10 April 2013

Solving the E-Waste Problem (StEP) Green Paper

E-waste Country Study Ethiopia

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SOLVING THE E-WASTE PROBLEM

ISSN: 2219-6579 (Online)
ISSN: 2219-6560 (In-Print)

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Acknowledgements

We take pleasure in thanking those StEP members and external experts who have actively contributed to the development of this StEP Green Paper.

- Isack Amare, Director of Private Sector ICT Development Coordination Directorate, Ministry of Communication and Information Technology (MCIT), Ethiopia
- Wondwossen Sintayehu, Director Environmental Management Systems, Environmental Protection Authority (EPA), Ethiopia
- Gezahegn Chalchisa, MCIT, Ministry of Communication and Information Technology (MCIT), Ethiopia
- Dereje Masresha, Manager of the Demanufacturing Facility (DMF), Ethiopia.

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by

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Acronyms

ABS	Acrylonitrile butadiene styrene
AG	Advisory Group
AU	African Union
CFL	Compact fluorescent lamp
CRT	Cathode ray tube
CRTC	Computer Refurbishing and Training Centre
DMF	Demanufacturing Facility
EEE	Electrical and electronic equipment
EEWoG	Ethiopia E-waste Management Working Group
EPA	Environmental Protection Authority, Ethiopia
EPCO	Ethiopian Electric Power Corporation
GDP	Gross domestic product
GEF	Global Environment Facility
GNI	Gross national income
IBLF	International Business Leaders Forum
ICT	Information and communication technology
ICT4D	Information and Communication Technology for Development
MCIT	Ministry of Communication and Information Technology, Ethiopia
MoFED	Ministry of Finance and Economic Development, Ethiopia
PAN	Pesticide Action Network
PPP	Purchasing power parity
PVC	Polyvinyl chloride
PWB	Printed wiring board
SC	Steering Committee
StEP	Solving the E-waste Problem Initiative
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
UNU	United Nations University
USEPA	United States Environmental Protection Agency
WEEE	Waste electrical and electronic equipment (also known as “e-waste”)

Exchange rate: 100 Birr = USD 5.52

Executive Summary

The Solving the E-waste Problem (StEP) Initiative and the United States Environmental Protection Agency (USEPA) have established a formal partnership focusing on the development of a sound e-waste management system for Ethiopia. In service of this goal, this study was carried out by Öko-Institut and PAN-Ethiopia in order to generate reliable data on e-waste volumes and current management practices and options, as well as to investigate possibilities for improved e-waste management and other relevant aspects.

The study shows that the use of many types of electrical and electronic equipment (EEE) in Ethiopia is mostly restricted to urban centres, as the lack of electricity and purchasing power in rural communities often hampers the use of devices such as TVs, refrigerators and computers. Nevertheless, these rural communities do make use of battery-powered devices such as torch lights and radios. Thus, e-waste generation in Ethiopia reflects the existing rural-urban disparities with small e-waste volumes in rural areas (predominantly waste batteries, radios and torch lights) and a much broader e-waste mix in urban communities.

The analysis also revealed that e-waste is not yet a major source of environmental pollution or health and safety impacts in Ethiopia. Compared to other African countries such as Ghana and Nigeria, the volume of end-of-life EEE is still quite moderate and – even more important – there are no indications that unsound recycling and disposal are practiced systematically. Although there are some hints that e-waste is disposed of in an uncontrolled manner, the majority of obsolete EEE is currently stored in government premises, offices, international organizations and households or awaiting future solutions. An estimation based on previous work carried out by PAN-Ethiopia in 2011 suggests that, in the country's 10 largest cities, this stored volume reached more than 4,300 tonnes of non-functional computers, TVs, mobile phones and refrigerators.

Nevertheless, this situation also requires action as market penetration of EEE is rapidly increasing. In recent months, four companies started mobile phone production in Ethiopia, thus underlining the fact that the country is increasingly regarded as an important consumer market and manufacturing base. Ethiopia is one of the fastest growing economies in Africa. As such, consumption and disposal patterns will change rapidly in the near future. As consumer electronics become common in Ethiopia, devices such as computers, mobile phones and TVs will no longer be regarded as luxury goods. The willingness to store such obsolete devices will thus decrease and e-waste volumes will increase. It is therefore of high importance to prepare for this situation by installing adequate collection and recycling systems and defining aspects related to policy and legislation, finance mechanisms, monitoring and control, and awareness-raising measures.

While there is no fully functional e-waste management system in place yet, some promising efforts can serve as important starting points for developing environmentally-sound e-waste management systems. The most relevant initiative is the Demanufacturing Facility (DMF) located 30 km south of Addis Ababa in Akaki. This facility, managed by the Ministry of Communication and Information Technology (MCIT), collected 17,162 devices such as computers, typewriters, printers and copy machines from federal government offices between October 2011 and December 2012. The collected devices have partly been dismantled and the DMF is currently searching for downstream markets and solutions for the various output fractions (steel, aluminium, cables, printed wiring boards, plastics etc.).

It is highly recommended that this initiative be strengthened by, for example, expanding e-waste collection, optimizing pre-processing and storage, widening the scope of collection and management efforts to other types of EEE, and developing solutions for non-valuable fractions.

In addition to supporting the DMF, environmentally-sound e-waste management in Ethiopia requires a national e-waste strategy, which should be based on existing regulative frameworks and initiatives. In addition, such a strategy shall take into account aspects related to (1) policy and legislation, (2) business and finance mechanisms, (3) recycling technology, skills and downstream markets, (4) monitoring and control, and (5) marketing and awareness.

It is also advised that Ethiopia follows international legislative efforts to reduce adverse environmental impacts in the life cycle of electrical and electronic products. This could, for example, be achieved by aligning with regulations such as the European RoHS Directive banning the use of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ether (PBDE) in EEE.

A national e-waste strategy should also consider the need for a financing mechanism, as the costs of e-waste collection, recycling and disposal are usually not fully covered by the revenues from material recovery. It is recommended that such a financing mechanism be based on the principle of extended producer responsibility (EPR), in which producers and importers take responsibility for their share of the annual e-waste generated in the country. This share should be equivalent to the amount of EEE they put on the Ethiopian market during a defined time period.

1 Introduction

The Solving the E-waste Problem (StEP) Initiative, hosted by United Nations University (UNU), and the United States Environmental Protection Agency (USEPA) established a formal partnership in late 2010 in order to help countries address the problems created by waste electrical and electronic equipment (e-waste). Among the various e-waste-related issues to be addressed in this partnership is the e-waste situation in Africa, including Ethiopia. In October 2011, under this partnership, national and international experts and decision-makers gathered for a two-day meeting in Addis Ababa, where they agreed to establish the “Ethiopia E-Waste Management Working Group” (EEWoG), consisting of a Steering Committee (SC) based in Ethiopia and an international Advisory Group (AG). The SC is made up of local stakeholders, mainly representatives from the Ethiopian EPA, Ministry of Communication and Information Technology (MCIT) and other Governmental organizations, as well as academia and NGOs. The AG consists of non-Ethiopian experts from various organizations. The SC is responsible for initiating and controlling e-waste-related activities in Ethiopia that are carried out under this cooperation. The AG will support the SC with expertise and knowledge transfer.

In order to build a strong foundation for the development of Ethiopia’s e-waste management strategy, it was deemed necessary to generate reliable data on e-waste volumes and current management practices and options, as well as to investigate possibilities for improved e-waste management and other relevant aspects.

While some of these requirements were already met by studies previously carried out by PAN-Ethiopia (2012) and Öko-Institut (2011), many aspects required further investigations and/or extrapolations to the whole of Ethiopia.
This study was jointly carried out by the Germany-based Öko-Institut e.V. and PAN-Ethiopia, an Ethiopian NGO. It aims to fill key knowledge gaps and provide a more solid base for further decision making. It also contains recommendations supporting the work of the EEWoG, as well as the implementation of the upcoming Global Environment Facility (GEF)-funded project titled “Investment Promotion on Environmentally sound Management of Electrical and Electronic Waste”.

The information contained in this report is derived from existing literature sources and statistics, interviews conducted in Ethiopia, and field assessments in Addis Ababa in August 2012.

2 Ethiopia: Facts and geographic overview[1]

Figure 1 Shaded relief map of Ethiopia (Source: University of Texas Libraries, Perry-Castañeda Library Map Collection)

[1] The following section is widely based on data provided by the CIA World Fact book (CIA 2012)

The Federal Democratic Republic of Ethiopia is located on the horn of Africa and shares borders with Eritrea, Djibouti, Somalia, Kenya, South Sudan and Sudan. The landlocked country covers an area of 1.1 million km^2, roughly equalling the size of Germany and France together.

Apart from the plains in the eastern and southern parts of the country, Ethiopia's terrain is mountainous, with high plateaus and mountains reaching up to 4,533 m (Ras Dejen). The Great Rift Valley, running from the northeast (Denakil Depression) to the south, is a main geographic feature separating the country's eastern mountain regions from the western and northern ones.

Table 1 Selected figures and indicators for Ethiopia

Indicator	
Area	1.1 million km^2
Population	91 million
Population growth rate	+ 2.9% per year
Urban population	17% of total population
Biggest city	Addis Ababa (3 million inhabitants)
GDP per capita	USD 1,100
GDP growth	+ 7.5% (2010)
GDP composition by sector	agriculture: 46.6%; industry: 14.5%; services: 38.9%

Despite significant growth in the country's GDP in recent years, Ethiopia is still classified as one of the world's least developed countries (UN-OHRLLS 2010), with 39 per cent of the population living on less than USD 1.25 per day (see Table 1). The economy is largely based on agriculture, which employs 85 per cent of the country's workforce.

