & Gensch 2007), the majority of devices that reach end-of-life in Europe is still based on the CFCs R11 and R12 or the HFC R134a. In fact, only 15% of the cooling and freezing equipment that reached end-of-life in Germany in 2008 were already based on hydrocarbons with much lower greenhouse gas potential (Holst 2008). As West African countries meet their demand for household appliances to a large extent by the import of devices which were diverged from the waste collection in European countries,[22] it can be estimated that a large amount of imported second-hand refrigerators contains CFCs or HFC.

As these devices are mostly refurbished and used for several further years, the end-of-life stream of cooling and freezing equipment in West Africa will continue to have very high shares of CFC and HFC appliances in the near future. In addition, it is estimated that there are around 6 million refrigerators older than 10 years in service in Nigeria which mostly contain CFCs (Grammig 2010).

Table 8 Type and amount of refrigerant and foaming agent according to year of manufacture *(Sources: Gabel et al. 1998; Rüdenauer & Gensch 2007; IPCC 2007)*

Date of manufacturing	**before 1988**	**1988–1993**	**1993–1997**	**from 1994**
Refrigerant	R12	R12	R134a	R600a
Amount in „small“ appliance	140 g	105 g	95 g	36 g
Amount in „large“ appliance	332 g	249 g	226 g	85 g
Foaming agent (PUR-foam)	R11	R11	R134a	Cyclopentane
Amount in „small“ appliance	358 g	247 g	165 g	194 g
Amount in „large“ appliance	851 g	587 g	392 g	460 g

22 In contrast to many other used electric and electronic equipment imported to W-Africa, shipments of refrigerators from North-America are negligible, as the refrigerators designed for the North-American 110V grid cannot be used in W-African countries.

Date of manufacturing	before 1988	1988–1993	1993–1997	from 1994
GHG-potential of refrigerant & foaming agent [CO_2e]				
CO_2e in „small“ appliance	3.23 t	2.32 t	0.37 t	0.0022 t
CO_2e in „large“ appliance	7.66 t	5.50 t	0.88 t	0.0053 t

Table 9 Specification of the chemicals used as refrigerant and foaming agent *(Sources: IPCC 2007; LANUV 2009)*

	Technical name	Chemical formula	Ozone Depleting Potential [R11 = 1]	Global Warming Potential$_{100a}$ [CO_2 = 1]	Flammable
CFC	R11	CCl_3F	1.00	4,750	no
	R12	CCl_2F_2	1.00	10,900	no
HFC	R134a	CH_2FCF_3	0.00	1,430	no
Hydrocarbon	R600a (Isobutene)	$CH(CH_3)_3$	0.00	3	yes
	Cyclopentane	$c\text{-}C_5H_{10}$	0.00	11	yes

In addition to ozone depleting substances (ODS) and other greenhouse gases, especially older refrigerators and freezers contain other fractions of concern which include mercury switches and PCB-containing capacitors. Flame retardants are not a major problem of cooling and freezing equipment. They might, however, be an issue related to the plastic fraction that is closely interlinked with electric components. Nevertheless, the PVC of cable isolations is of concern when it is heated or burned. Furthermore, the cooling circuits of absorption refrigerators[23] contain ammonia and chrome-VI, so that end-of-life management of these devices is also critical.

Additionally, many end-of-life air conditioners also use CFCs as cooling agent. Therefore, solutions for refrigerators and freezers can also be applied to air conditioners.

5.3.2 Presently applied recycling technologies

The presently applied recycling in Nigeria begins with the collection of the devices. Refrigerators and freezers are mostly collected by informally operating individuals and groups that pick up the obsolete devices from households and shops. Usually, these people pay between 50 and 120 Naira (US$ 0.34 to US$ 0.81) for one device. Then, the refrigerators and freezers are transported to a scrap metal yard by handcart, where the refrigerators are manually dismantled. Thereby, the focus is on the recovery of steel, copper

23 Absorption refrigerators represent only a small percentage of the total cooling and freezing appliance market. Absorption refrigerators are usually only used in hotel rooms and mobile homes.

and aluminium. Other fractions, including CFCs, plastics and foam, do not undergo any particular management. Although the carcases are sometimes reused as boxes, the plastics and the foam are routinely discarded or burned.

Picture 14 Discarded carcases of fridges after manual extraction of all metals and metal-containing components

5.3.3 Best applicable recycling technologies

For an environmentally sound recycling of CFCs- or HFC-containing refrigerators and freezers, the capture and destruction of refrigerants and foaming agents is indispensable. Furthermore, other fractions of concern (mercury switches, PCB-containing capacitors, ammonia, chrome-VI and cable insulations) have to be handled.

Collection

The refrigerators have to be collected and transported to dedicated recycling facilities. During transport, it is important that the cooling circuit is not damaged to prevent CFC or HFC emissions.

Step 1 of CFC recovery

Step 1 of the recycling process encompasses the recovery of the refrigerants in the cooling circuits of refrigerators and freezers. This is carried out in a semi-automated process: First, the main electricity cable and unhitched parts in the interior (e.g. glass shelves, gridirons, plastic boxes) are removed manually. The valuable fractions of these removed parts (glass, polystyrene, iron, aluminium) are passed on for further processing. Additionally, the capacitors[24] and – if present – the mercury switches are removed. These parts have to undergo special hazardous waste disposal.

For the subsequent degassing of the cooling circuit, the refrigerator has to be lifted and tilted. Then, the cooling circuit is tapped at its lowest point using a special device that minimises potential leakage (Picture 15). The cooling circuit is then evacuated using negative pressure. The oil-refrigerant mixture is collected in a tank and treated thermally to separate the refrigerants.

Step 1 is followed by a manual extraction of the compressor and possibly the cooling grid at the backside of the device. The carcases are passed on to step 2 of the CFC recovery process.

[24] Although not all capacitors contain PCB, the differentiation is difficult in many cases. Therefore, it is recommended to treat all capacitors uniformly as hazardous waste.

Picture 15 Step 1 of CFC recovery from refrigerators

Step 2 of CFC recovery

In step 2 of the refrigerator recycling process, the CFCs in the isolation foam (PUR foam) of the devices are recovered. Generally, there are two major ways to carry out step 2:

The first option is based on manual extraction of the foams, using scraping and cutting tools to separate the PUR material from the casing material. The foam is then passed on to a treatment facility that is able to incinerate the foam at temperature regimes that destroy the CFCs. According to the TEAP Task Force on Destruction Technologies, cement kilns or municipal solid waste incinerators are suitable for this operation (UNEP 2007). Nevertheless, some experts argue that cement kilns and waste incinerators might be unable to guarantee complete CFC destruction, as the temperature regime within these plants is often non-uniform and frequently falls below the necessary 850°C (Becker 2010). Furthermore, during manual extraction of the PUR-foam, a significant share of the CFCs is already emitted in the breaking and cutting operations. According to a study carried out by Schüler & Dehoust (2010), these losses amount to 10% to 33% of the CFCs contained in the foam. Therefore, this kind of foam treatment can only be regarded as a low standard and low cost alternative.[25]

The second option is based on fully automated treatment that is completely situated in a sealed environment. In this set-up, the devices are passed through an airlock into a shredder and shearing system. To separate the foam material, the shredder output is passed through an air stream separator. Subsequently, the foam is milled in order to free the CFC. Then, the resulting foam powder is heated whereby the CFC contained in the PUR-material evaporates. The CFC-containing process air is then passed through a charcoal absorber. After the absorber's capacity is exhausted, the charcoal is heated to liberate the CFC and to regenerate the absorber. The CFC is collected in a tank and shipped to further treatment using thermal or plasma destruction technologies.

