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Table of Contents

Executive Summary	6
Section 1: Introduction: Study Objectives, Scope and Methodology	10
1.1 Study Objectives and Scope	11
1.2 Study Methodology	12
Section 2: E-waste: Definition and Composition	14
2.1 What is e-waste	15
2.2 Hazards of Electronic Waste.....	17
Section 3: Global Scenario: E-waste Quantum and Regulations	21
3.1 Global Scenario - Quantum	22
3.2 Global Scenario – Policies and Regulations.....	24
Section 4: Indian Scenario: E-waste Quantum and Regulations	26
4.1 Indian Scenario - Quantum	27
4.2 Indian Scenario – Policies and Regulations	28
Section 5: E-waste in KMA: Disposal Behavior and Quantum	30
5.1 Disposal Practices of Users in KMA	31
5.2 E-waste quantities in KMA	38
Section 6: E-waste Recycling in India and KMA	47
6.1 E-waste Recycling Practices in India.....	48
6.2 E-waste Recycling in KMA.....	51
Section 7: Conclusions and Recommendations	62
7.1 Key Conclusions about KMA's e-waste Industry	63
7.2 Way Forward: Recommendations.....	65
Annexure	68
List of References & Glossary	94

List of Figures

Figure 1: Snapshot of Study Methodology	12
Figure 2: E-waste Type and Composition	16
Figure 3: Typical pathways for release of Pollutants from e-waste	19
Figure 4: Typical Process of PCB Recycling in Unorganized Sector.....	19
Figure 5: Key Facts about Global e-waste Industry.....	23
Figure 6: Forecasts of e-waste generation in India	27
Figure 7: Sample Size Break-up of Households.....	32
Figure 8: Disposal Behavior of Households – Considerations while Disposal	34
Figure 9: Sample Size Break-up of Business Establishments	35
Figure 10: Disposal Behavior of Business Establishments – Key Reasons for Replacements	36
Figure 11: Business Establishments – Methods and Considerations while Disposal.....	36
Figure 12: Expectations of Business Establishments from a Formal Recycling Company.....	37
Figure 13: Funnel Approach for e-waste estimation.....	38
Figure 14: E-waste generation in KMA in 2010.....	41
Figure 15: Potential Annual e-waste in KMA – by type of Product Categories	41
Figure 16: E-waste from Desktops – Break-up by User Segments.....	42
Figure 17: E-waste from Desktops – Forecasts for next ten years.....	42
Figure 18: E-waste from Notebooks – Break-up by User Segments	43
Figure 19: E-waste from Notebooks – Forecasts for next ten years.....	43
Figure 20: Total Potential Annual E-waste - Forecasts.....	46
Figure 21: E-waste Industry Trade Chain	52
Figure 22: Geographical Mapping of e-waste industry in KMA	60
Figure 23: Pyramid Structure of e-waste industry.....	61

List of Tables

Table 1: Sample Sizes covered in the Study	13
Table 2: Occurrence of Toxic elements in e-waste	17
Table 3: Potential e-waste hazards.....	20
Table 4: E-waste generation across the globe.....	22
Table 5: Policies/Regulations in Developed Countries.....	25
Table 6: Disposal Behavior of Households – Obsolescence Rates	32
Table 7: Disposal Behavior of Households – Methods of Disposal.....	33
Table 8: Disposal Behavior of Businesses – Obsolescence Rates.....	35
Table 9: Awareness Levels of Business Establishments.....	37
Table 10: Steps in Estimation of Potential Annual e-waste	39
Table 11: E-waste at three levels of Funnel – By Type of Product Categories	41
Table 12: Forecasts of e-waste from Printers	44
Table 13: E-waste from Consumer Electronics – Forecasts for next ten years.....	45
Table 14: Break-up of E-waste forecasts by Product Categories	46

Executive Summary

Introduction - Kolkata has emerged as an important destination/hub for recycling of e-waste generated in West Bengal. Currently, e-waste recycling in Kolkata is completely undertaken by the unorganized sector. The processes involved in e-waste recycling by the informal sector are highly polluting and are not only hazardous for the environment, but also to the health of workers. The problem is further complicated by higher consumption and disposal rates among the users leading to increase in volume of e-waste. Due to growing quantities and health & environment hazards involved in e-waste recycling, immediate action from all concerned is required to curb the risk and improve the situation. *(Various risks and hazards associated with e-waste recycling and its adverse impact on human health, environment etc are detailed out in Section 2.2 of the report as well as in Aneexure D,E &F.)*

The report focuses on estimating and forecasting the quantities of e-waste generation in KMA, West Bengal. In addition to estimating the volumes, the report focuses on mapping the current scenario of e-waste recycling industry in KMA.