Road-based transport infrastructure significantly improved over the last decade. The railway line connecting Addis Ababa with the port country of Djibouti does not provide reliable service. Generally, distances, terrain and infrastructure make trade with neighbouring countries difficult. Due to political disputes with Eritrea, border crossing and transboundary trade between the two countries are currently not possible. The ports in Djibouti and Somalia (Berbera) are used to serve international sea trade.

3 Electrical and electronic products in Ethiopia

3.1 Development, infrastructure and ICT penetration

The development indicators in Table 2 and Table 3 provide important background for framing the current e-waste situation in Ethiopia.

The data in these tables allow for some initial assertions regarding the use of electrical and electronic products within the country.

Table 2 Selected development indicators for Ethiopia and other African countries

Indicator	Unit	Year of data	Ethiopia	Djibouti	Sudan	Kenya	Nigeria	Ghana	South Africa
Human Development Index	rank	2011	174	165	169	143	156	135	123
Human Development Index	value	2011	0.363	0.430	0.408	0.509	0.459	0.541	0.619
Population below income poverty line	% of population with less than PPP USD 1.25 a day	2000-2009	39	18.8	no data	19.7	64.4	30	17.4
Urban Population	% of total population	2011	16.8	76.3	40.8	22.5	50.5	52.5	62.2
Adult literacy rate	%	2005-2010	29.8	no data	70.2	87.0	60.8	66.6	88.7
Primary enrolment ratio	% gross[2]	2001-2009	102.5	54.5	74.0	112.7	89.5	105.2	101.2
GNI	PPP $ billions	2011	94.3	no data	no data	71.7	374.1	45.5	545.7
GDP growth	average annual growth rate	1970-2008	1.3%	-2.1%	1.9%	0.5%	1.0%	1.1%	0.6%
Population without electricity	%	2008	85.1	no data	65.3	84.6	53.3	47.1	24.2

Source: UNDP 2010, UNDP 2011, World Bank 2011

Table 3 Selected ICT development indicators for Ethiopia and other African countries

Indicator	Unit	Year of data	Ethiopia	Djibouti	Sudan	Kenya	Nigeria	Ghana	South Africa
Mobile-cellular telephone subscriptions	per 100 inhabitants	2011	16.67	21.32	56.25	64.84	58.58	84.78	126.83
Annual growth rate of mobile-cellular telephone subscriptions	% (population-based)	2006-2011	71.0	31.4	36.4	26.4	21.0	29.3	9.1
Population covered by mobile phone network	%	2008	10	85	66	83	83	73	100
Individuals using the internet	%	2011	1.10	7.00	19.00	28.00	28.43	14.11	21.00
Annual growth rate of individuals using the internet	% (population-based)	2006-2011	28.8	40.7	18.6	30.0	38.7	39.0	22.5
Fixed (wired) broadband subscriptions	per 100 people	2011	0.03	1.25	0.04	0.12	0.13	0.25	1.80
Households with a computer	%	2010	1.38	13.01	No data	No data	8.00	9.14	18.33

Source: ITU 2012, UNDP 2010

[2] Values can exceed 100 per cent due to the inclusion of over-aged and under-aged students because of early or late school entrance and grade repetition.

- 39 per cent of the country's population live on less than USD 1.25 per day. These people are very likely not in the position to purchase any type of electrical and electronic equipment apart from very basic devices such as torch lights.
- 64.1 per cent of the adult population is illiterate; this means that almost two-thirds of the adult population are precluded from using information and communication technologies such as computers. Nevertheless, the net primary school enrolment ratio is very high in Ethiopia, suggesting that the literacy rate will increase significantly in the near future.
- In 2008, 85 per cent of Ethiopia's population was not connected to an electricity supply. Thus, the majority of the population – and especially the rural population, which almost uniformly lacks access to an electricity supply – cannot make use of many types of electric and electronic equipment such as refrigerators, computers or televisions. It should be noted, however, that many households without access to an electricity supply may have access to batteries and/or solar panels, thus allowing them to use devices such as radios, torches and mobile phones.
- According to official statistics from 2008, only 10 per cent of Ethiopia's population lives within an area that is covered by a mobile phone network, meaning that 90 per cent of the population could make little use of mobile phones in daily life. Nevertheless, coverage has since increased at rapid pace. As of mid-2012, mobile phone network coverage had reached 75-80 per cent of the country's territory (Gezahegn 2012).
- In 2011, 16.67 per cent of Ethiopians subscribed to mobile phone services. While this rate is below the rates of other African countries, Ethiopia's extremely high growth rate in mobile-cellular telephone subscriptions means that it will soon catch up with other African countries in terms of mobile phone usage. The trend toward greater mobile phone usage is facilitated by the availability of affordable handsets with Amharic language software (see Section 3.2), inexpensive SIM cards[3] and pre-paid air-time available for as little as Birr 10 (USD 0.55). In total, Ethio Telecom has already given out 15.9 million SIM cards. However, not all of these cards are still active, as they are usually taken out of service once they are not used for a certain period of time (Gezahegn 2012)[4].
- In 2010, only 1.38 per cent of Ethiopian households owned a computer. Nevertheless, the annual growth rate of individuals using the internet is quite high, averaging over 28.8 per cent between 2006 and 2011, suggesting that the general demand for computers and household internet access will likely increase. It is thus likely that further economic growth will lead to increased household penetration by computers and other ICT equipment.

These indicators suggest that Ethiopia's generation of e-waste is still relatively low. As government bodies and other types of offices (e.g. banks, businesses, NGOs) have until recently been the dominant consumers of electrical and electronic equipment, they are currently the most significant sources of e-waste in the country. Nevertheless, the rapid penetration of ICTs in Ethiopian society will soon alter this picture to a more heterogeneous e-waste situation.

[3] The purchasing price for a SIM-card is 45 Birr (USD 2.48), which already includes 15 Birr air-time. Besides these costs, customers have to register and provide two passport-sized portrait photographs and a copy of their passport.

[4] As a consequence, the number of SIM-cards (15.9 million) is not identical with the numbers of mobile phones in active use in Ethiopia.

Furthermore, it can be asserted that e-waste is mostly generated in urban areas and not in rural settlements. Table 4 gives an overview on the Ethiopian cities with more than 100,000 inhabitants as of 2006 and indicates which cities PAN-Ethiopia included in its e-waste survey (see PAN-Ethiopia 2012).

Table 4 Major cities in Ethiopia

Rank	Name	Estimated population for 1 July 2012	Region	Detailed e-waste assessment by PAN-Ethiopia available
1	Addis Ababa	3,040,740	Addis Ababa	X
2	Mekele	273,601	Tigray	
3	Adama	271,562	Oromia	
4	Dire Dawe	262,884	Dire Dawe	X
5	Gondar	254,450	Amhara	
6	Awasa	212,665	SNNPR	X
7	Bahir Dar	191,015	Amhara	X
8	Jimma	149,166	Oromia	
9	Dessie	147,592	Amhara	
10	Jijiga	147,482	Somali	

Source for population data: Central Statistical Agency of Ethiopia cited after Wikipedia 2012

With 3 million inhabitants, Addis Ababa is by far Ethiopia's largest city and home to 40 per cent of the country's urban population. It is well connected to all major overland routes within the country and head of the (currently non-functioning) railway line that connects Ethiopia with the port country Djibouti. In addition, Addis Ababa is Ethiopia's capital and its economic centre. The city also hosts the African Union (AU) and, along with Nairobi, is one of only two cities in Africa to serve as a centre for the United Nations (UN), thus signalling the city's regional and global political importance. Furthermore, Addis Ababa is host to embassies from most foreign governments, as well as offices of many development agencies and NGOs. With its large population and role as a political and economic centre, Addis Ababa is also the city with the highest demand for EEE and generates the most e-waste in Ethiopia.

Exemptions from the urban-rural disparities in the use of EEE are battery-powered devices such as torch lights and radios/cassette players. It has been reported that more than 300 million dry cell batteries are consumed in Ethiopia annually (UNIDO 2010). As many households are not connected to an electricity supply, they make use of low-price, non-rechargeable standard batteries. These batteries often feature short lifetimes and contain heavy metals such as lead or cadmium.

Finally, efforts to promote decentralised rural electricity supply often use solar panel installations coupled with lead-acid battery storage systems. Once obsolete, these systems (and in particular the lead-acid batteries) are of high environmental and health concern.

3.2 Manufacturing and imports

There are various producers of EEE located in and around Addis Ababa and Bahir Dar. These producers primarily assemble mobile phones from imported parts and components. Currently, all producers focus on the domestic mobile phone market. The following producers are of particular relevance:

- Tecno Mobile Ethiopia: Tecno Telecom Ltd. is a Hong Kong-based mobile phone manufacturer that launched operations in Ethiopia in September 2011 with a capital investment of more than USD 1 million. The company started producing the first smartphone model in Ethiopia in mid-2012 and employs around 300 local and 15 foreign people. Tecno Telecom's Ethiopian production focuses on providing mobile phones with Amharic language applications, which is realised by the Ethiopian company Information Technology Transfer Services (ITTS) (2Merkato.com 2012; extensia 2012).