The complete recycling process, including the automated option for step 2 of the CFC recovery process, yields the following output:

- steel fraction,
- aluminium fraction,
- copper fraction,
- polystyrene fraction,
- PUR powder,
- mixed plastics fraction,
- glass fraction,
- refrigerants and foaming agents (mix of CFCs, HFCs, cyclopentane),
- oil,
- hazardous fraction (PCB-capacitors, mercury switches…).

End-processing

While the metal fractions can be organised together with the metal outputs from other e-waste fractions (see section 5.1.3), the polystyrene of refrigerators and freezers is of quite good quality and free from additives like flame retardants. Therefore, it can be passed on to

[25] Another possible obstacle for incineration in cement kilns is the fact that the chlorine content negatively influences cement quality, which might provoke the opposition of cement producers.

the plastics recycling industry. In Nigeria, there are several recyclers of thermoplastics who could make use of this material.

The PUR powder can be used as oil binding agent without further processing. The mixed plastic fraction is composed of various types of plastics including thermosets and elastomers, which cannot be recycled. Therefore, this fraction should be incinerated in cement kilns or waste incinerators along with other problematic waste fractions (see section 5.1.3).

The glass fraction can be fed into local glass recycling industries.

The recovered CFCs should be treated in certified facilities using one of the destruction technologies approved by the UNEP Task Force on Destruction Technologies. Such facilities are currently installed in Europe, Australia, Brazil, Canada and Japan (UNEP 2007). Alternatively, small scale plasma ovens could be imported and installed in Nigeria. The oil from the cooling circuit can be passed on to oil-fired industrial plants to be used as fuel.

The hazardous fraction needs to undergo specific treatment and disposal. For PCB-containing capacitors, it is noteworthy that the Global Environment facility (GEF) intends to finance a project on PCB management and disposal in Nigeria, which might include the installation of a demonstration unit for the environmentally sound management of PCB-containing wastes. The project will be implemented by the Federal Ministry of the Environment and the World Bank between end of 2010 and end of 2014 (World Bank 2010). Although the project mainly addresses PCB in industrial applications (electricity generation and distribution), co-processing of capacitors from refrigerators and freezers should be feasible.

Interim conclusion

In the Nigerian context, the best applicable recycling technologies for refrigerators and freezers can be sketched as follows:

- House-to-house collection of refrigerators and freezers and careful transport to prevent leakages of the cooling circuit,
- semi-automated extraction of CFCs from cooling circuits,
- automated recovery of CFCs from foams,
- refinery of steel and aluminium fraction in domestic plants,
- export of copper fraction,
- local recycling of polystyrene,
- marketing of PUR-powder as oil binding agent,
- export and destruction of CFCs in certified facilities,
- controlled incineration / energy recovery of oil and remaining plastic fraction,
- controlled management of hazardous fraction.

The question, whether a step 2 recycling unit is feasible in the short or medium term remains open. In contrast to step 1, an automated step 2 CFC recovery operation requires significant investments into machinery and generates only very little employment. On the other side, manual extraction of foams and its direct incineration in cement kilns is also associated with problems. As a possible middle-way, it might be elaborated to search for a third option based on the manual extraction of foams, combined with an automated recovery of CFCs. Nevertheless, there is no machinery readily available for such an alternative treatment path.

Generally, refrigerator recycling should, in any case, be linked to sound quality assurance mechanisms. Such mechanisms could be provided by independent organisations such as RAL Quality Assurance for the Demanufacturing of Refrigeration Equipment or other technical inspection associations.

5.3.4 Economic incentives for environmentally sound recycling

The intrinsic material value of refrigerators is mainly based on the bulk metals copper, steel and aluminium (see Table 10). Depending on the applied treatment technology, between 96% and 99% of the ferrous and between 80% and 92% of the non-ferrous metals can be recovered in the recycling processes (Dehoust & Schüler 2007). It is assumed that a partial deployment of manual dismantling and sorting processes will lead to the above-average recovery rates of 99% for ferrous metals and 92% for non-ferrous metals.

The value of the various types of plastics is difficult to determine: While the polystyrene of refrigerators – which on average makes up 45.2% of the total plastic content – is of high purity and may achieve a considerable market price after recovery, the pulverised PUR foam (approximately 4 kg per device) can be used as oil binding agent. The other plastic fractions are of low quality and may only be suitable for energy recovery (Dehoust & Schüler 2007). Generally, there is no globally interlinked market for secondary plastics, so that prices in one region cannot be easily transferred to another region. Therefore, the material values for plastics listed in Table 10 are indicative figures only. The table indicates that – from a resource perspective – the best applicable technology is preferable for its better utilisation of plastics, namely polystyrene and PUR. The recovery rates for metals are equal to those of the presently applied technologies.

Additional incentives for an environmentally sound recycling of refrigerators and freezers result from the high greenhouse gas potentials of the refrigerants and foaming agents: A sound recovery and destruction of these gases, as carried out with the best applicable technologies would generate significant greenhouse gas emission reductions that – under certain preconditions – can be certified and sold under one of the existing emission reduction certification schemes, namely the Clean Development Mechanism (CDM), the Climate Action Reserve (CAR) or the Voluntary Carbon Standard (VCS). In order to facilitate an overview on these trading schemes, some important characteristics are presented for each of them:

- CDM only allows emission trading credits from gases that are covered by the Kyoto Protocol. As CFCs are listed under the Montreal Protocol and not under the Kyoto Protocol, R134a is the only relevant gas contained in refrigerators and freezers that could be used to generate CDM credits. Therefore, CDM seems only attractive for projects that have a strong additional focus on emission reductions through increased energy efficiency (replacement of old refrigerators by more efficient devices)[26].
- CAR additionally included the destruction of CFCs into possible emission reduction measures in early 2010 (CAR 2010). It gives credits for CFCs from cooling circuits but not for CFCs from foams. Therefore, projects can only generate CAR-credits from step 1 CFC recovery and destruction. Moreover, R 22, a refrigerant frequently used in air-conditioners, is not eligible under CAR. The recovered CFCs have to be shipped to the USA for destruction. ODS recovery and destruction projects are temporally limited to 12 months. Long-term CFC recovery and destruction efforts might have the possibility to be accepted as a series of several 12-month projects.
- In parallel to CAR, also VCS included ODS destruction into its scheme in early 2010 (VCS 2010). In contrast to CAR, VCS does not provide a methodology laying out the basis for CFC recovery and destruction projects. Methodologies have to be developed according to the framework provided by VCS (VCS 2008). As there have already been several ODS destruction methodologies submitted to the Voluntary Carbon Standard Association, it can be assumed that applicable project methodologies will soon be available. In contrast to CAR, both, refrigerants and foaming agents are eligible. The targets for recovery and destruction efficiency are 85% of the addressed CFCs. This means that especially CFC recovery from foams will have to meet high standards.