In the backdrop, the report briefly analyzes the current National and Global situation of e-waste industry in terms of Quantities and Policies.

The e-waste recycling industry in KMA is still in its nascent stage. In the present scenario, it is handled only by the unorganized sector. This study aims to recommend action points for improvising the current situation. The section wise summary of the report is as follows -

E-waste Definition and Composition

As per the e-waste management guidelines provided by Government of India, definition of e-waste is as follows - "E-waste comprises of wastes generated from used electronic devices and household appliances which are not fit for their original intended use and are destined for recovery, recycling or disposal. Such wastes encompass wide range of electrical and electronic devices such as computers,

hand held cellular phones, personal stereos, including large household appliances such as refrigerators, air conditioners etc.”

Apart from recoverable materials such as plastic, iron, aluminum, copper and gold, e-waste also contains significant concentration of substances that are hazardous to human health and the environment. Therefore even small quantities of e-waste entering the residual waste will introduce relatively high amount of heavy metals and halogenated substances. During treatment and land filling these pollutants find their way to the soil, water, and air. Therefore it is of critical importance that safety measures are in place during treatment of this waste.

Global Scenario – E-waste Quantum and Regulations

E-waste is becoming an important issue in many parts of the world. Some 20 to 50 million metric tonnes of e-waste is generated globally every year. A major proportion of this e-waste is recycled and reprocessed through transboundary movement from developed to developing countries.

Europe and Japan have been the leader in formulating policies for WEEE/E-waste followed by their institutionalization and implementation. Europe acted as a pioneer in enacting the first two e-waste regulations by formulating the WEEE and RoHS Directives. Other countries followed and framed their national policies modeled around these two directives.

Indian Scenario – E-waste Quantum and Regulations

Based on the e-waste national level assessment study, conducted by IMRB in 2007, it is estimated that a total of 3,82,000 tonnes of e-waste is generated annually in India. It is estimated that e-waste generated in India will touch 486,000 tonnes by 2011.

Recently, Government of India has released its Guidelines for Environmentally Sound Management of e-waste for the State PCBs and industries handling e-waste. The guidelines lay down rules and procedures for import, export, handling, management, recycling and reuse, treatment, storage and disposal of hazardous waste. The guidelines also provide content for labeling, packaging and transport of hazardous waste and materials. However, effective implementation of these guidelines is still lacking.

E-Waste in KMA – Disposal Behavior and Quantum

A quantitative survey was conducted among 710 households and 390 business establishments of KMA to understand the disposal behavior of users. It was found that selling in second hand market and exchanging old products for new ones are the most commonly adopted methods of disposal among users of KMA. Major consideration of users at the time disposal of their old electronic or IT products is the monetary benefit.

Business Establishments were also checked on their awareness levels about e-waste problems and it was found that the awareness is still low and needs improvement.

Input and Obsolescence method along with the funnel approach was adopted to estimate the quantum of e-waste generation in India. It was estimated that KMA generates around 26000 tonnes of potential annual e-waste annually, of which 9290 tonnes is available for recycling and only 2000 tonnes gets recycled.

This potential annual e-waste is expected to grow up to as high as 50,265 by 2015 and 1,44,823 tonnes by 2020.

E-Waste Recycling in India and KMA

Indian E-waste recycling is presently concentrated in the informal (unorganized) sector. Operations of the informal sector are mostly illegal and processes are highly polluting. In terms of recycling, the informal sector of India gets engaged in dismantling, sale of dismantled parts, valuable resource recovery, export of processed waste for precious metal recovery.

The e-waste trade chain can be broadly classified into three stages – Generation, Handling and Processing.

It was found that unorganized e-waste recycling industry (dismantling/recycling activities) is only present in Kolkata and Howrah region of KMA. In case of Kolkata, the industry is spread across Chandni Market , Princep Street , Grey Street, Hazra Crossing (Richie Road), Bondel gate, Khidderpore-Metiaburuz area, Rifle Range Road, Keshav Sen Street, Tarak Pramanick Road / Girish Park,

Rajarhat, Raja Bazaar, Topsia Tiljala Belt and Kankurganchi-Kapdapara-Phool Bagan belt. For Howrah, the areas are Ghusuri and Bajrangbali.