- Tana Communications is an Ethiopian company that provides mobile phones with Amharic software to the Ethiopian market. Software development and manufacturing are based in Bahir Dar. Production started in the first quarter of 2011; by February 2012, the company had produced 50,000 handsets. Currently, the plant employs around 200 people, 80 per cent of whom are women. The phones, which are targeted at the low-price market, are sold for Birr 370 (USD 20) on the Ethiopian market (Ezega 2012).
- Smadl is a Chinese company that started mobile phone manufacturing operations in Ethiopia in July 2011. The facility is located around Gerji and employs around 100 local workers in the assembly process (extensia 2012).
- Geotel is a manufacturer of mobile phones that recently started production in Ethiopia. The first domestically-produced mobile phones from Geotel were planned to be out on the market in late August 2012.
- Until some years ago, Vestel operated a TV-assembly facility in Alem Gena in the southwest of Addis Ababa. The production was terminated because of declining demand for cathode ray tube (CRT)-TVs.
- Sheba Cable & Wire Industries (linked to All African Steel Mills, see Section 1.1) maintains a cable and wire production facility in Akaki Kality.

In addition to these enterprises, more investments might be made in the future. As an example, there is an IT park under construction near the Bole-Airport in Addis Ababa. This IT park is intended to host companies engaged in IT services, software development and manufacturing (Gezahegn 2012).

While manufacturers located in Ethiopia provide some of the EEE consumed in the domestic market, the vast majority of EEE on the Ethiopian market is imported. The following companies and structures characterise this influx:

- Glorious is the only authorised Ethiopian distributor of many electrical and electronic products manufactured by brands such as Ariston, Sony, Hitachi and Philips. It imports and distributes EEE and maintains a wholesale centre and six retail showrooms in Addis Ababa, as well as one in Nazareth. In addition, the company supports subsidiary branches in Harar and Dire Dawa, as well as a network of sub-agents. Today, the company directly employs around 250 workers at various professional levels (Glorious 2012).
- Garad is the exclusively authorised Ethiopian distributor of Samsung products and maintains various distribution and retail shops in the country.
- According to Ezega (2012), about 80 per cent of the mobile phones on the Ethiopian market are illegally smuggled into the country, in part to avoid paying the high import taxes. According to independent experts, other types of electronic equipment have until recently also routinely been il-

legally imported from Djibouti and Somalia (via Jijiga). Recently, stricter customs enforcement seems to have reduced illegal import flows.

- EEE from brand name companies, such as LG, Philips and Samsung, is imported and distributed via agents who maintain shops and showrooms in all major cities.
- Due to rapidly rising demand for ICTs, major companies such as HP and MTN opened distribution and service offices in Addis Ababa in 2012 (Gezahegn 2012).
- A significant volume of ICT equipment is also imported and distributed under the auspices of ICT4D-projects[5]. For example, the project “One Laptop Per Child” imported and distributed 5,900 XO-laptops to Ethiopian schools[6].
- In conjunction with efforts to bring electricity to rural households and to overcome the problem of electricity shortages, the Ethiopian Government launched various energy access projects, which were supported in part by the World Bank. One of these projects includes the import and distribution of 5 million compact fluorescent lamps (CFLs) in exchange for incandescent bulbs (Öko-Institut 2011). The CFLs are given to the Ethiopian Electric Power Corporation (EPCO), who then sells the devices to rural consumers at well below market price.

Regarding import and refurbishing of used computers, the **Computer Refurbishment and Training Centre (CRTC)**, managed by the Ministry of Communication and Information Technology (MCIT), deserves special attention. The centre is located in Akaki, 30 km south of Addis Ababa, and was built up by the Government of Ethiopia, financed by the World Bank and consulted by the International Business Leaders Forum (IBLF)-digital partnership. The Centre imports and refurbishes high quality used computers from Europe and North America to supply the Ethiopian market with affordable ICT equipment. The CRTC has imported more than 10,000 used computers, and 7,068 of them were refurbished and provided to Ethiopian organizations (e.g. schools, health facilities and community based organizations). Between September 2011 and June 2012, the Centre delivered 1,229 complete computer systems to Ethiopian organizations. In addition to the import, refurbishment and distribution of ICT equipment, the CRTC provides vocational training on hardware and software, as well as on business management. Finally, the Demanufacturing Facility (DMF) was established next to the refurbishment centre in order to provide a solution for waste ICT equipment put onto the Ethiopian market (see Section 4.4).

The project establishing the CRTC and the DMF was carried out between 2006 and 2010. It was financed by the World Bank and the Ethiopian Government. As the refurbishment centre achieved full cost-recovery conditions in 2010, operations now continue beyond the actual project phase. Recently, the CRTC expanded its activities on refurbishing used computers from domestic sources. This effort is synchronised with the e-waste collection activities organized by MCIT (see Section 4.3), which led to an influx of 17,162 used and obsolete EEE, mostly from Ethiopian Government offices, between October 2011 and December 2012, nearly 700 of which were refurbished. The remaining

[5] ICT4D = Information and Communication Technology for Development

[6] The project One Laptop Per Child (OLPC) was initiated in Ethiopia in 2008 and is run by a US non-profit organization of the same name. It focuses on the development, construction and distribution of robust, low-cost laptops to be used in developing countries. In Ethiopia the project was implemented by former GTZ (now GIZ) and the Engineering Capacity Building Program (ECBP) (OLPC 2011). Since June 2010, the project was taken over by the Ministry of Civil Service (formerly Ministry of Capacity Building.

devices were dismantled or are awaiting dismantling in the nearby Demanufacturing Facility (see Section 4.4).

3.3 Distribution of EEE

Electrical and electronic equipment is mostly sold in small shops distributed all over urban Ethiopia. In Addis Ababa, one major distribution cluster is located in the Kazanchis area, where more than 100 shops sell new and used electronic products such as printers, copy machines, computers and mobile phones.

Photo 1 Electronic equipment retail shops in Kazanchis, Addis Ababa

3.4 Data on stocks and volumes

Globally, there is a paucity of reliable data on the generation, collection, import and export of e-waste, and on e-waste management in general. Environmental impacts and trade of e-waste at local and international levels have driven many countries, particularly developing countries, to take measures to control this situation. Ethiopia has ratified the Basel Convention and, in accordance, has put in place some start-up measures for the management of e-waste.

The rate of e-waste generation in Ethiopia is not well understood or documented, and an inventory was needed to guide future measures that ensure environmentally-sound management of e-waste. Therefore, a survey was conducted in four major Ethiopian cities (Addis Ababa, Bahir Dar, Dire Dawa and Hawassa) focusing on four selected types of EEE: 1) personal computers and related accessories; 2) televisions and related accessories; 3) mobile phones; and, 4) refrigerators.

The work was implemented by the Pesticide Action Nexus Association (PAN-

Ethiopia) under the guidance and direct supervision of the Federal Environmental Protection Authority (EPA), Ethiopia. The full report was published by PAN-Ethiopia in 2012 (PAN 2012).

The survey included respondents from various stakeholder groups, including: households, business entities, academic and research institutions; wholesalers and retailers; government officers; and, maintenance and repair shops.

A random sampling technique was used to select sample households from the four cities after determining the sample size using a single population proportion formula.[7] For all other categories of respondents, all existing institutions in Bahir Dar, Dire Dawa and Hawassa were surveyed. However, this approach was not possible in Addis Ababa due to its large size and its numerous institutions. Thus, total stock numbers could only be calculated for Bahir Dar, Dire Dawa and Hawassa.
This section presents key data and findings from this study. Table 5 shows the stocks and penetration of the four types of EEE in the surveyed entities.

Generally, household ownership of EEE was seen to cut across all income segments in the study. However, the number of electrical and electronic devices owned was larger in the high-income segment. Among commercial entities, the possession of EEE such as personal computers increased with the size of entities, as such equipment is necessary to run their businesses effectively and efficiently. The number of refrigerators, televisions and mobile phones was found to be higher in star hotels and restaurants, though it varied depending on the type of services provided, the number of customers served and the number of hotel rooms they had. In academic and research institutions, the number of personal computers was larger in higher institutions (colleges, universities), the possession of televisions was higher in development institutions, and a large number of refrigerators and mobile phones were found in research institutions. Among government offices and NGOs, ownership of personal computers and refrigerators is higher in governmental organizations, whereas NGOs owned more TVs and mobile phones.

Data on the registered import volumes of the four types of EEE covered in the survey was obtained from the Ethiopian Revenue and Customs Authority. Table 6 shows the number of electrical and electronic devices legally imported into Ethiopia mid-2004 until the time of inventory in 2011.

The data of Table 6 show a dramatic spike in mobile phone imports in 2006, followed by a sharp decline in 2007. One possible explanation for this spike and decline is that Ethiopia has only one mobile phone service provider, which lacks capacity to meet public demand for mobile phones. Thus, it is possible that fluctuations correspond with the level of service provision in a certain time period. Another possible explanation is that the peak import number in 2006 caused temporary market saturation, leading to reduced import numbers the following year.

While these numbers provide some insights into the growth rate of the EEE stock in Ethiopia, they only tell part of the story. A significant share of EEE is smuggled into the country (see Section 3.2), thus rendering official import data insufficient for estimating total stock numbers.

[7] Further details on the methodological approach are laid out in the original project document (see reference PAN 2012).