Table 10 Material content, intrinsic and net values of an average refrigerator at 2007 resource prices *(Sources: DTI 2006; USGS 2009; CSR 2009)*

	Amount contained in a refrigerator [kg/unit]	Average material price 2007 [US$/t]	Intrinsic material value 2007 [US$/unit]	Estimated recovery rates with presently applied technology	Estimated recovery rates with best applicable technology	Net material value with presently applied technology [US$/unit]	Net material value with best applicable technology [US$/unit]
Steel	20	253*	5.06	99%	99%	5.01	5.01
Plastics	16	310**	4.96	0%	65%	0	3.22
Copper	1.6	7,231	11.57	92%	92%	10.64	10.64
Aluminium	1.2	2,700	3.24	92%	92%	2.98	2.98
Glass	0.4	31	0.01	92%	92%	0.01	0.01

[26] Every CDM activity involving refrigerator replacement needs to ensure sound measures for CFC recovery and destruction from cooling circuits and foams – disregarding the fact that the emission reductions from CFC destruction are not eligible under CDM.

	Amount contained in a refrigerator [kg/unit]	Average material price 2007 [US$/t]	Intrinsic material value 2007 [US$/unit]	Estimated recovery rates with presently applied technology	Estimated recovery rates with best applicable technology	Net material value with presently applied technology [US$/unit]	Net material value with best applicable technology [US$/unit]
Others	0.8	-	-	-	-	-	-
Sum	**40**		**24.84**			**18.65**	**21.87**

** Prices for iron and steel scrap   ** Prices for mixed plastics*

The VCS and CAR emission reduction schemes undoubtedly support the economic basis for refrigerator recycling in developing countries. These schemes are already economically utilised by three fridge recycling facilities in Brazil. In addition, initiatives in other emerging economies and developing countries are planned or under way (e.g. China, Ghana). Generally, it can be assumed that market prices of several US$ per ton of prevented CO_2e-emission can be achieved[27]. Thereby, the pricing will also depend on the quality of the recycling project, including its verification mechanism and its compliance with international standards.

5.3.5 Environmental benefits

In contrast to the currently applied recycling of refrigerators and freezers, the best applicable technologies would reduce the emissions of CFCs from the cooling circuit and – if step 2 of the recovery operation is implemented – also those from the foams. With an implementation of up-to-date technology of step 1 and 2 recovery units, a minimum of 90% of CFCs contained in refrigerators and freezers can be recovered. Depending on the size and type of refrigerator, this would lead to a proper management of 2-7 t CO_2e per device.

Additionally, sound recycling operations would improve the management of hazardous components such as PCB-containing capacitors or mercury switches.

Positive aspects also result from the utilisation of the plastic fraction, namely the recycling of polystyrene and the PUR material. Regarding the PUR powder from step 2 recovery of CFCs, it is noteworthy that this output can be used as oil binding agent or agent to thicken liquid hazardous wastes.

5.3.6 Health and safety issues and labour intensity

The health and safety risks during the recycling operations of refrigerators and freezers can be divided into three categories:

[27] By the end of 2010, the market price for carbon credits has reached a level of around 10US$ per t CO_2e under the CAR scheme (Grammig 2010).

- health risks from hazardous substances contained in the devices;
- safety risks from handling heavy devices;
- safety risks from the operation of recycling machinery.

Hazardous substances are present in mercury switches of old box type freezers, in PCB-containing capacitors as well as in the ammonia and chrome VI contained in the cooling circuits of absorption refrigerators. The CFCs and HFCs contained in foams and cooling circuits are not directly hazardous to human health. Therefore, leakages and spills of these substances are undesirable from an environmental perspective, but do not affect workplace health and safety.

Although the components containing pollutants can be easily identified by trained workers, the substances of concern are all present in a liquid form so that proper management guidelines and handling procedures must be in place. Furthermore, workers have to be trained in how to recognise and treat the relevant components.

Additionally, risks associated with handling and lifting of heavy devices with partly more than 40 kg have to be taken into account.

In terms of safety risks from the operation of recycling machinery, special emphasis on fire risks is needed: As non-CFC and non-HFC refrigerators contain flammable hydrocarbons, a co-processing with CFC and HFC refrigerators leads to an accumulation of flammable gases within the recovery machinery of recycling step 1 and 2[28]. Especially during CFC recovery step 2, these hydrocarbons can cause fires or explosions within the recovery unit. Therefore, sophisticated precaution measures have to be installed. Amongst others, automated CFC recovery units must be operated in a nitrogen atmosphere.

Operation of one unit of the step 1 CFC recovery process requires about six workers and one engineer. With this workforce, roughly 30 devices can be treated per hour and 60,000 per year. The automated step 2 CFC recovery operation requires one or two additional engineers to achieve the same treatment capacity. Additional manual labour can be deployed to further dismantle and sort some of the recycling outputs such as the evacuated compressors.

5.3.7 Interim conclusion and possible business models

The comparison of the presently applied recycling technologies and the best applicable technologies reveals that there are significant untapped environmental and possibly economic improvement potentials. These potentials can be realised by the recovery of CFCs and HFCs from cooling circuits and foams and the destruction of these Ozone Depleting Substances in dedicated facilities. Additionally, the sound management of hazardous components and a better utilisation of the plastic fraction add to the benefits of sound refrigerator

[28] The co-processing of hydrocarbon devices is to some extent unavoidable, as some devices are insufficiently marked or may have lost their marks during their life-time.

recycling. Economic benefits can be tapped, if the CFC and HFC recovery and destruction are marketed within one of the existing emission trading schemes. The Carbon Action Reserve (CAR) and the Voluntary Carbon Standard (VCS) just established the frameworks for such financing.

From a social perspective, the recovery and destruction of CFCs and HFCs do not create significant employment. Nevertheless, the establishment of a sound refrigerator recycling infrastructure can help to form a nucleus of a future recycling industry and therefore play a more indirect role in creating decent employment in an environmentally sound industry.

From the type of operations needed in Nigeria, machinery to recover CFCs and HFCs are required. The investment costs for one full step 1 recovery unit with a capacity of 30 devices per hour are approximately US$ 280,000 (€ 200,000). Nevertheless, a certain share of the equipment could possibly be manufactured locally, which could reduce the total costs significantly. As step 1 of the recovery can be conducted in an open area (by deploying a recovery unit built into a container), a building is not necessarily needed. Nevertheless, paved floor, electricity and sufficient space to store and handle obsolete refrigerators are required. The investment costs for an integrated operation of step 1 and 2 amount to US$ 6.3 million (€ 4.5 million) for a complete facility. Also here, some parts of the machinery could be produced locally in Nigeria, which would reduce the investment costs.

Considering these investment costs and the tasks to tackle issues around export of CFCs, certification and compliance, the informal e-waste sector might not be in the position to manage this kind of recycling alone. Nevertheless, businesses should closely interlink with the current e-waste recycling structures to avoid competition in acquiring obsolete refrigerators. The informal e-waste sector could in particular be engaged in the collection of obsolete refrigerators, the transport to the recycling facility and the manual recycling steps.