Recycling of PCBs which is one of the key activities in e-waste recycling business and involves maximum risk to the environment and health of the workers does not take place anywhere in KMA or West Bengal. PCBs are sent to Delhi and Moradabad for metal extraction.

It was estimated that around 1400 stakeholders are involved in the KMA's e-waste recycling industry.

Recommendations

Formalization should be the initial focus of the West Bengal State Government with following two objectives -

1. Improvising the processes of existing informal industry and limiting their presence till Collection and Dismantling stage
2. Integrating a formal recycling company with the informal sector for taking over the hazardous recycling processes

First step towards meeting this objective is to create awareness among the trade stakeholders about the potential health risks.

The informal sector currently plays a vital role in collection, segregation and dismantling of e-waste. This role should complement the formal recyclers as supply chain partners and formal recyclers should take on the hazardous and higher technology recycling processes.

Intermediaries and facilitating bodies like NGOs should be consistently involved in educating the people in informal sector for integration with the formal one.

In addition to the formalization initiatives, the State Government should work towards awareness creation and defining the roles of key stakeholders (Extended Producer Responsibilities and Consumer Responsibilities) in order to develop an environmentally sound e-waste management system which is sustainable and successful in long term.

Section I

Introduction – Study Objectives, Scope and Methodology

I.1 Study Objectives and Scope

West Bengal Pollution Control Board and Indian Chamber of Commerce in association with Gtz, have taken up the initiative of inventorization of e-waste in the Kolkata Metropolitan Area, West Bengal. In this regard, BIRD (Business and Industrial Research Division) of IMRB International was assigned to undertake the research work for meeting the following objectives:

- To estimate the quantity of e-waste that is being generated currently in Kolkata Metropolitan Area (KMA), West Bengal
- To project the growth of the quantity of e-waste to be generated over the next ten years
- To understand the disposal behavior of users (households and businesses) of electronic equipment
- To study the pattern of e-waste obsolescence rate in different categories namely business & offices and households in Kolkata Metropolitan Area, West Bengal
- To identify and quantify the hazardous and valuable components in each of the waste categories
- To assess the risk of e-waste recycling by unorganized sector
- To identify various stakeholders in the e-waste value-chain
- To evaluate the capabilities of existing stakeholders and infrastructures for reuse, recycling and disposal of e-waste in an environmentally sound manner
- To study the present disposal practices of the hazardous components in each of the waste categories and identify any existing e-waste recycling facilities (formal & informal) in Kolkata Metropolitan Area, West Bengal, with their present status;
- To suggest eco-friendly recycling/disposal options for e-waste

This study had a defined scope in terms of Geography and Product categories. This is as follows:

- Geographical Scope – Kolkata, Howrah, Salt Lake City, Kalyani, Barasat, South Dum Dum, Uluberia
- Product Category Wise Scope – Computers (Desktops and Laptops), Printers, UPS, Televisions, Refrigerators, DVD/VCD Players, Mobile Phones

1.2 Study Methodology

A blend of Qualitative and Quantitative Research was adopted to meet the study objectives. Depending upon the category of stakeholders and objective, the study was divided into three modules as shown below.

Figure 1: Snapshot of Study Methodology

	What?	How?	Why?
Module 1	Quantitative Estimation of e-waste	<ul style="list-style-type: none"> • Input and Obsolescence Method • Secondary data collection for estimating the quantities of inputs • Quantitative survey to calculate the obsolescence age 	<ul style="list-style-type: none"> • To map the annual quantities of e-waste being generated in KMA • To estimate these quantities for coming years
Module 2	Understanding current Disposal Practices	<ul style="list-style-type: none"> • By carrying out extensive primary Quantitative survey among both the user segments – Households and Establishments 	<ul style="list-style-type: none"> • To calculate product wise and user segment wise obsolescence rates • To identify the most common methods of disposal used currently • To understand user considerations while disposing
Module 3	Studying current e-waste recycling practices in KMA	<ul style="list-style-type: none"> • Through Qualitative research with existing recyclers – both informal as well as formal (if any) 	<ul style="list-style-type: none"> • To understand the existing recycling practices in KMA • To identify various stakeholders in the e-waste value-chain; • To evaluate the capabilities and infrastructures of existing stakeholders

Module 1 - For estimating the quantities of e-waste, Input and Obsolescence method was used which is explained in detail in later part of this report.

Module 2 - For understanding the obsolescence rates and disposal behavior among the users, a quantitative survey was conducted across the Household and the Business establishments of KMA (in all the stipulated seven areas under the scope of the study).