Table 5 Number of devices present in the various types of entities in the four surveyed cities[8]

City	Entity	Number of computers & accessories	Number of TVs & accessories	Number of mobile phones & accessories	Number of refrigerators & accessories
Bahir Dar	Households (n=422)	76	585	840	240
	Research institutions (n=32)	13,828	254	38	104
	GOs & NGOs (n=105)	7,723	219	296	92
	Businesses (n=233)	1,206	612	53	412
	Wholesalers & retailers (n=58)	589	157	1,960	222
Dire Dawa	Households (n=422)	699	331	920	298
	Research institutions (n=15)	588	14	32	29
	GOs & NGOs (n=60)	1,461	165	68	127
	Businesses (n=301)	2,934	128	2,703	599
	Wholesalers & retailers (n=34)	370	539	2,020	131
Hawassa	Households (n=422)	375	636	901	222
	Research institutions (n=33)	3,508	151	41	44
	GOs & NGOs (n=155)	10,086	237	276	191
	Businesses (n=450)	2,947	928	486	534
	Wholesalers & retailers (n=89)	315	558	1,674	109
Addis Ababa	Households (n=409)	169	265	647	243
	Research institutions (n=272)	43,614	1,385	126	654
	GOs & NGOs (n=123)	33,510	792	578	241
	Businesses (n=403)	2,126	711	47	130
	Wholesalers & retailers (n=251)	8,740	2,667	7,196	591
Total (4 cities)	**Households (n=1675)**	**1,319**	**1,817**	**3,308**	**1,003**
	Research institutions (n=352)	**61,538**	**1,804**	**237**	**831**
	GOs & NGOs (n=443)	**52,780**	**1,413**	**1,218**	**651**

[8] The numbers indicated in the table represent only the number of devices identified in the surveyed entities and do not represent total stock numbers.

City	Entity	Number of computers & accessories	Number of TVs & accessories	Number of mobile phones & accessories	Number of refrigerators & accessories
	Businesses (n=1387)	9,213	2,379	3,289	1,675
	Wholesellers & retailers (n=432)	10,014	3,921	12,850	1,050
Grand total	(n=4289)	134,864	11,334	20,902	5,210

Source: PAN 2012

Table 6 Total number of electrical and electronic devices legally imported into Ethiopia, 2004-2011

Year[9]	Number of computer & accessories	Number of TVs & accessories	Number of mobile phones & accessories	Number of refrigerators & accessories
2004	41,974	21,388	17,179	5,620
2005	387,642	204,672	310,633	55,662
2006	331,939	342,201	1,051,048	77,051
2007	520,889	390,677	50,507	89,306
2008	260,025	333,683	193,728	116,921
2009	331,303	411,307	379,980	98,245
2010	284,005	490,779	429,644	122,641
2011	263,116	177,047	346,084	53,368

Source: PAN 2012

Table 7 Estimated number of EEE in use in private households in four selected cities in 2011

	Personal Computers	TVs	Mobile Phones	Refrigerators
Addis Ababa	322,165	505,170	1,233,377	463,231
Bahir Dar	8,820	67,896	97,492	27,855
Dire Dawa	111,651	52,870	146,952	47,600
Hawassa	48,456	82,182	116,425	28,686

Source: PAN 2012

Table 8 Estimated number of EEE in use in private households in the 10 largest cities of Ethiopia in 2011 (rounded)

Type of equipment	In-use stock in private households in the 10 largest cities of Ethiopia in 2011
Personal Computers	656,000
TVs	946,000
Mobile Phones	2,129,000
Refrigerators	758,000

Calculated on the basis of data from PAN 2012

Table 9 Estimated stock of non-functional equipment in three selected cities in 2011 (number of devices)

	Personal Computers	TVs	Mobile Phones	Refrigerators
Bahir Dar	4,908	451	912	97
Dire Dawa	6,531	1,188	3,040	886
Hawassa	2,839	328	637	151

Source: PAN 2012

[9] The data for the years 2004 and 2011 is incomplete and do not cover the entire year.

Table 10 Estimated stock, by weight (kg), of non-functional equipment in three selected cities in 2011

	Personal Computers	TVs	Mobile Phones	Refrigerators
Bahir Dar	147,000 kg	15,800 kg	90 kg	6,800 kg
Dire Dawa	196,000 kg	41,600 kg	300 kg	62,000 kg
Hawassa	85,200 kg	11,500 kg	60 kg	10,600 kg

Source: PAN 2012

Table 11 Estimated total stock, by weight (kg), of non-functional equipment in Ethiopia's 10 largest cities in 2011

Type of equipment	Stock of non-functional equipment in the 10 largest cities of Ethiopia in 2011
Personal Computers	3,200 t
TVs	510 t
Mobile Phones	3 t
Refrigerators	590 t
Total	**4,300 t**

Source: PAN 2012

Based on the household survey carried out by PAN-Ethiopia, the EEE stock in private households can be calculated for four Ethiopian cities (see Table 7).

If the data presented in Table 7 are extrapolated to Ethiopia's 10 largest cities using the population data presented in Table 4[10], this yields an estimated in-use stock in private households in 2011 (see Table 8)[11].

Table 9 indicates the estimated number of electrical and electronic devices considered as non-functional and not suitable for repair[12] stored in the various types of surveyed entities in 2011. The data were generated through questionnaire answers indicating the number of stored non-functional devices at the time of the survey.

While these figures could be generated for Bahir Dar, Dire Dawa and Hawassa, no quantifications could be made for Addis Ababa due to resource limitations that made it impossible to achieve representative results.
Taking the actual figures from Table 9, average weights for personal computers, TVs, mobile phones and refrigerators were assumed and used to estimate the stock of non-functional EEE by weight[13] (Table 10).

If the data presented in Table 8 is extrapolated to Ethiopia's 10 largest cities using the population data presented in Table 4[14], this yields an estimated stock of around 4,300 tonnes of non-functional equipment in 2011 (see Table 11)[15].

[10] According to Table 4, the cities of Addis Ababa, Bahir Dar, Dire Dawa and Hawassa are populated by 3,707,304 people (out of 4,951,157 people in the 10 biggest cities). Thus, the volumes of Table 7 were multiplied by the factor of 1.336 (4,951,157 / 3,707,304).

[11] This extrapolation yields indicative values only as socioeconomic structure varies significantly between the various cities.

[12] The figures are associated with some uncertainties mainly resulting from varying definitions of 'non-functional' and 'repairable'. In practice, reparability mostly depends on the level of skills available in a certain location. Thus, interview responses are partly influenced by such subjective and local factors.

[13] Personal computers: 30 kg; TVs: 35 kg; mobile phones: 0.1 kg; refrigerators: 70 kg.

[14] According to Table 4, the cities of Bahir Dar, Dire Dawa and Hawassa are populated by 666,564 people (out of 4,951,157 people in the 10 biggest cities). Thus, the volumes of Table 10 were multiplied by the factor of 7.428 (4,951,157 / 666,564).

[15] This extrapolation yields indicative values only as socioeconomic structure varies significantly between the various cities.

The results obtained from the samples are considered to be sufficiently representative for major urban environments in Ethiopia, taking into account variation in ownership of the four types of EEE across different institutions and the four cities. However, the data do not allow for extrapolation to smaller urban areas or to rural settlements, as socio-economic structures and EEE use patterns diverge significantly from those in urban centres in such environments (see Section 3.1).

In this era of rapidly advancing technologies, EEE has come to be considered a necessity in nearly all segments of society, ranging from individuals to business entities, institutions and industry. Combined with the increasing population and economic projections of continued growth of the country's gross domestic product (GDP), the volume of e-waste in Ethiopia is likely to increase in the future and will require a concerted effort by both the authorities and the public to properly manage its flow.

4 Current e-waste management practices

4.1 Solid waste management situation in Ethiopia

Photo 2 a & b Filled solid waste containers

Waste collection in Ethiopia is mostly restricted to urban areas. The following analysis is based on Addis Ababa, though the levels of organization and infrastructure vary between cities.[16]

Since January 2003, the municipal solid waste service for Addis Ababa was shifted from the Environmental Sanitation Department to a newly-established agency called the Sanitation, Beautification and Parks Development Agency (SBPDA), with power decentralized to sub-city and kebele[17] levels. Currently, the agency has solid waste divisions in all 10 sub-cities and their kebele administrations. In addition to the SBPDA, various civil society associations (youth group associations, women associations, etc.), community-based organization, NGOs, private institutions and governmental organizations (GOs) are also now engaged in different waste management activities. Their activities range from collecting solid waste to composting, re-using and recycling of municipal solid waste.

Currently, the official household waste collection scheme in Addis Ababa makes use

[16] The focus on Addis Ababa was chosen because it is by far the country's biggest city with the highest economic importance. Thus, it is also the most relevant city for developing e-waste related strategies.

[17] Kebele is the smallest unit of urban administration.

of organized groups of collectors, which the municipality pays according to the volume of waste they collect. The costs of this collection are covered by fees charged to households along with their water bills. A household's waste collection fee amounts to two per cent of its water bill. One advantage of this approach to waste collection fees is that household waste generation volumes typically correlate with water consumption, thus allowing for a roughly volume-dependent fee system.

A significant disadvantage of this waste collection system is that it gives a monetary incentive to collectors to focus their collection efforts on high volume waste such as organic waste (grass, leaves etc.).Some of this organic waste does not necessarily need waste treatment. Furthermore, this system provides no incentive for composting.