5.4 Possible risks and unintended side-effects

The business potentials from improved e-waste recycling as analysed in the chapters 5.1 to 5.3 can have multiple positive impacts on the environment and the Nigerian society. Nevertheless, the business models might also face obstacles and entrepreneurial risks. Additionally, the implementation of the business models might also cause unintended side-effects that can in turn have negative impacts on the environment and the Nigerian economy. Although it is virtually impossible to make an exhaustive assessment of these risks, the following collection of issues highlights some topics that need to be considered in the future.

5.4.1 Negligence of non-valuable fractions

The business opportunities identified in the chapters 5.1 to 5.3 are based on revenues generated from e-waste fractions with positive net values. These fractions encompass PWBs and IC contacts (precious metals), copper, steel, aluminium and neodymium magnets. With regard to refrigerators, revenues could possibly be generated from CFCs via voluntary emission reduction schemes. Nevertheless, other fractions like plastics or composite materials will not find major markets within or outside Nigeria. Environmentally sound end-of-life management is therefore at best cost neutral. With regard to hazardous components like CRT glass, PCB-containing capacitors, mercury switches or ammonia, sound end-of-life management is costly and dependent on additional financing mechanisms.

This issue needs careful consideration in any follow-up activity. If the business models described above are implemented without additional safeguard mechanisms to care for these deficit fractions, it is very likely that non-valuable fractions will be disposed of in the cheapest possible manner, disregarding possible risks to human health and the environmental. One possible finance mechanism is to use a share of the revenues generated from the valuable fractions to manage the deficit fractions.

5.4.2 Changing composition of e-waste

The analysis conducted in chapters 5.1 to 5.3 is based on the current e-waste situation in Nigeria, where desktop computers, CRT devices (TVs and monitors) and CFC refrigerators are amongst the most dominant types of e-wastes. Nevertheless, this situation will gradually change within the next decade: As many of these devices are replaced by notebooks, LCD screens and CFC free refrigerators, the e-waste stream will also change its composition once these products reach their end-of-life. Although this will have many positive effects, as new devices often contain less hazardous substances as old ones[29], modifications in product design and technologies will inevitably create the need to adapt the end-of-life management. One important example is LCD technology: Although LCD monitors have not yet reached the Nigerian waste stream in significant quantities, this is just a matter of time as use and demand – either as stand-alone devices or as parts of notebooks or other appliances – are increasing. LCD-screens carry significant amounts of valuable metals, but at the same time are quite difficult to dismantle without causing mercury emissions from broken backlights. To date, the optimal recycling of these devices is still unresolved (Huisman et al. 2007).

Therefore, efforts for environmentally sound e-waste recycling need to consider these changes in material compositions and to regularly update their know-how and recycling practices.

5.4.3 Variations of resource prices

Recycling approaches that are financed by the net material value of e-waste have to take into account possible variations of resource prices. As illustrated by Figure 1, the net material value provided by precious metals and copper is characterised by long- and short-term variations with a major peak around mid-2008 and, in the following period, by a downturn

[29] E.g.: New RoHS-compliant electronics with reduced concentrations of heavy metals, PBB and PBDE.

caused by the financial crises. Although the values almost reached this level by the end of 2009, the future developments are uncertain. Currently, many experts predict that prices for most commodities will remain at high levels for the next years (World Bank 2010). These predictions generally assume a stable development of the world economy. With regard to e-waste recycling, the high importance of the gold price is noteworthy. Although high gold price levels currently support the profitability of e-waste recycling, price levels might as well decline in the future.

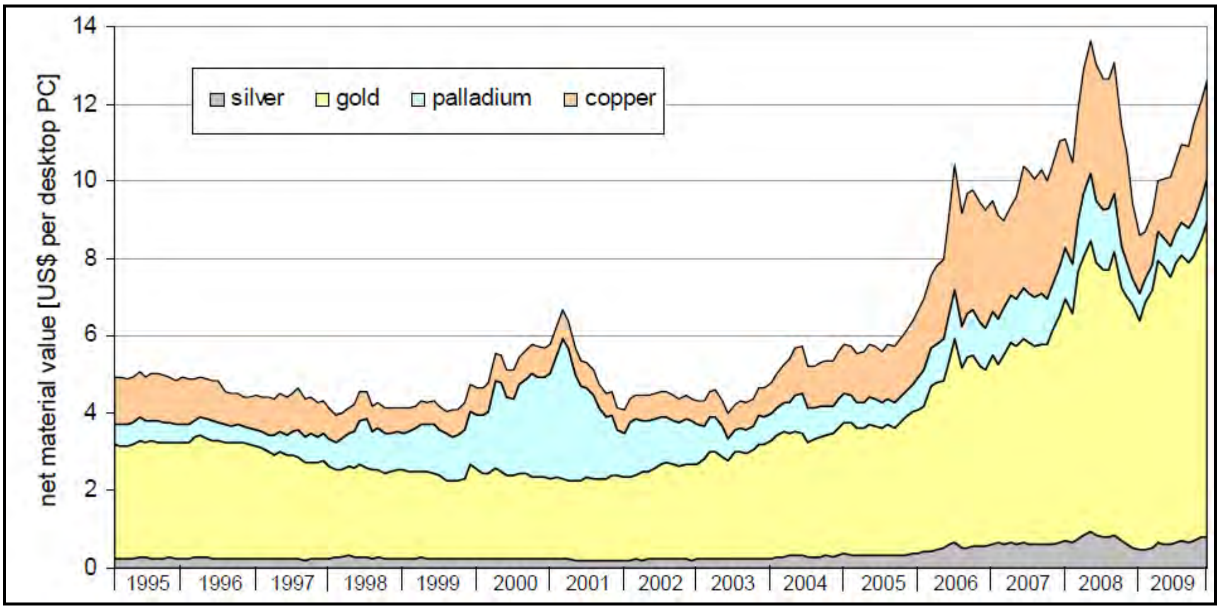


Figure 1 Net material value of the copper and precious metals content of an average desktop PC from January 1995 to October 2009 *(Sources: Own calculations with data from Gmünder 2007 and LME 2009)*

5.4.4 Indirect stimulation of illegal e-waste imports

The business models described in section 5.1.7 and 5.3.7 would lead to increased revenues for the Nigerian e-waste recycling industry, which could also have effects on the problem of e-waste imports. If the economic benefits from e-waste would be greatly enhanced, there might also be increased benefits for the shipping of used and obsolete equipment to Nigeria. Although it seems unlikely that the recyclers themselves will actively participate in this trans-boundary trade, they might be willing to spend more for acquiring obsolete e-products – either collected from Nigerian households and businesses or from the importers and refurbishers organised in the second-hand markets. This premium will increase the revenues of traders that do not only import used goods, but also non-functioning equipment.

This possible stimulation of the e-waste imports would not only be a problem because they contravene the Basel Convention, but also for environmental reasons: Even with improved e-waste recycling as proposed in this study, many processes and end-of-life management options still carry the risk of collateral pollution. This is particularly the case for the controlled incineration of plastics, the management of CRT glass and other hazardous fractions. Although such impacts can hardly be avoided for domestically generated e-waste, imported e-waste destined for recycling instead of reuse should not be tolerated in Nigeria at all.