Module 3 – For mapping the current recycling practices of KMA, qualitative in-depth interviews were conducted with different

stakeholders of e-waste recycling industry – scrap collectors, dismantlers and recyclers.

Details of sample sizes covered as a part of the study for quantitative as well as qualitative interviews are as shown in the table below.

Table I: Sample Sizes covered in the Study

Respondent Segment	Type of Interviews	No. of Interviews	Remarks
User Segment – To study disposal behavior and obsolescence rates			
Households	Quantitative	710	Interviews were conducted in such a manner that there is significant representation of different geographies and product categories under the scope of the study
Institutional Users	Quantitative	390	While conducting these interviews significant coverage of different type of businesses establishments was ensured
Recycling Industry Stakeholders – To study current e-waste recycling practices			
Scrap Collectors	In-depth Interviews and observation	20	Reference / Snow balling sampling methodology was used for identifications of this category of stakeholders.
Scrap Traders/ Dismantlers	In-depth Interviews and observation	20	All the seven areas under the scope of the study were visited to ensure complete coverage and identification.
E-waste recyclers / Processors	In-depth Interviews and observation	15	Apart from the stakeholders met in KMA, recyclers were interviewed in Delhi and Moradabad as well for validating some of the findings.
Formal e-waste recycling company	In-depth Interview	1	The company isn't operational yet, its in the planning stage. Interview was conducted to understand the plans of the company in terms of capacity and technology to be adopted for environmentally friendly disposal of e-waste

Section 2

E-waste – Definition and Composition

2.1 What is e-waste?

There is no standard definition of e-waste. A number of countries and associations have come out with their own definitions, interpretations and usage of the term e-waste.

The e-waste management guidelines provided by Government of India defines e-waste as follows: “E-waste comprises of wastes generated from used electronic devices and house hold appliances which are not fit for their original intended use and are destined for recovery, recycling or disposal. Such wastes encompass wide range of electrical electronic devices such as computers, hand held cellular phones, personal stereos, including large household appliances such as refrigerators, air conditioners etc.”

Internationally, the most accepted definition of e-waste is the definition as per the WEEE Directive which defines electronic waste, "e-waste" or "Waste Electrical and Electronic Equipment" ("WEEE") as the 'waste material consisting of any broken or unwanted electrical or electronic appliances.' Electrical and electronic equipments have been further classified into components, assemblies and sub-assemblies. (Detailed list is provided in Annexure to the report)

E-waste Type: E-waste includes the following product categories:

- Large household appliances
- Small household appliances
- IT and telecommunications equipment
- Consumer equipment
- Lighting equipment
- Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
- Toys, leisure and sports equipment
- Medical devices (with the exception of all implanted and infected products)
- Monitoring and control instruments
- Automatic dispensers

E-waste Components and Composition

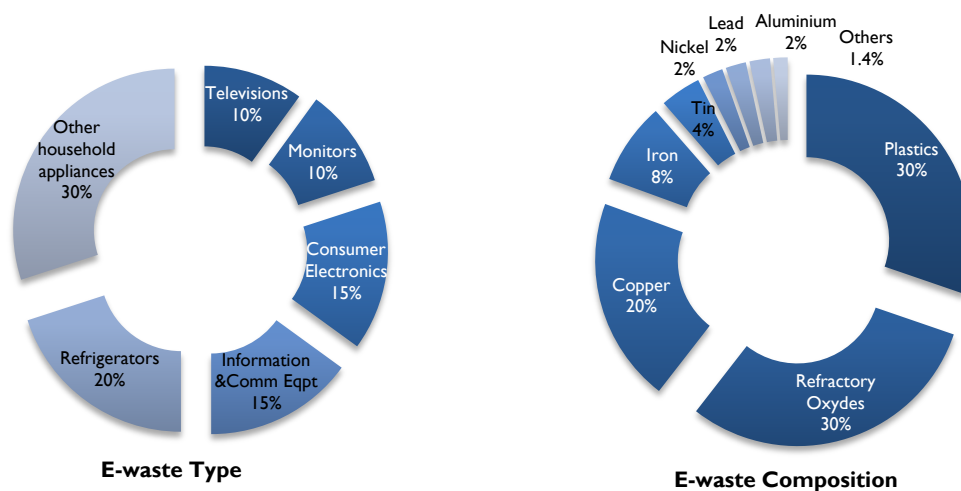
Primary materials and components produced thereof, which are assembled to produce “Electrical and Electronic Equipment” include metal, motor/ compressor, cooling, plastic, insulation, glass, LCD, rubber, wiring/ electrical, concrete, transformer, magnetron, textile, circuit board, fluorescent lamp, incandescent lamp, heating element, thermostat, FR/BFR-containing plastic, batteries, CFC/HCFC/HFC/HC, external electric cables, refractory ceramic fibers, radioactive substances and electrolyte capacitors (over L/D 25 mm).