Source: PAN-Ethiopia 2011

Photo 3 a & b People picking through mixed solid municipal waste in Addis Ababa (left) and Bahir Dar (right)

In Addis Ababa, all waste collected by this household waste collection scheme is disposed at the Reppi dump site (also known as 'Koshe'), located 13 km southwest of the city centre and covering 25 ha. According to Kuma (2004), it has the status of a sanitary landfill. The site was established in 1968 and is still used, despite little remaining capacity. It is surrounded by settlements and spontaneous fires[18] cause local air pollution (Kuma 2004).

In Addis Ababa and other major cities in Ethiopia, almost all households have the habit of separating recyclable or reusable solid waste items that have direct market value. In addition to households, some individuals and informally-organized groups called 'Quorales' carry out waste separation in different areas, including at disposal sites. However, there is no well-organized system or organization that can regularly collect sorted solid waste items.

In Addis Ababa, numerous factories have use for the sorted waste. Facilities that produce paper, plastic, iron, glass and other materials have a high demand for the separated waste, which they use as raw material.

With regards to e-waste, however, households and institutions usually store nonfunctional items. The PAN-Ethiopia survey conducted in 2011 noted that most institutions register all EEE in use. Thus, disposing of old EEE requires deregistering, a process which is not smoothly established in all entities yet.

[18] Spontaneous fires are common on waste disposal sites in Africa. They are caused by congested methane reacting with ambient oxygen in the air. These fires do not require human ignition.

4.2 Repair shops

According to the study conducted by PAN-Ethiopia, a significant volume of the four types of EEE addressed in this report flows to informal repair shops. These repair shops repair the EEE manually using common repair tools such as screwdrivers, voltmeters, hot guns, fans or suckers, and soldering tools. The process starts by conducting tests to identify the problem with the equipment. The repairer then disassembles the equipment's casings to access the internal components that need to be repaired or changed.
When the repair has been done, the equipment is tested before being reassembled to be returned to the owner. If the equipment cannot be repaired, the repair shops usually negotiate to buy it from the owners to use it as a source of spare parts.
According to the survey, the preferred methods for dealing with non-functional computers and other EEE are to store the items or to dispose of them along with other municipal waste.
Most of the maintenance shops said that they were willing to pay for collectors to take away their non-functional electrical and electronic equipment. Most of them were also willing to pay for a pickup service, but they do not care whether the e-waste is actually disposed of properly[19].

4.3 E-waste collection

Currently, there are three types of formal e-waste collection systems in Ethiopia. These can be described as follows:

- The manufactures of mobile phones in Ethiopia (see Section 3.2) partly maintain service centres where damaged phones can be handed in for repair or exchange (extensia 2012). As Ethiopian mobile phone production did not start before September 2011, no significant return volumes can be expected yet.
- The Computer Refurbishment and Training Centre (CRTC) (see Section 3.2) takes back all computers that it distributes in Ethiopia. Once one of the end-of-life computers is brought back to the Centre, it will be sent to the DMF for dismantling. As the CRTC started the distribution of computers only few years ago, the volume of computers taken back remains small at this point.
- As part of the effort to make the Demanufacturing Facility (DMF, see Section 4.4) operational, the Ministry of Finance and Economic Development (MoFED) has written a circular letter to all federal ministries to hand over stored end-of-life EEE to the MCIT, which operates the DMF (EEWoG SC 2012). Following this initiative, 25 offices of the federal government in and around Addis Ababa delivered used and obsolete office equipment to the DMF. Between October 2011 and December 2012, the DMF received 17,162 devices such as computers, uninterruptible power supplies, TVs, mobile phones, typewriters, printers and copy machines (Masresha 2013). So far, the collection effort is mostly focused on offices of the federal government. Equipment from offices from regional government offices and from other sources (e.g. banks, businesses, education-centres, NGOs) is planned to be included in future. The African Development Bank, The World Bank and the World Food Program have also handed over 1,785 pieces of used and end-of-life EEE.

There is no significant informal e-waste collection developed in Ethiopia. This might result from the facts that general e-waste volumes – in particular from private

[19] This attitude might root in a lack of awareness regarding the hazardous nature of many e-waste components.

households – are still moderate (see Section 3.4) and that consumers generally do not give away obsolete devices because they are still considered valuable (Cochrane 2011; PAN 2012).

Nevertheless, observations in Merkato Market in Addis Ababa and the findings from the research carried out by PAN-Ethiopia (2012) suggest that some moderate volumes of e-waste are collected and managed by scrap metal collectors and recyclers (often referred to as 'scavengers'). These collectors and recyclers do not specifically focus on e-waste, but on any type of metal-containing waste. This means that some e-waste is channelled to existing scrap metal markets, which often operate under informal conditions. In the case of EEE such as cables and radios, it was also observed that collectors often cooperate with local repair and second-hand shops in order to increase the resale value from the collected items by providing devices for re-use or as a source of spare parts.

In Addis Ababa, it is estimated that 85 per cent of household solid waste is collected by the formal waste collection scheme (Kuma 2004), and it is likely that some e-waste is collected by formal waste collectors along with other household waste. In addition, PAN reports that uncontrolled e-waste dumping has also been observed in some Ethiopian cities (PAN 2012). In rural Ethiopia, there is no formal collection of waste, which means that e-waste such as end-of-life torches and batteries are disposed of in an uncontrolled manner.

In sum, e-waste in Ethiopia today is generally handled as follows:

- Prolonged storage of e-waste (e.g. office equipment, mobile phones, TVs etc.) in households, offices and governmental premises
- Formal collection of e-waste from governmental offices and delivery to DMF
- Informal refurbishing and recycling of waste items and components (e.g. cables, radios etc.) in and around scrap metal markets
- Uncontrolled dumping of waste items such as batteries, lamps, refrigerators etc.
- Disposal of e-waste along with household waste

Photo 4 Computer dismantling in the Demanufacturing Facility in Akaki

4.4 Pre-processing

There is one pre-processing facility in Ethiopia. Located in Akaki, 30 km south of Addis Ababa, the Demanufacturing Facility (DMF) is managed by the government. The DMF was established in conjunction with, and is located next to, the CRTC (see Section 3.2).

Both facilities are managed by MCIT and work closely together in the fields of e-waste collection and functionality testing. Used and obsolete office equipment from domestic sources is first delivered to the CRTC to undergo quality control. If suitable for re-use, the devices will be treated within the CRTC. If not suitable for re-use, they will be handed over to the DMF for recycling.

The DMF primarily targets obsolete and outdated ICT equipment (e.g. computers) and carries out manual dismantling and sorting. According to Cochrane (2011) and Peters-Michaud (2011), the centre had difficulties acquiring sufficient volumes of e-waste, which severely hampered its operation until autumn 2011. The collection initiative of MoFED and MCIT (see Section 4.3) led to an influx of 17,162 used and obsolete pieces of EEE between October 2011 and December 2012. While dismantling and sorting activities are proceeding, no dismantling output has been delivered to downstream markets yet. Currently, there are more than 18 tonnes of steel scrap and 6.8 tonnes of mixed plastic in stock at the DMF.

The DMF is currently using a building located in Akaki. This building is rented from another government agency and lacks adequate storage capacity. While storage space could theoretically be added inexpensively by placing containers next to the facility, the setting of the compound does not allow for such additional storage without blocking the access road for the neighbouring warehouse.

In order to overcome this problem, MCIT has earmarked Birr 3 million (USD 165,600) to construct a new facility on unoccupied land next to the CRTC.

As mentioned in Section 4.3, a certain share of the e-waste generated is channelled towards scrap metal markets, which tend to operate informally. One example of such an informal scrap metal market is the recycling section of Merkato Market in Addis Ababa. There, most businesses focus on waste plastics, glass and scrap ferrous metals. The latter is collected and either used for the manufacturing of new products (e.g. stoves) or loaded onto trucks to be delivered to one of the secondary steel plants in Ethiopia (see Section 1.1). In addition, the market also handles some moderate volumes of used and obsolete EEE such as cables, electric motors, power tools and – in small quantities – computers, TVs and radios. The products are either sold as second-hand goods or are used as sources of spare-parts. It is estimated that around 50 small shops in Merkato Market deal with used and obsolete EEE. Parts and components not suitable for re-use are either stored (e.g. on the shops' roofs) or dismantled and sold to downstream scrap metal dealers buying steel, aluminium and copper.

Photo 5 a & b Shops dealing with used EEE in Merkato Market, Addis Ababa

4.5 End-processing

Manual pre-processing of most electronic devices, as conducted by the DMF or informal recyclers, produces the following output fractions:

- Steel
- Aluminium
- Copper cables
- Printed wiring boards (PWBs) and connectors for data transmission
- Copper-steel-plastic mix (e.g. motors, plugs, hard-switches)
- Pure copper (e.g. from CRT-yokes)
- Plastics (mostly ABS with flame retardants)
- CRT-glass

Some of these fractions can be seen in Photo 6, which shows a manually dismantled and sorted desktop PC without monitor and peripherals. In addition, some other fractions such as various types of batteries, toner cartridges, mercury-switches, PCB-capacitors, CFLs and LCD-displays constitute output fractions on their own and require specific treatment due to their contents of hazardous substances. While the management of these fractions is very important from an environmental perspective, they make up a relatively small share of the total e-waste composition by volume.