6 Final conclusions and recommendations

The socio-economic impacts of the currently practiced refurbishing, collection and recycling of e-products are manifold and encompass severe negative impacts on human health, especially for people directly engaged in these sectors. Collectors and recyclers of obsolete e-equipment are the ones who are most exposed to these adverse health risks. Refurbishers also face health risks, especially those people working long hours in soldering operations in poorly ventilated work places. Besides, health impacts on neighbouring communities and the environment as such are of considerable concern. Here, the generation and unsound management of waste – including the open incineration of cables and plastic fractions – are major issues to be addressed in future policies and programmes. Nevertheless, refurbishing, collection and recycling of used and obsolete e-products also have some positive socio-economic impacts, which have to be carefully considered for any strategy aiming to resolve the e-waste problem in Nigeria: Refurbishing in Lagos alone provides jobs and income opportunities for more than 20,000 people. While informal collection and recycling provide jobs for a poor workforce with a low qualification level, refurbishing activities are technically quite demanding and therefore create income opportunities for a more educated workforce. It is also important to mention that the sector itself is quite strong in organising and conducting a kind of informal vocational training programme that generates more than 2,000 alumnis per year. On top of that, the major refurbishing clusters in Lagos – Alaba Market and Ikeja Computer Village – developed into very dynamic business clusters which are unique in West Africa. The particular role of the refurbishing sector was already discovered by the World Bank and was praised as one of the most promising economic developments in Nigeria in the last years (Abiola 2008, World Bank 2009).

Nevertheless, the problems around human and environmental health call for urgent action. In order to solve the problems concerning the emissions of heavy metals, persistent organic pollutants, greenhouse gases and ozone depletion substances, business and policy approaches must be launched and synchronised to address the various issues and root-causes of the current situation. The following chapter proposes principles and activities that should be endorsed and implemented by the Nigerian government, the domestic and international recycling industry and international donors aiming to support Nigeria in its efforts to solve the e-waste problem.

6.1 General recommendation to policy-makers and the Nigerian recycling industry

Acknowledge and support the refurbishing clusters

The socio-economic survey clearly revealed that the refurbishing of e-products is an important economic sector in Nigeria. Besides providing jobs for an estimated number of 21,600 people, and occupational training for more than 2,000 youths per year, it is a well-organised and dynamic industry that holds the potential for further industrial development. Indirectly, the sector has another important role in Nigeria's economy as it supplies low and middle income households and businesses with affordable second-hand equipment.

On the other side, the refurbishing sector bears some serious heath and safety risks for employees and also for neighbouring communities. One particular problem is the unresolved management of wastes.

In the view of the sector's outstanding socio-economic performance, all policy measures aiming to improve e-waste management in Lagos and Nigeria should refrain from undifferentiated banning of refurbishing activities and strive for a co-operative approach by including the market and sector associations.

Incorporate the informal collection and recycling sector

The informal collection and recycling sector is a key player in e-waste management in Nigeria. Despite deficits in resource recovery, health and environmental standards, efficiency is already high in house-to-house and business-to-business collection of e-waste and in the recovery of steel and aluminium.

The informal collection and recycling sector provides employment for several thousands inhabitants of Lagos, mostly for people originating from the rural northern parts of Nigeria. The informal sector activities – despite its adverse impacts on human health and the environment – therefore provide both, a nucleus to develop a more advanced recycling industry, and important income opportunities for poor people. Any strategy addressing the Nigerian e-waste management should therefore carefully consider the various potentials of the informal collection and recycling before establishing a parallel system in competition to these structures. In particular, it is recommended that those people that are currently engaged in informal e-waste collection and pre-processing become an officially acknowledged part of the recycling chain. This is particular important when it comes to the strategies and roles filled out by the Lagos Waste Management Authority (LAWMA): Clear terms of interaction between the informal players and the formal LAWMA scheme are likely to increase the overall efficiency of the collection and recycling system and can act as key instrument to steer e-waste flows into the desired management channels.

Informal collectors could, for example, continue to engage in the house-to-house collection of fridges. These, however, should then be transported to dedicated recycling plants capable of properly managing the CFCs contained in the cooling circuit and the isolation foams. After the extraction of CFCs and other hazardous components, informal recyclers could again take over the manual dismantling and sorting of the fridges' metal fraction.

Deploy manual labour for pre-processing

The comparison between the presently applied recycling techniques in Nigeria and the technologies applied in European countries reveals that European solutions are only partially applicable in the Nigerian context. Especially pre-processing machinery developed and applied in Europe is often optimised to reduce labour costs rather than to maximise resource efficiency. Under the socio-economic conditions of Nigeria, recycling can make use of much more manual labour, which can be beneficial in economic, environmental and social terms. While investments into machinery parks often appear to be attractive solutions, this is not necessarily the case in e-waste management in Nigeria. Although some types of machinery like CFC-recovery units for refrigerators and air conditioners, fume hoods for CRT treatment and electric or pneumatic tools for dismantling are required to improve e-waste recycling, large scale shredder and mechanical sorting facilities are counterproductive and would entail job losses. Therefore, any approach to improve e-waste recycling in Nigeria should utilize the potential of the abundant pool of labour instead of deploying expensive shredding and sorting machinery.

Support and maintain international recycling co-operations

The improvement potential described in chapter 5 mostly requires international recycling co-operations. Although there are many recycling steps that can be carried out within Nigeria, certain refinery processes – especially those for precious metals – need to be carried out in high-tech-facilities that are only available in very few countries. As these facilities require investments of several billion US$ and waste volumes, much larger than those available in Nigeria and its neighbouring countries, it is currently not a realistic option to establish such a facility in Nigeria. It is therefore recommended that Nigerian recyclers interlink with international recycling companies and networks to develop market outlets for their pre-processed e-waste. This also demands that government bodies guarantee a smooth, reliable and timely handling of export licences and other administrative procedures to facilitate exports of certain e-waste fractions.

Focus on high quality recycling products

Nigerian recyclers have remarkable opportunities in the pre-processing phase of electronic products such as computers, DVD-players and hi-fi-systems. Here, recycling outputs could realize market prices that are above the average unit prices achieved by European pre-processors. A high quality can be achieved by thorough manual dismantling and sorting of these products. Nigerian e-waste recyclers should focus on these quality aspects to occupy this niche market.

Develop regulative framework

A key problem of Nigerian e-waste recycling is cherry-picking. Fractions with high material value are recovered and sold, while hazardous fractions with low material value such as CRT glass and plastics containing brominated flame retardants are dumped or burned uncontrolled. Even if international recycling co-operations are implemented in the field of precious metals recovery, the problem of cherry-picking will not be not automatically solved. For recyclers, a sound end-of-life management of hazardous fractions will always be more costly than uncontrolled dumping or burning. Even if cost-efficient solutions like co-incineration of plastic materials in cement kilns can be identified, this might still imply additional transport costs for recyclers. Therefore, environmentally sound e-waste recycling is dependent on a sound regulatory framework that includes the obligation to care for all e-waste fractions. Naturally, such regulatory framework also needs stringent implementation and regular inspections.

Develop appropriate finance mechanisms

Although the net material value of some e-waste types can contribute to cover the costs for a sound management of low value and hazardous fractions, the example of CRT devices shows that it will be very difficult to achieve environmentally sound end-of-life management without additional financing mechanisms. One solution could be the implementation of the principle of extended producer responsibility (EPR). This could be done, for example, by raising a fee for every e-product entering the Nigerian market through import. As the demand for e-products is widely covered by the import of second-hand goods in Nigeria, this fee would also be applicable to the importers of this equipment. The fees could either be distributed to the e-waste recyclers or be used to facilitate sound end-of-life management options, such as the establishment and maintenance of a disposal site for hazardous waste.