The composition of these components is very diverse and may contain many different substances which fall under “hazardous” and “non-hazardous” categories. These consist of ferrous and non-ferrous metals, plastics, glass, wood and plywood, printed circuit boards, concrete and ceramics, rubber and other items.

A rough break-up of e-waste by type of product categories and by components is shown in the charts below.

Figure 2: E-waste Type and Composition

(Source: Basel Action Network, Sodhi, M. S. & Reimer, B. (2001))



2.2 Hazards of electronic waste

E-waste and its components are classified as a hazardous waste because of the presence of elements like Lead, Mercury, Arsenic, Cadmium, Selenium, Hexavalent Chromium and flame-retardants beyond threshold quantities.

Following table summarizes the presence of toxic contents in e-waste.

Table 2: Occurrence of Toxic Elements in e-waste

(Source Umwelbundesamt, 2004)

Toxic elements/Pollutants	Occurrence
Arsenic	Semiconductors, diodes, microwaves, LEDs (light-emitting diodes), solar cells
Asbestos	Irons, boilers, toasters (heat insulation)
Barium	Electron tubes, filler for plastic and rubber, lubricants additives
Brominated flame-proofing agent	Casing, circuit boards (plastic)
Cadmium	Batteries, pigments, solder, alloys
Chrome	Dyes/pigments, switches, solar
Cobalt	Insulators
Copper	Conducted in cables, copper ribbons, coils, circuitry pigments
Lead	Lead rechargeable batteries, solar, transistors, lithium batteries, PVC (polyvinyl chloride) stabilizers, lasers, LEDs, thermoelectric elements
Liquid crystal	Displays
Lithium	Mobile telephones, photographic equipment, video equipment (batteries)
Mercury	Components in copper machines and steam irons; batteries in clocks and pocket calculators
Nickel	Alloys, batteries, relays, semiconductors, pigments
PCBs (polychlorinated biphenyls)	Transformers, capacitors, softening agents for paint glue
Selenium	Photoelectric cells, pigments, photocopiers, fax machines
Silver	Capacitors, switches (contacts), batteries, resistors
Tin	Soft solder, fusible alloys, flame-proofing agent
Zinc	Steel, brass, alloys, disposable and rechargeable batteries, luminous substances

Risks associated with E-waste Recycling

Apart from recoverable materials such as plastic, iron, aluminum, copper and gold, e-waste also contains significant concentration of substances that are hazardous to human health and the environment. Therefore even small quantities of e-waste entering the residual waste will introduce relatively high amount of heavy metals and halogenated substances. During treatment and land filling these pollutants find their way to the soil, water, and air. Therefore it is of critical importance that safety measures are in place during treatment of this waste. Otherwise these pollutants might seriously affect the health of the recyclers who treat the waste – by entering their body through respiratory tracts, skin, or the mucous membrane of the mouth and the digestive tract.

Currently, most e-waste recycling activities undertaken by the unorganized sector in India involve physical breaking using tools like hammer, chisel, screw driver and bare hands. Given the associated value, following materials are recovered from electronic waste items for further recycling:

- Copper: Including printer and other motors, wires and cables, CRT yokes, Circuit boards, etc
- Steel: Including internal computer frames, power supply housings, printer parts, etc.
- Plastic: Including housings of computers, printers, faxes, phones, monitors and keyboards
- Aluminium: Printer parts, capacitors, etc.
- Printer Toner: from spent toner cartridges
- Circuit Boards: These come from many appliances including computers, phones, disc drives, printers, monitors, etc.

The next three figures are illustrations to show the risks involved in unsafe handling of e-waste. First figure summarizes the typical pathways for the release of some of pollutants from e-waste; second box contains in brief the details of PCB recycling – an activity which has maximum risk of occupational and environmental hazards associated with it; and the third table summarizes the common processes of recycling e-waste and potential occupational & environmental hazards associated with those processes.