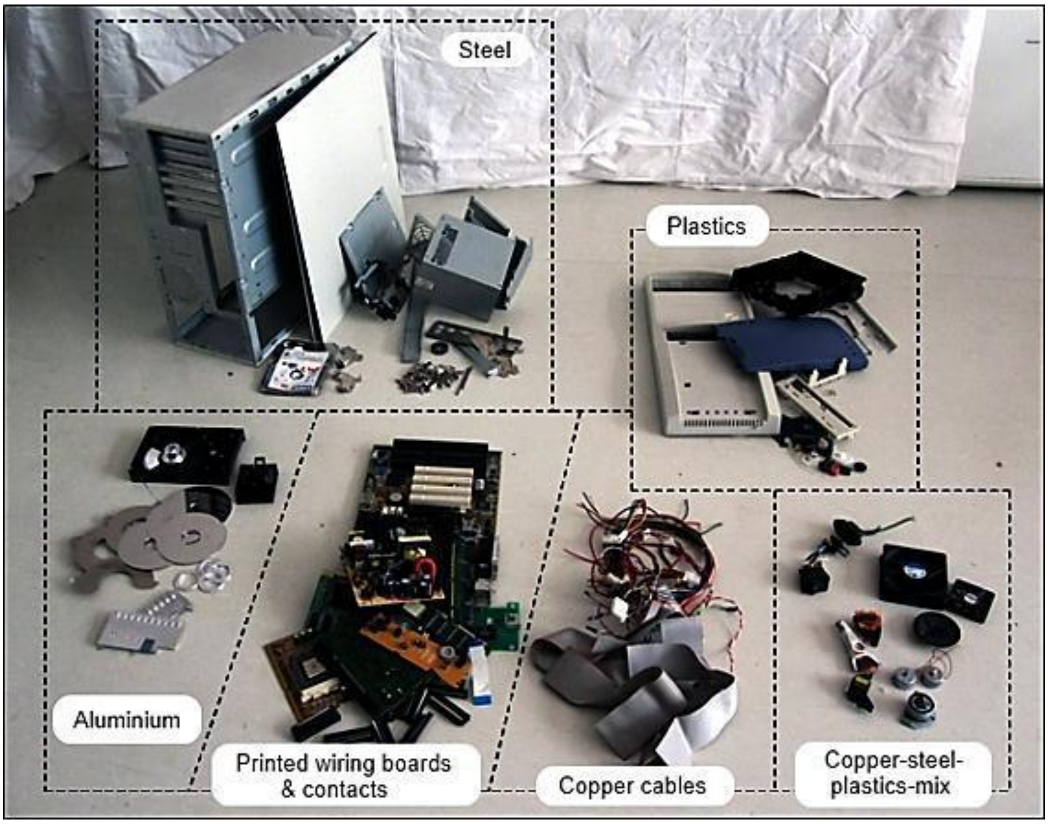

Photo 6 Manually dismantled and sorted desktop PC

The above listed fractions can be further pre-processed to some degree in order to reduce the number of output fractions. Cables can, for example, be mechanically liberated from their insulation to retrieve pure copper; motors, plugs and switches can be further processed to separate the various materials in order to be managed along with other fractions.

All materials require some form of end-processing or final disposal. With regards to end-processing, some capacities are available in Ethiopia, as will be described in the next sections.

To date, none of the end-processing options described in this chapter are utilised for e-waste management in Ethiopia on any significant scale[20]. Thus, this chapter illustrates potential end-processing options in Ethiopia rather than describing current e-waste flows and management practices. Further information on end-processing is compiled in Sections 4.3 and 4.4.

4.5.1 Steel

Several secondary steel plants are located in the region of Debre Zeit and Akaki Kality east of Addis Ababa, including:

- Abyssinia Steel Mill
- All Africa Steel Mills / Sheba Steel Mills
- Zuquala Steel Rolling Mill
- Mame Steel Mill PLC
- Ethiopia Iron and Steel
- Waliya Steel Industry
- Arati Still PLC
- Habesha Steel Mills
- Steel RMI PLC
- Anson Steel

These plants typically pay cash on the delivery of steel scrap based on daily market prices.

[20] One exemption might be the treatment of steel as this end-processing option is typically also used by informal sector recyclers as described in Section 4.3 and 4.4.

4.5.2 Plastics

There are several plastic recycling companies located in the east and southwest of Addis Ababa in Akaki Kality and Alem Gena. These companies recycle various types of thermoplastics such as Polyethylene (PE) and Polypropylene (PP) from local sources. Currently, there is no recycling capacity in Ethiopia for the thermoplastics typically used in EEE (e.g. ABS with flame-retardants).

4.5.3 Aluminium, copper and printed wiring boards

No end-processing facility for copper and printed circuit boards presently exists in Ethiopia. A few formal secondary aluminium smelters operate in and around Addis, including: Tana Engineering PLC, Radel Foundry PLC, Arefe'ayne Foundry PLC. In addition, smaller quantities of wrought aluminium might be used in artisanal local industries such as jewellery production.

4.6 Final disposal

There is no hazardous waste disposal site or waste incinerator within Ethiopia. Cement kilns represent the only potentially-feasible and domestically-available hazardous waste disposal capacity. As the kilning stage requires very high operating temperatures, the process could theoretically be used to destroy certain types of organic pollutants contained in some e-waste fractions (e.g. flame retardant plastics). In addition, the material can be used as a substitute for fuel in the process.[21]
The following cement kilns operate in Ethiopia:

- Derba Cement Factory (Derba, 70 km north of Addis Ababa)
- Messobo Cement Factory (northern Ethiopia)
- Bedrock Cement (southwest of Addis Ababa)
- Haile Robi Cement Factory (Akaki Kality)
- Muger Cement Factory (70 km north of Addis Ababa)
- National Cement Share Company (Dire Dawa)
- Zhongshun Cement Factory (Dukem, 37 km east of Addis Ababa)
- Holleta Cement Factory (Holleta, Oromia Region)
- Dejen Cement Factory (Dejen, East Gojjam)
- Capital Cement Factory (North of Addis Ababa)
- Habesha Cement factory(Near Holeta, West of Addis Ababa

There are, however, serious concerns about using these kilns for the disposal of hazardous waste. Some of these concerns go back to the so called "Africa Stockpiles Program" (ASP), which was designed to rid Africa of stockpiles of obsolete pesticides, and which was implemented in Ethiopia starting in 2005. Prior to the ASP, Ethiopia had since 2000 disposed of obsolete pesticides by sending stockpiles to the EU for incineration. The decision to send the waste to the EU, however, was not reached at once, but after assessing and evaluating the option of cement kilns as means of disposal in the country and finding that there were high environmental and health risks connected to the disposal of hazardous waste in kilns.

After reinvestigating the possibility of using cement kilns as a disposal technology option for pesticides (DTO), ASP (2006) concluded that, due to high leakage rates (approximately four per cent of all material put into the kilns leaks out), cement kilns did not amount to a viable DTO in Africa including Ethiopia. Further arguments

[21] Nevertheless, some cement producers reject co-firing waste material, as the composition of the waste can negatively affect cement quality. This is particularly the case for chlorine-containing wastes such as PVC.

against using cement kilns as a DTO for pesticides include: 1) the kilns are supposed to operate at a low oxygen level (3-4 per cent), which is impossible to maintain; 2) there is a lack of strong regulations and insufficient capacities to monitor such operations in Africa.

Concerns for using cement kilns for other materials such as e-waste plastics are based on observation in other countries. Generally, this management option requires significant investments in technical pollution control measures as well as sophisticated know-how to reduce the emission of pollutants in day-to-day operation.

As such, cement kilns in Ethiopia or in any neighbouring country currently cannot be recommended for the incineration of plastics or other hazardous materials from e-waste.

5 Downstream markets

As illustrated in Sections 4.4 and 1.1, there are no end-processing or disposal solutions available for the following fractions:

- Copper cables
- Printed wiring boards (PWBs) and IC-contacts
- Copper-steel-plastic mixes (e.g. motors, plugs, hard switches)
- Pure copper (e.g. from CRT yokes)
- Plastics (mostly ABS with flame retardants)
- CRT-glass

Potential solutions and downstream markets are discussed for each of these fractions in the following sections.
To date, none of the downstream markets described in this chapter are utilised for e-waste management in Ethiopia. Thus, this chapter outlines potential downstream markets rather than describing current e-waste flows and management practices. Related information on e-waste collection and pre-processing can be found in Sections 4.3 and 4.4.

5.1 Copper cables

From both an environmental and economic perspective, copper cables are a crucial e-waste fraction. The intrinsic material value of copper makes it economically attractive, with pure copper generating the highest revenues. The economic incentive provided by the market value of copper often leads to the practice of open cable burning, an extremely toxic process.[22] Open cable burning should be avoided in all cases Ethiopia.

As alternatives to cable burning, two management options are available:

- mechanical liberation of copper (e.g. stripping, shredding, granulating)
- export of insulated cables to environmentally-sound treatment facilities

While the first option generates more value from e-waste locally, it requires another downstream solution for the insulation material, which is often composed of PVC. Furthermore, cable shredders or granulators require significant financial investments, as well as investments in training and safety measures.[23]

Numerous companies are available internationally to treat pure copper (option 1) or copper cables with insulation (option 2).

[22] Cable burning is carried out because it requires almost no manual labour input to retrieve pure copper. Nevertheless, this economic equation neglects the fact that costs caused by massive pollution is externalised to society and the environment.