Alternatively, EPR could also be implemented by demanding producers and importers to organise and implement an environmentally sound recycling system within Nigeria at their own expenses (either individually or collectively organised). Such a strategy would have the distinct advantage that it would be largely free of administrative burden. Of course, government has to define the framework conditions and environmental requirements for such systems.

Provide solutions for locally generated hazardous waste

Currently, Lagos has only a limited infrastructure to properly manage hazardous waste. Nevertheless, this infrastructure is indispensable to provide local solutions for hazardous e-waste fractions. In this context, it is noteworthy that Lagos is home to several cement kilns, which could be used for high temperature incineration of various plastic fractions, in particular of those containing bromated flame retardants[30]. It is important to establish links between the recycling system – including the Lagos Waste Management Authority (LAWMA) – and the companies operating the kilns. Depending on kiln capacities, the companies could offer to co-incinerate certain plastic waste on a regular basis. In turn, the Lagos Waste Management Authority could take over logistics and transport of these wastes.

In addition, solutions for other hazardous waste fractions such as CRT glass, PCB-containing capacitors and mercury switches must be identified. Therefore, Nigeria should strive to develop such an infrastructure in line with local and national development efforts. Priority in particular should be given to establishing a well managed hazardous waste disposal site, since this could simultaneously provide end-of-life management solutions for many hazardous waste fractions. As mentioned before, the costs for establishing and maintening of such a site could partly be covered by appropriate e-waste financing mechanisms.

Furthermore, Nigeria should make best use of the planned GEF-project on PCB management and disposal. As the project will also encompass the installation of a demonstration unit for environmentally sound management of PCB containing wastes, this plant could form another nucleus for Nigeria's hazardous waste infrastructure.

Regulate the import of used products

As described above, the refurbishing sector constitutes an important economic sector for Lagos and all of Nigeria. Since this sector sources a large percentage of its devices from the Lagos ports, it is inevitably interwoven with the transboundary trade of used and end-of-life e-products. The trade currently comprises all, functioning, non-functioning but repairable, and non-functioning and non-repairable equipment. Although a complete ban of all second-hand imports seems inappropriate, Nigerian decision-makers should define a clear line between the types of equipment acceptable, and those types and qualities unacceptable for imports.

Besides reducing the volumes of imported hazardous waste, this measure is also considered to be a pre-requisite for the long-term success of international recycling co-operations: Especially in the field of CFC recovery and destruction, it would be unacceptable if recyclers in Nigeria earned money by managing end-of-life devices that had been directly imported from Europe: As an environmentally sound management is obligatory in Europe and since it is already financed by producer responsibility schemes, the end-of-life management in Nigeria would abuse this system and would subsequently damage the recognition of the Nigerian recycling efforts. In this context, the enforcement of an existing ban on imports of CFC refrigerators is an important step towards a responsible national e-waste strategy.

[30] In addition to the destruction of organic pollution in the high-temperature-incineration, this end-of-life solution of plastics would also substitute other fuels in the kilning stage and therefore be part of a "waste-to-energy-strategy"

Similar efforts should be undertaken for obsolete and outdated electronic equipment and other appliances[31].

6.2 Specific recommendations for pilot follow-up activities

In order to facilitate the implementation of the proposed applicable recycling technologies, it is recommended to set up one or more e-waste recycling demonstration projects in Lagos. These initiatives should help to overcome some of the current obstacles for improvements and shall also provide a platform for learning and demonstration. All these initiatives should closely work together with the Nigerian authorities, the refurbishing clusters, local collectors and recyclers, as well as international recycling networks in order to achieve sustainable solutions by testing and implementing the business models elaborated in chapter 5 and striving for a sound implementation of social and environmental standards in order to maximise socio-economic benefits.

Generally, it is recommended that such pilot activities are implemented for all three product groups covered by the analysis of chapter 5: Computers, CRT devices and refrigerators. The processes and technologies required for these three product groups will allow to extend recycling to most other types of e-waste.

The following recommendations are meant to sketch some important principals that are considered to be crucial elements of possible pilot implementation projects:

Insure strong linkages with key administrative bodies

In partnership with NESREA, LASEPA, LAWMA and BCCC-Nigeria, the Federal Ministry of Environment (FMENV) should act as coordinating body for such a pilot implementation project. This structure encompassing many key administrative bodies concerning e-waste and environment issues will facilitate the feeding of lessons learned from pilot activities into the administrative decision-making process.

Additional key stakeholders, such as the Scrap Metal Dealers Association of Nigeria and the associations of the major refurbishment clusters should also be integral part of the project activities.

Conduct pilot operations in or close to existing recycling or refurbishing clusters

In order to make use of the dynamics of the existing refurbishing and recycling industries and to provide a showcase on how to improve business operations, all physical pilot recycling activities should be carried out within or close to existing scrap metal markets and/or refurbishing clusters. The geographical proximity would also avoid pilot activities from being regarded as competition by the established players in refurbishing and recycling.

[31] Here, it has to be mentioned that Nigerian government bodies represented by the Customs, the Navy and NESREA already returned two shipment of e-waste to the Netherlands in the first half of 2010.

Improve social standards

Although some of the business models proposed in chapter 5 will result in higher incomes for Nigerian recyclers, this does not automatically solve the social problems of the sector. There is still the need to ensure that additional revenues are shared in such a way that the most vulnerable groups in the recycling chain, too, can improve their living and working conditions. Additionally, mechanisms that secure the penetration of skills and know-how on issues regarding health and safety, improved recycling technologies as well as on market prices and access need to be introduced,.

Ensure rapid cash flow

Most of the identified economic improvement potentials feature a severe obstacle for small scale recyclers in Nigeria: In contrast to the currently practiced recycling approaches, it will take several months before revenues will be generated. As many people engaged in e-waste collection and recycling live on less than US$ 1 per day, it is of utmost important that alternative business models, too, can guarantee them a rapid cash flow to cover their daily needs. This can either be achieved by appropriate micro-finance systems, or by intermediaries that have the financial resources to buffer the delays in payment. Here, the local traders such as those from the Alaba Market recycling community (see section 3.3.4) could play an important role.

Focus on all e-waste fractions

Pilot projects should not only focus on the high value fractions such as PWBs, but also search for solutions for hazardous and low value fractions such as CRT glass, mercury switches, PCB-containing capacitors and plastics. These solutions could be based on the local infrastructure and installations such as cement kilns, hazardous waste disposal sites and the construction industry. Each identified solution should be supported by appropriate tests and risk analyses to minimise environmental impacts and to prevent cross-contamination.

In addition, pilot projects should also address the problem of cable burning, providing robust and economically feasible alternatives to liberate the copper.

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Annex I: SLCA-Assessment Sheet for Informal SMEs

Introduction

The following Assessment Sheet is aimed to support the collection of socioeconomic data and information in a structured way. It transforms the SLCA-indicators into various clusters / topics that should be filled with information. The assessment shall be done by a combination of structured interviews and visual inspections. In previous assessments, it proved useful to roughly follow the content and chronology of the Assessment Sheet during the interviews. Nevertheless, building up trust is important in such assessments so that interviews should be carried out in an informal and flexible way. It is up to the interviewer and dependent on the general situation if the collected information is filled in right during the interview or whether the interview is conducted orally without taking notes. In the latter case, it is recommended to fill in the information right after the interview has been carried out. Please use clearly readable handwriting!