Figure 3: Typical pathways for release of pollutants from e-waste

(Source: Johri Rajesh, "E-Waste: Implications, Regulations and Management in India and Current Global Best Practices", TERI Press, 2008)

Heavy metals	Dioxins and Furans	Acids
<ul style="list-style-type: none"> • Dust generated during mechanical treatment, for example, the dismantling and crushing of WEEE. • Flue gas released during thermal treatment, for example, the release of metals from compounds during the incineration of plastic. • Vaporization wherein metals are released from compounds in an acid bath 	<ul style="list-style-type: none"> • Dioxins and furans are emitted during the thermal treatment of WEEE, for example during - • The combustion of cable insulation containing PVC in order to recycle copper wiring • The incineration of epoxy resin containing flame retardant from circuit boards in order to recycle the metal they contain 	<ul style="list-style-type: none"> • Released in the form of vapour when metals are released from compounds. May also get distributed throughout the surrounding area in the following ways • Factory air and dust being blown into the vicinity • Leaching through waste water and seepage • Release of flue gas into the atmosphere as a result of open incineration of furnace combustion

Figure 4: Typical process of PCB recycling in unorganized sector

Recycling of PCBs - The methods of salvaging material from circuit boards are highly destructive and harmful as they involve heating and open burning for the extraction of metals.

First, there is manual removal of gold-plated pins and the few ICs that can be reused. The core of each motherboard has a flat laminated gold plate.

These laminated parts are cut down and sold to gold-smiths for gold recovery. Subsequently, pre-heating is done to remove resalable components like ICs, condensers, bearings (pulleys) from floppy drive and hard drive. Pre-heating involves putting the motherboard on a burning stove. Low heat is maintained to loosen only the chemical bond between solder and plastic.

At this stage, resalable chips, condensers, etc, are plucked out from these pre-heated plates. The pre-heated circuit boards are then bought by other dealers for recovery of solder (which consists of lead and mercury). The method of solder recovery is very rudimentary. A burning kerosene gas kit is placed in a small water tub to store molten lead. The circuit boards are simply put on top of the stove; tongs are used on all sides. The lead extracted due to heat application goes into a water tub – it floats due to low density. After de-soldering, the circuit boards go for roasting or acid bath to recover copper from them. Copper retrieval is done through two processes:

1. **Open burning** – After separating all remaining components, motherboards are put for open pit burning to extract the thin layer of copper foils laminated in the circuit board. The ash content is washed out and copper, with some carbon impurity, goes to another recycling unit.
2. **Acid Bath** – In this process, the collected mother boards are dipped in the acid for few hours. The acid, along with motherboard, is heated in a big container to formulate crystal copper sulphate. Then, acid iron chips are added and sludge containing copper is extracted which is further put into ion exchange process to recover copper from it

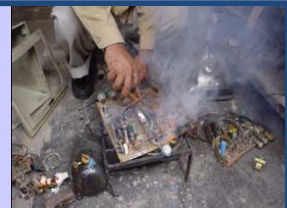


Table 3: Potential E-waste Hazards

(Source: Adapted from Puckett, Byster, Westervelt, et al.;2002)

Computer component	Common process of recycling	Potential occupational hazard	Potential environmental hazard
Cathode ray tubes/ monitors	Breaking, removal of copper yoke, recycling of glass	Silicosis, cut injury, inhalation or direct contact with phosphor containing cadmium and other metals such as Pb, Hg	Release of lead, mercury, barium, toxic phosphor, and other heavy metals into water and soil
Printed circuit board	De-soldering and removing of computer chips	Inhalation of tin, lead, dioxin, beryllium, cadmium, mercury	Air emission of metals and dioxin
Dismantled printed circuit board	Burning of waste boards to remove chips and final metals	Inhalation of tin, lead, dioxin, beryllium, cadmium, mercury and respiratory irritation	Tin and Lead contamination of soil and water, emission of brominated dioxin, beryllium, cadmium, mercury
Chips and other related components	Chemical processing using nitric acid and hydrochloric acid	Corrosive injury to eye and skin, inhalation of acid fumes and harmful gases such as chlorine and sulphur dioxide	Hydrocarbons, heavy metals, halogenated substances, acids in water and soil, and air emission
Wires and cables	Burning to recover metal wire	Inhalation of brominated and chlorinated dioxin, PAHs (polycyclic aromatic hydrocarbons)	Emission of brominated and chlorinated dioxin, PAHs
Miscellaneous computer parts enveloped in rubber	Burning to recover metals	Inhalation of dioxin, PAHs	Emission of dioxin, PAHs
Toner cartridges	Brushes to recover toner	Respiratory irritation, unknown carcinogenic impact of carbon black, cyan, yellow and magenta toners	Soil and water pollution
Secondary steel, copper, and precious metal smelting	Furnace to recover steel and copper	Heat injury, inhalation of dioxins and heavy metals	Emission of dioxins and heavy metals

Details of occurrence of hazardous substances in e-waste, their usage and risks associated with each of the substance and regulatory requirements/threshold quantities are given in the form of annexure to this report.