[23] Working with shredders and granulators requires special training as the physical nature of the process can cause severe injuries to workers. In addition, it has to be made sure that the equipment does not run hot as this can again lead to the formation of pollutants (dioxins).

5.2 Printed wiring boards (PWBs) and contacts

Printed wiring boards and contacts for the transmission of digital data (e.g. plugs, sockets) contain a broad variety of materials, including hazardous substances, copper and precious metals (gold, silver and palladium). Only a limited number of international companies are capable of refining precious metals out of this type of e-waste fraction, including

- Umicore (Belgium)24
- Xstrata (Canada)
- Aurubis (Germany)
- Dowa (Japan)
- Boliden (Sweden)

These companies usually only accept shipments of printed circuit boards and IC contacts in 20 foot or larger containers. Due to the relatively rich concentration of precious metals in the circuit boards of some electronic products, this fraction provides significant revenues for pre-processing enterprises.

5.3 Copper-steel-plastic mix

Dismantling activities such as those carried out by the DMF in Akaki yield various components like motors, speakers, switches and plugs that are composed of various materials, predominantly steel, copper, aluminium and plastics. While these parts can be further treated to liberate the various materials, this is often not economically feasible using only manual labour, as the parts gained from further treatment are typically quite small and manual labour yields relatively small amounts of pure metals.[25] Nevertheless, this manual option could be tested and economically monitored in the Akaki facility.

Other options for handling these heterogeneous fractions include:

- shredding and mechanical separation (within Ethiopia or in another country)
- export to specialised steel-copper refineries (e.g. those operated by Elmet in Spain)

If the latter treatment option is chosen, it is recommended that larger plastic parts be removed in order to increase the fractions' purity and thus economic revenues.

5.4 Pure copper

Pure copper like that retrieved from the dismantling of CRT has a very high economic material value.[26]

As there are no copper refineries in Ethiopia or any neighbouring countries, this copper fraction will need to be exported to one of the numerous copper refineries operating worldwide.

[24] Umicore maintains not only a facility for the refining of copper and precious metals from printed wiring boards, but also another plant to recover copper, nickel and cobalt from Li-Ion and NiMH batteries typically applied in mobile electronic devices and cordless power tools. Thus the company is providing downstream markets for two e-waste recycling fractions.

[25] In the informal recycling sector in Accra, Ghana, it was observed that these components are typically dismantled by children. This is because the dismantling of small motors, speakers and switches is physically less demanding compared to the dismantling of larger equipment (Prakash & Manhart 2010). Of course such child-labour input is violating international labour standards and should in no way be promoted in Ethiopia or anywhere else.

[26] Due to the high value of copper scrap and other valuable fractions (e.g. printed wiring boards), they should be stored in secure places to minimize the likelihood of theft.

Photo 7 Pure copper retrieved from the yokes of CRTs

5.5 Plastics[27]

The plastic fractions from e-waste are mostly composed of ABS and polycarbonates used for casings and structural components. Other types of plastics are also found in e-waste, including PVC from cable insulations and smaller quantities of some elastomers not suitable for material recovery. Most of these plastic types are permeated with brominated flame retardants, especially those plastic parts that are exposed to heat during the products' use-phase. The thermoplastics (ABS and polycarbonates) can theoretically be recycled into new products. However, relying on established recycling methods, the presence of flame retardants in these plastics significantly reduces their utility in secondary applications. The secondary use of these materials will only postpone the end-of-life problem associated with hazardous flame retardants. Recycling and mixing them with plastics containing no or other flame retardants might lead to cross-contamination.

Even secondary applications in new EEE is in most cases not feasible, as the majority of new products are designed to comply with the European RoHS-Directive, which bans the use of the flame retardants PBB and PBDE. Although ongoing research projects seek 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. However, as discussed in Section 4.5.2, all of the cement kilns currently operating in Ethiopia fall well below the required standards for environmentally-sound incineration of e-waste plastics (see Section 4.5.2).

Alternatively, plastics could also be disposed of in engineered landfills for hazardous waste. Other methods for screening out certain plastic types with particularly low contamination from flame retardants (e.g. with a handheld screening-device) are also currently under study.

[27] This section is based on an assessment carried out by Manhart et al. (2011).

5.6 CRT-glass[28]

While a considerable volume of CRT remains in use today, the production of CRT has declined dramatically as LCD and plasma technology now dominate the market for TVs and computer monitors. Various management options are available for glass from waste CRTs.[29] From an economic and environmental perspective, the recycling into new CRT glass (glass-to-glass recycling) is the most preferable as it enables a recycling-rate of 100 per cent for this fraction (Kang & Schoenung 2005). There is only one remaining CRT production facility in India that accepts secondary CRT glass of high quality. However, this facility has an established supplier structure so that it is unlikely that new players will be able to enter the supply chain of this plant.

The second established management option is the use of CRT glass in lead or copper smelters (glass-to-lead recycling). In this process, the glass is used as flux agent and substitute for silica sand. Some of the lead from the glass can be recovered in the process. The silica composing the glass then moves into the slag phase. There are only a few smelters that are technically designed to process CRT glass. In 2003, there were three smelters that would accept 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, let alone all of Europe (ICER 2003). In the USA, there are only two smelters processing CRT glass (Kang & Schoenung 2005). This limited capacity (in terms of both glass-to-glass and glass-to-lead operations), combined with the currently high levels of waste CRT glass generation, leads to a negative market value for this output fraction. Refineries typically charge around USD 150-200 per tonne for sound treatment.[30]

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 Ethiopia 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 (in particular lead) incorporated in the building materials constitute no risk to human health or the environment.

Other recycling options include the production of foam glass, ceramic bodies and insulating glass fibre. However, these applications are still in a development stage and thus are not yet available as 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 contained within the tubes needs to be disposed of as hazardous waste.

6 Legal framework of e-waste management

The Federal Environmental Protection Authority of Ethiopia has formulated a new regulation on Management and Disposal of Electrical and Electronic Waste under the Environmental Pollution Control Proclamation of 2002. This regulation is planned to be presented to the Ethiopian Parliament by the end of the current Ethiopian budget year (June 2013).

The issue of EEE has even been taken up regionally at the Third International Conference for Chemicals Management

[28] The following section is widely based on an assessment carried out by Manhart et al. (2011).

[29] Prior to treatment of waste CRT glass, the vacuum inside each CRT needs to be equalised during the dismantling process. Depending on the subsequent management option, such as those described here, the front- and funnel-glass have to be separated and cleaned from their internal phosphorous coatings, requiring separate treatment.

[30] In addition to these charges, other costs arising from transport and transboundary shipments must be factored into the cost calculus.

(ICCM3). There, the African region became the main negotiator for the inclusion of the life cycle approach to EEE management in the Global Plan of Action (GPA). This decision received full acceptance by the parties and also reflected positively on the African resolution.
Ethiopia is signatory of most of the international conventions, including the Basel, Bamako, Rotterdam, Stockholm and other conventions, for most of which the Federal Environmental Protection Authority (EPA) is the Designated National Authority (DNA).
Other national policies and regulations related to waste management and environmental protection are listed in the following table.

Table 12 Ethiopian policies and regulations related to waste management and environmental protection

No.	Policy item	Main theme	Remark phrases
1	Article 44 of the Constitution of Ethiopia	Environmental rights	All persons have the right to live in a clean and healthy environment
2	The Health Policy of 1993	Health system issues	Very few items that are related to solid waste problems in terms of environmental hygiene are included in the policy document.
3	Establishment of EPA in 1995	Need for an independent body dealing with environment	The Federal Environmental Protection Authority (EPA) is a national government body responsible for environmental policy issues
4	Environmental Policy of Ethiopia, 1997	High priority in waste management	Focuses on community participation and environmental economics in development activities
5	Environmental Pollution Control Proclamation of 2002	Management of Municipal Waste	All urban administrations shall ensure the collection, transportation, and appropriate recycling, treatment or safe disposal of municipal waste through an established system to undertake integrated municipal waste management
6	Solid Waste Management Proclamation No.513/2007	Promotion of waste as a resource	Enhance at all levels capacities to prevent the possible adverse impacts from solid waste while creating economically- and socially-beneficial assets out of solid waste
7	Addis Ababa City Solid Waste Management Regulation, 2004	Solid waste management	Addis Ababa solid waste management, collection and disposal system

7 Recommendations

The analysis carried out in Chapters 3 and 4 reveals that e-waste is not yet a severe source of environmental pollution or a threat to health and safety in Ethiopia. Compared to other African countries, such as Ghana and Nigeria, end-of-life volumes are still quite moderate and – even more importantly – there are no indications that unsound recycling and disposal is practiced systematically. Although there are some indications that e-waste is disposed of in an uncontrolled manner, the majority of obsolete EEE is currently stored in government premises, offices, international organizations and households awaiting future solutions.
The study could not quantify the share of second-hand equipment in the total EEE imports. In addition, little is known about the typical quality and functionality levels of imported used equipment. Generally, it is known that low-quality equipment with short remaining lifetimes can significantly add to the e-waste problem, while high-quality second-hand equipment is far less problematic and can even contribute to bridging the digital divide. Thus, high-quality second-hand EEE should not be classified as e-waste. Research in West Africa reveals that the widespread availability

of cheap second-hand IT equipment can help significantly to bridge the digital divide (Schluep et al. 2012).