If accepted by the interviewed enterprise, photographs can be used to support the observations.

In cases where the required level of trust and transparency is not achieved during the interview, the assessment does not have to be pushed beyond the limits of what is acceptable for the interview partners. Instead, the assessment should rather focus on some key aspects and visual inspections.

GENERAL INFORMATION

Date of assessment:

Name of conductor(s):

Name of enterprise:

Location of enterprise:

Address:

Phone number:

E-mail:

Name of owner:

Name of manager:

GENERAL BUSINESS INFORMATION

Type of business

Describe the main business activities and add information on possible side businesses.

Example: *Enterprise xyz is active in the refurbishment and resale of used mobile phones. It purchases used and obsolete mobile phones from internationally operating dealers in order to serve the local market. Enterprise xyz passes its products (functioning mobile phones) to a loose network of street vendors. As a side business, the company sells scrap mobile phone parts (those turning out not to be repairable) to local waste dealers.*

Workspace description

Describe the area (room / hall / backyard) where the business operations are conducted. Include information on illumination / lighting and aeration / ventilation.

Example: *The repair activities are carried out in a small hall (about 10 x 5m) equipped with 5 desks for repair operations. The spare parts and the waste are stored in buckets and sacks on the floor and around the desks. The hall has 4 windows on one side, which provide enough daylight for about half of the room. The back of the room is illuminated by some light tubes. As the windows and the door are normally left open, the hall is well aerated.*

Production processes & technologies

Please describe the technologies and processes applied by the enterprise. Above, describe the type of tools and machines used for these processes. Include information on implemented health protection measures.

Example: *The repair of mobile phones is carried out with quite simple tools like screwdrivers and soldering irons. For most repairs, workers have to exchange and load the battery, clean the contacts, the display and the housing with cleaning liquid and partly exchange some electronic components by unsoldering the damaged parts and putting in new components. For health protection, the management offers respiration masks. Because of the hot indoor temperature, most workers do not like the masks and work without them.*

Health & safety issues

List and describe obvious health and safety risks from the operations carried out. See Annex II for a rough checklist to identify possible health and safety risks. In addition, check on other less specific risks (e.g. accident risks from heavy machinery, risks from poorly maintained electricity wiring). Try to elaborate on possible health problems for which workers might blame their professional activities.

Example: *Health and safety risks might stem from the soldering operations. As the workers are bowed over their repair desks, they frequently inhale the fumes from the soldering operations. One worker claimed that – after a long day of soldering operations – he feels a stabbing pain in his lungs.*

Business outputs

Try to quantify the enterprises' monthly / annual production in absolute and monetary terms.

Example: *The enterprise repairs approximately 800 mobile phones per month. They are sold to the street vendors for $ 5–10 per piece, depending on the quality. The revenues from scrap mobile phones are negligible and may sum up to $ 50 per month. On average, 1000 waste mobile phones are sold to scrap dealers per month.*

Business inputs

Try to quantify the enterprises' monthly / annual business inputs needed to generate the described outputs. Focus on materials and running costs (no investments into machinery or others)

Example: *The enterprise purchases between 1500–2500 used and obsolete mobile phones per month, which cost between $ 0.50 and $ 1.00 per piece, depending on the quality and condition. Amongst these mobile phones are also many unrepairable devices, which are important sources of spare parts. The enterprise uses approximately 2-3 mobile phones to produce a functioning one. Besides mobile phones, there are little further materials needed: Solder, cleaning liquid, glue and batteries, which are purchased on the local market. These additional costs sum up to less than $ 50 per month.*

Ownership and rent

Collect information on the ownership of the used business facilities. If rented, give figures on the weekly, monthly or annual rent.

Example: *The house the business is located in belongs to a local investor who owns large part of this business quarter. The rent is $ 75 per month.*

Taxes and fees

Collect information on official and unofficial taxes or fees.

Example: *The business owner pays $ 200 taxes to the local administration annually. The tax is collected by an administration representative. Additionally, the business pays $ 10 to the local market association per month.*

INFORMATION ON STAFF AND EMPLOYMENT

Number of employees / workers

Give figures and differentiate between different tasks and hierarchy levels.

Example: *Enterprise xyz employs 8 persons (not counting owner and manager): 1 person takes care of management and financial issues, but also engages in the repair of mobile phones if necessary. 6 people are fully occupied with repair and refurbishment of mobile phones. 1 person (a low-skilled youth) is employed for conducting daily necessities like cleaning tasks, shopping of basic goods and food and the delivery of mobile phones to some customers.*

Level of required skills

Give a description of skills required for this business. Focus on the skills needed for the key business activities.

Example: *The repair of mobile phones generally requires a high level of technical knowledge. Two of the employed people have a University degree in electronics engineering and are therefore the ones instructing new workers and taking over the more complex repair tasks. After detailed instructions and some practical experiences, the majority of repairs can be carried out by people with average education (elementary school education). Nevertheless, it is a mandatory requirement that repair personnel have good eyes and are skilled in handling small parts and components.*

Employment status

Type of employment (differentiate between people with formal working contracts, people with oral agreements and people with other arrangements)

Example: *Besides the 2 persons with university degrees, none of the workers hold formal contracts.*

Caution: *The topic is somewhat sensitive. It might be better to address this issue more indirectly after having built up some trust. Workers can serve as a valuable source of information.*

Sex and age distribution

Give information on the sex and age distribution of personnel (this section can also be based on observations).

Example: *Only men are working in the enterprise. Most men are aged around 20 to 30. One of the repair personnel appears to be older than 45.*

Social security

Collect information on possible (official and unofficial) mechanisms in case of illness, pregnancy / maternity leave, unemployment, retirement or any other case of social difficulty.

Example: *None of the employees are covered by any social security system. Also those employees that hold formal contracts have no kind of social insurance like health or unemployment insurance or old age pension. In the past, the owner of the enterprise gave some financial support for medical treatment of his employees.*

Education & Apprenticeship

Describe possible apprenticeship- and training mechanisms. Include information on the financial and social conditions of apprentices and staff on training.

Example: *Usually an apprentice is in the enterprise for 1 or 2 years, depending on his speed of learning. During that time, the apprentice works for free, but is given free housing and catering. Additionally, he receives a considerable amount of tools and a small budget to start up his own business after his education. Normally this start-up-package is worth around 300$. In the past, most apprentices did not start their own businesses but stayed with the enterprise as paid technicians. In addition to this apprenticeship system, technicians also receive trainings on an irregular basis. Normally training is given when technicians are confronted with new technologies so that they have to build up their technical knowledge as well. Usually, this kind of training is organised by the market association and lasts 1 or 2 days.*

Salaries

Collect information on the salary / income of the various staff members, including the type of payment and possible variations of income (e.g. advance payment, performance-linked payment, bonus- malus-systems)

<u>Example:</u> *The repair personnel are paid per outcome: For each repaired mobile phones, a persons receives a certain amount of money from the enterprise ($ 0.50 for normal repairs, $ 0.75 for difficult repairs).The money is paid to the workers on the end of every month. If a worker damages a valuable mobile phone or an important working tool, the resulting losses are deducted from his salary.*

<u>Caution:</u> *This topic touches sensitive issues. Therefore this section should be addressed more indirectly after having built up a certain level of trust. Be aware that workers may serve as alternative information sources.*

Salaries in relation to living expenditure

Collect information on whether the salaries are sufficient to secure a basic living standard (housing, food, transport, clothing, medication, education, social participation). Besides the subjective statements of the employees, the introduction of a proxy indicator might be useful. One proxy indicator could be the question on school fees: ‘Is the salary enough to cover the school fees for the children?’ Although the answer depends on a variety of factors, including the number and age of the children, it might be an interesting means to verify initial statements.