Also, the details of material / value recoverable from e-waste are provided in the annexure.

Section 3

Global Scenario: E-waste Quantum and Regulations

3.1 Global Scenario - Quantum

Rapid technological innovations encourage the purchase and frequent upgrading of electronics products. This increase is directly linked to rise in the amount of used electronic equipments and thus the waste generated from it.

E-waste is becoming an important issue in many parts of the world. Some 20 to 50 million metric tonnes of e-waste is generated globally every year. A snapshot of quantities of e-waste generated in different parts of the world is shown in the table below.

Table 4: e-waste generation across the globe

(Source: http://www.ewaste.ch/facts_and_figures/statistical/quantities/)

Country	Total E-waste generated (Tonnes/Year)	Categories of Appliances counted in e-waste	Year
Switzerland	66,042	Office & Telecommunications Equipment, Consumer Entertainment Electronics, Large and Small Domestic Appliances, Refrigerators	2003
Germany	1,100,000	Office & Telecommunications Equipment, Consumer Entertainment Electronics, Large and Small Domestic Appliances, Refrigerators	2005
UK	915,000	Office & Telecommunications Equipment, Consumer Entertainment Electronics, Large and Small Domestic Appliances, Refrigerators	1998
USA	2,158,490	Video Products, Audio Products, Computers and Telecommunications Equipment	2000
Taiwan	14,036	Computers, Home electrical appliances (TVs, Washing Machines, Air conditioners, Refrigerators)	2003
Thailand	60,000	Refrigerator, Air Conditioners, Televisions, Washing Machines, Computers	2003
Denmark	118,000	Electronic and Electrical Appliances including Refrigerators	1997
Canada	67,000	Computer Equipment (computers, printers etc) & Consumer Electronics (TVs)	2005

Given the increasing quantities and economic value (due to the presence of base and precious metals) attached to these products at the end of life, recycling of e-waste is increasingly catching attention. At the same time, due to the presence of hazardous substances, unsafe handling of e-waste is also a growing matter of concern. A major proportion of recycling and reprocessing of e-waste happens through transboundary movement from developed to developing

countries. More often the developing countries lack the infrastructure and technical capacity necessary for safe disposal of such wastes. Not only the physical infrastructure, developing countries are also deficient in terms of stringent health and environment regulations. According to BAN (Basel Action Network), about 50-80% of the e-waste from United States is exported to developing countries due to cheap labor, tax standards, absence of law to prevent such toxic import to the developing country and the export practices are accepted legally in the country which exports the waste. The e-waste recycling and disposal methods in countries like India, China and Pakistan often pollute the environment with processes like open burning of plastic waste and dumping of the recycled remains in rivers.

Recycling when practiced in environmentally friendly manner will lead to both development and trade in developing countries.

Listed below are a few more facts related to global e-waste industry.

Figure 5: Key facts about Global e-waste industry

(Source: <http://www.ban.org>, <http://www.computertakeback.com>, <http://www.aeanet.org/>)

- | | |
|---|--|
| <ul style="list-style-type: none">▪ Industrialized nations like the USA are the largest producer and consumers of electronic goods▪ 48.5 million Computers are discarded in the United States each year. 1.5 million of those machines end up in landfills annually▪ 50-80 percent of e-waste collected for recycling is exported from the U.S. to Asia▪ Each European, on an average, contributes 14 kg (entire Europe- 6.5 million metric tons) per year▪ China had the highest growth in number of computer users per capita in the period 1993-2000. It grew by a massive 1052%, compared to a world average of 181%▪ In 1994, approximately 20 million Personal Computers (PCs) become obsolete worldwide and in 2004 it had increased to 100 million PCs | <ul style="list-style-type: none">▪ A recent report from the International Association of Electronics Recyclers projects that around 3 billion units will be scrapped during the rest of this decade in the US or an average of about 400 million units a year, including 200 million televisions and one billion units of computer equipment▪ According to BAN about 75 percent of old electronics are in storage as consumers store them, feeling they have some value but uncertain about how to dispose them▪ According to Richard Gutierrez, a toxics policy analyst for the Seattle, Washington-based Basel Action Network, most of the e-waste sent for disposal in recycling in developing nation is being re-used with slight modification▪ According to European IMPEL enforcement program along with Netherlands, Germany, Britain, Poland and six major European ports, 22% of the e-waste exports were found to be illegal |
|---|--|