While the social and economic benefits of new and high-quality, affordable second-hand EEE appear significant, this situation also requires action as market penetration of EEE is rapidly increasing. Ethiopia is one of the fastest growing economies in Africa, meaning that consumption and disposal patterns will change rapidly in the near future. Once devices such as computers, mobile phones and TVs are not regarded as luxury goods any more, the willingness to store obsolete devices will also decrease. In addition, urban centres – and in particular Addis Ababa – are already host to informal collection and scrap metal businesses, which typically also take over e-waste recycling once sufficient quantities are available. If informal e-waste collection and recycling systems develop uncontrolled (as has been the case in Ghana and Nigeria) and come to command a significant share of e-waste handling, severe negative environmental and health effects have to be anticipated. Therefore, it is advised to take proactive measures, such as those listed below, to prevent such adverse developments in Ethiopia.

7.1 Further develop the e-waste collection from offices and businesses

As e-waste volumes will increase rapidly and disposal habits will likely change, the current situation should be regarded as a unique opportunity to design appropriate and thorough collection and recycling systems. The activities of the recycling centre in Akaki and the collection activities from federal government offices in Addis Ababa (see Section 4.3) should be maintained and expanded step-by-step to other government offices (e.g. regional governments, other cities), non-government organizations, businesses and foreign institutions in Ethiopia. The strength of this strategy is that organizing collection from government and non-government offices is typically less demanding than collection from private households, thus providing the opportunity to collect a large volume of e-waste relatively efficiently and gain important initial e-waste management experience.

While government offices, in particular, are willing to give away obsolete EEE free of charge, private households (and possibly also some small businesses) might perceive these goods as valuable and ask collectors to pay them to pick-up their e-waste[31]. Therefore, e-waste collection from private households and businesses requires different strategies, economic considerations and financing mechanisms. The initial focus on collecting e-waste from offices enables the development of both the physical recycling infrastructure and knowledge about the economics and technical aspects of e-waste recycling, all of which are prerequisites to developing a financing mechanism for household collection.

7.2 Optimise pre-processing and storage in the Demanufacturing Facility

As laid out in Section 4.4, the Demanufacturing Facility in Akaki has made considerable progress in recent months. However, the activities are still focused on collection, dismantling and storage; to date, no recycling output has been delivered to any downstream market. In order to proceed in this direction, the DMF should strive to interlink with downstream markets as soon as possible by offering its outputs (steel, printed circuit boards, cables, aluminium, plastics etc.) to national and international markets (for details, see Chapter 5). Networking with downstream markets should

[31] This is typically the case in many other African countries where e-waste is already collected from private households on a larger scale.

also be done in order to receive feedback on quality aspects of output fractions, which in the medium-turn will help improve dismantling strategies and recycling processes in order to increase economic returns.
Furthermore, the DMF is in urgent need of storage space for both incoming e-waste and produced output fractions.

7.3 Widen the scope to other EEE

While the collection of e-waste from government institutions primarily yields office equipment, the DMF already receives a broad variety of non-office equipment such as fans, vacuum cleaners and refrigerators. If collection efforts are to be further expanded to other offices and, in the long-term, also to private households, this influx will further increase. Therefore, it is advised that recycling capabilities be expanded to include these other types of equipment and their components.
Furthermore, office equipment in Ethiopia is often attached to the use of uninterruptible power supplies (UPS) to protect data and equipment losses resulting from power cuts. These UPS all contain one lead acid battery, which should be recycled along with starter batteries from cars and trucks. As uncontrolled lead acid battery recycling is regarded as one of the worst polluting industries in the world (Blacksmith Institute 2008), environmentally-sound solutions for this waste stream must also be identified[32].

7.4 Develop solutions for non-valuable fractions

E-waste recycling does not only yield profitable output fractions, but also material that has a cost for sound end-of-life management due to high concentration of pollutants and/or a relatively low material value. While some of these fractions accumulate quite slowly (e.g. mercury switches, PCB-capacitors), others represent mass fractions (e.g. CRT glass, plastics) and will soon challenge the present and future storage capacities. For these fractions, viable and environmentally sound solutions have to be identified. Thereby, it has to be kept in mind that some solutions for dealing with mass fractions, such as export for treatment in other countries, might be very costly. These costs could quickly challenge the overall economic efficiency of its recycling.
Generally, it is advised to identify national solutions such as sound treatment and disposal for hazardous wastes. In the light of Ethiopia's rapid economic development, such solutions will also be necessary to manage other types of industrial waste.

7.5 Develop a national e-waste strategy

Experiences from many other countries show that e-waste management requires more than just a collection system and recycling plants. Recycling and pollution prevention standards are needed in order to define the mode of operation and to create a level playing field for all actors in the management chain. Additional financial sources might be needed to cover the collection costs and the management of the hazardous fractions. Enforcement measures must be in place to make sure that all actors adhere to the established rules. Collection efforts must be accompanied by measures to increase awareness, which is necessary to achieving public participation. And, finally, the principle of extended producer responsibility must be defined in a way that enables importers and producers to play an effective role in e-waste management.

[32] Other types of batteries are also widely used in Ethiopia and require environmentally-sound solutions.

All of these measures require careful planning and collaboration between various government, industry and civil society stakeholders. The development of an e-waste management system is a task encompassing numerous technical, organizational and administrative aspects. The activities involved in the development of a national e-waste policy and a functional e-waste management system generally fall under one of the following five core fields:[33]

- Policy and legislation
- Business and finance mechanism
- Recycling technology, skills and downstream markets
- Monitoring and control
- Marketing and awareness

7.6 Take into account the whole life cycle of electrical and electronic products

As indicated in Section 3.2, mobile phone manufacturing began in Ethiopia in recent months. It is possible that other manufacturers might also start producing EEE in Ethiopia in the future. This, together with constantly rising import volumes, call for a broader and more concerted approach to sustainability aspects of EEE and e-waste in Ethiopia. In addition to e-waste management considerations, such an approach should target hazardous substances in the production phase as well as energy-efficiency aspects in the use phase. This could be achieved by aligning with regulations and initiatives in other world regions such as the European Union. Here, the RoHS-Directive [34] and the implementing measures under the Ecodesign Directive[35] are of particular relevance. They require manufacturers and importers to be in line with energy-efficiency standards and to phase out lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ether (PBDE). By aligning with international efforts and standards, Ethiopia would not produce or receive equipment with below-average environmental performance. Additionally, its products will be compatible with the requirements of major overseas markets, thus opening the doors for exports.

7.7 Develop a financing mechanism

As indicated in the recommendations above, e-waste management systems are typically not economically self-sustaining and many problematic fractions can require additional financing. While such financing could be secured by import or product taxes, such measures should take into account that a significant portion of EEE in Ethiopia today has been smuggled into the country to evade taxes. An increase of import taxes might further aggravate this problem.

Financing mechanisms can also be based on non-tax measures such as legal obligations on producers and importers within the framework of extended producer responsibility schemes (EPR). As an example, producers and importers can be obligated to take charge of the environmentally-sound management of an annual e-waste share that is equivalent to their market-share of products brought onto the Ethiopian market during a defined time period. Such a system design can also help to increase cost-effectiveness as importers and companies have a direct incentive for designing and supporting efficient collection and recycling systems. Of course, such

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[33] This structure was developed by Swiss Federal Laboratories for Materials Science and Technology (EMPA) and proved to be very useful in e-waste strategy development processes in various countries.

[34] Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

[35] Directive 2009/125/EC on establishing a framework for setting of ecodesign requirements for energy-related products.

systems also require standards for collection and recycling, as well as independent monitoring and control. Furthermore, it requires that producers and importers are registered and required to periodically report their sales volumes in Ethiopia.

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"StEP envisions a future in which societies have reduced to a sustainable level the e-waste-related burden on the ecosystem that results from the design, production, use and disposal of electrical and electronic equipment. These societies make prudent use of lifetime extension strategies in which products and components – and the resources contained in them – become raw materials for new products."

Our name is our programme: solving the e-waste problem is the focus of our attention. Our declared aim is to plan, initiate and facilitate the sustainable reduction and handling of e-waste at political, social, economic and ecological levels.

Our prime objectives are:

- Optimizing the life cycle of electric and electronic equipment by
    - improving supply chains
    - closing material loops
    - reducing contamination
- Increasing utilization of resources and re-use of equipment
- Exercising concern about disparities such as the digital divide between industrializing and industrialized countries
- Increasing public, scientific and business knowledge
- Developing clear policy recommendations

As a science-based initiative founded by various UN organizations we create and foster partnerships between companies, governmental and non-governmental organizations and academic institutions.

StEP is open to companies, governmental organizations, academic institutions, NGOs and NPOs and international organizations which commit to proactive and constructive participation in the work of StEP by signing StEP's Memorandum of Understanding (MoU). StEP members are expected to contribute monetarily and in kind to the existence and development of the Initiative.

StEP's core principles:

1. StEP's work is founded on scientific assessments and incorporates a comprehensive view of the social, environmental and economic aspects of e-waste.
2. StEP conducts research on the entire life cycle of electronic and electrical equipment and their corresponding global supply, process and material flows.
3. StEP's research and pilot projects are meant to contribute to the solution of e-waste problems.
4. StEP condemns all illegal activities related to e-waste including illegal shipments and re-use/ recycling practices that are harmful to the environment and human health.
5. StEP seeks to foster safe and eco/energy-efficient re-use and recycling practices around the globe in a socially responsible manner.

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