<u>Example:</u> *The employees are mostly satisfied with their income. Although they claim not to be rich, they are all able to afford a certain standard of living including some prestige goods like large flat-screen TVs or motorbikes. For all staff, the earnings are sufficient to cover the school fees for their children.*

Working hours

Collect information on average daily, weekly and monthly working hours, including information on daily and weekly rest periods and annual paid and unpaid holidays. Also include information on working time in peak seasons (overtime) and low seasons (e.g. underemployment).

Example: *From Monday to Saturday, workers and management normally start working at 8am and finish at 5pm. Sunday is off. There is a 1 hour lunch break and two or three 15 minute breaks for smoking and tea distributed over the day. In peak seasons, i.e. after purchasing a new batch of used mobile phones, work typically continues after a 1 hour dinner break and continues until 10 or 11pm. In turn, work in low seasons is quite relaxed with many workers only working half day. Apart from the official holidays (national holidays, religious holidays) there is no paid holiday in this enterprise. Nevertheless, employees can take some days off in cases of emergency (e.g. family reasons, health reasons). This kind of leave is normally unpaid.*

Employment turnover

Give information on the typical length of the employments.

Example: *The repair personnel are typically working for the enterprise for long terms. One engineer has been working for the enterprise since its foundation in 2002. All others were employed as the enterprise grew bigger. Only one engineer suddenly didn't turn up again. Maybe he found some other job or returned to his home village.*

Job satisfaction

Collect information on the employees' satisfaction with their business.

<u>Example:</u> *The workers employed in the enterprise consider their jobs as quite prestigious as they regard themselves as somehow 'close to high-tech'. Additionally, the jobs are relatively safe and better paid than other available jobs in this region.*

INFORMATION ON THE BUSINESS SECTOR

General sector information

Collect information on the size, structure and functioning of the sector.

<u>Example:</u> *There are numerous mobile phone repair shops in this town. The area around harbour market is one of the two local centres of this industry. The other centre is located in the western outskirts of town on the road to Ruwade. Most repair shops are much smaller than this one (only 1 or 2 people), but there are also 5 or 6 enterprises of roughly the same size. Most of the small repair shops are not registered. This repair shop and some of the bigger competitors are the only official mobile phone repair enterprises in town. In addition, there are around 100 computer repair shops around harbour market. But these repair shops do not engage in the mobile phone business.*

Information on upstream sectors

Collect information on the size, structure and functioning of upstream activities.

Example: *The used and scrap mobile phones purchased for the repair business are sold by some few dealers that have their offices in the harbour area. These dealers not only trade with used mobile phones, but also with other used goods like furniture, computers and cloths. Most of the traded goods are imported via the harbour.*

Information on downstream sectors

Collect information on the size, structure and functioning of downstream activities.

Example: *The repaired mobile phones are mostly sold to a loose network of street vendors. The enterprise serves about 20 vendors that mostly focus on mobile phones, but also sell other products (e.g. batteries, calculators). Another group of roughly 20 vendors purchase mobile phones on an irregular basis. These vendors mostly run small shops with a broad variety of goods. The scrap from unrepairable mobile phones is sold to one scrap dealer who runs a recycling operation close to the harbour.*

INFORMATION ON THE LOCATION AND THE NEIGHBOURING COMMUNITIES

The following section addresses the surrounding of the assessed enterprise. Apart from interviews, visual inspections should be used for the collection of information.

Local setting

Describe the location in which the enterprise is operating. Include information on the local social set-up, the population density and other types of businesses.

Example: *The enterprise is located in a densely populated quarter. Cheap one- or two-floor buildings dominate the quarter, which is mainly populated by people that just recently moved from the country into the city. The quarter's main business sector is the repair and resale of electronic equipment (mobile phones, TVs, electric fans, computers, refrigerators). While the main traffic routes are flanked by shops and populated by street vendors, backyards are used for repair activities. There are still some small agricultural areas. There, corn and vegetable are grown for local consumption. Nevertheless, farming is only a side business of some few people.*

Water supply & sanitation

Give information on the water supply and sanitation of the enterprise

Example: *The enterprise is connected to the city's water supply and sanitation system and has 4 tabs and one toilet.*

Waste management

Describe the waste management practices. Especially address the waste stream that is generated by the assessed enterprise.

Example: *Household waste and waste generated by the repair businesses are collected by collectors and transported to a nearby field where the waste is sorted. Valuable fractions like metals and plastic bottles are sold to waste dealers. Other fractions are disposed of on one side of a field and the banks of a small waterway. There are many youths and children amongst the collectors.*

COMPLEMENTARY INFORMATION

Add any other complementary information / impression gained during the assessment. Note any additional information that might be of interest.

Example: *The relation between the manager and his staff seemed to be very friendly. The mutual support and trust between employees and management appeared to be strong. Furthermore, the manager seemed to be interested in exploring new business niches, where he could earn additional profits without neglecting his core business. The manger once mentioned that the direct neighbours complained about the smoke from the plastic waste that was formerly burnt in the backyard of the enterprise. Now, the enterprise does not burn waste any more, but sells everything to a waste dealer.*

Annex II: Checklist to identify health and safety risks

Checklist for obvious health and safety risks which arise during the refurbishing and recycling of electric and electronic equipment.

Product / component	Health hazards during refurbishing and recycling operations
Printers & toner cartridges	Emissions from toner dust and ink. Direct contact with toner dust and ink should be avoided.
CRT monitors	Damage to the tube leads to the emission of hazardous dust. In addition, CRT glass is penetrated with lead so that broken and pulverised CRT glass might cause lead emissions.
LCD monitors (flat screens)	Damages to the backlights of the screens can lead to the emission of mercury.
Electric and electronic equipment in general	Fumes from soldering operations (these fumes should not be inhaled)
Plastics from electric and electronic equip-ment	Most plastics from electric and electronic equipment are penetrated with partly hazardous flame retardants. Therefore, melting and burning of these plastics release substantial amounts of hazardous substances. Additionally, dust from breaking and crushing of plastics can lead to the emission of hazardous dusts.
Copper-containing parts in conjunction with plastics	In order to recover copper, the burning of cooper-containing parts and cables is quite widespread in many countries. During the incineration of plastics and especially PVC, significant amounts of hazardous substances are emitted.
Printed circuit boards	In some countries, recyclers extract precious metals from printed circuit boards by acid leaching. This process holds many health and safety risks.
Batteries of electric and electronic equipment	Damages to batteries can lead to the emission of hazardous substances.