3.2 Global Scenario – Policies & Regulations

In the international arena several countries and group of countries have framed laws and policies to manage and regulate the adverse effects of e-waste. Countries in Europe and Japan have been the leader in formulating policies/ laws/ regulations for WEEE/E-waste followed by their institutionalization and implementation. In 2003, two main directives were formulated by the European Union for e-waste reduction, recycle and reuse. These are 'Waste Electrical and Electronic Equipment Directive' (also known as WEEE Directive) and 'The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipments' (called the RoHS Directive). These two regulatory frameworks being the source of inspiration for legislation by a number of countries across the world, aim to help reduce the overall amounts of e-waste by pushing for adoption of environmentally friendly disposal methods.

WEEE directives provide a regulatory basis for collection, recovery and reuse/ recycling targets in EU. The fundamental principle of WEEE directive is "Extended Producer Responsibility", where producers are responsible for WEEE/ E-waste take back. Those European countries, which are not part of EU either follow EU directive or more stringent standards based on WEEE/ E-waste management. Majority of countries have regulations similar to WEEE directives. Countries like Japan have regulations focused on "Reuse, Recycling and Recovery". Other countries like Canada and Australia are developing their systems based on the similar principles of "Extended Producer Responsibility".

RoHS Directive, in effect from July 1 2006, aims to reduce the use of hazardous substances in electronic and electrical equipments to the extent possible. The directive provides that new electrical and electronic equipment put on the EU market must not contain lead, mercury, cadmium, hexavalent chromium, or the flame retardants PBB and PBDE beyond the prescribed limits. The applications which are exempt from the requirements of the Directive include mercury in certain types of fluorescent lamps, lead in the glass of cathode ray tubes, electronic components and fluorescent tubes, lead in electronic ceramic parts, and hexavalent chromium as an anti-corrosion of the carbon steel cooling system in absorption refrigerators.

A summary of regulatory structure and institutional mechanism adopted by developed countries for e-waste management is shown in the table below.

Table 5: Policies/Regulations and Institutional Roles for E-waste management in Developed Countries

(Source: E-waste Management Manual, UNEP)

Countries	Policies/Regulations	B2C e-waste collection	B2B e-waste responsibilities
Australia	No Specific WEEE/E-waste regulation. Voluntary product stewardship initiative are under development	Municipal collection system exists for major household items. Voluntary mobile phone industry recycling program exists (take back at retailers)	No industry wide take back exists
Canada	Canada's WEEE/ E-waste regulations are in the process of being developed at provincial level based on extended producer's responsibility/ stewardship. Alberta, Saskatchewan, British Columbia, Ontario and Nova Scotia have WEEE/ E-waste regulations in place.	Under development based on the principles of extended producer's responsibility/ stewardship	Under development
Japan	Reduce; Recycling; Recover, "The Law for Recycling of Specified Kinds of Home Appliances (Home Appliances Recycling Law)" 1998 and "The Law for Promotion of the Effective Utilization of Resources" 2000	Take back for home appliances by retailers for free. In case of non replacement with new item, consumers to pay for disposal/ recycling charges and transportation. Collection points are located at retailers, collection centers or post offices (for direct delivery to OEM) OEM responsible for collection and transportation of WEEE/E- waste but generator to pay for collection and management costs.	Exists
Korea	Producer Responsibility/ Product Stewardship. Article 2 of Act for Resource Recycling of Electrical and Electronic Equipment and Vehicles adopted on 2nd April 2007	Municipality collect for old discarded and charge for collection and disposal of WEEE/E-waste (in case of no new purchase) Take back of household by retailers for limited items (new purchase)	Limited mandatory free take back for WEEE (purchase of new product) by producers
USA	No specific legislation at federal level. But seven states have banned some electronics from landfills, and four have instituted recovery programs	Ongoing drop off at nonprofit institutions Ongoing drop off at retailers take back by retailers in some states Sporadic collection events	Not clearly defined. States have different systems

Section 4

Indian Scenario: E-waste Quantum and Regulations

4.1 Indian Scenario – Quantum

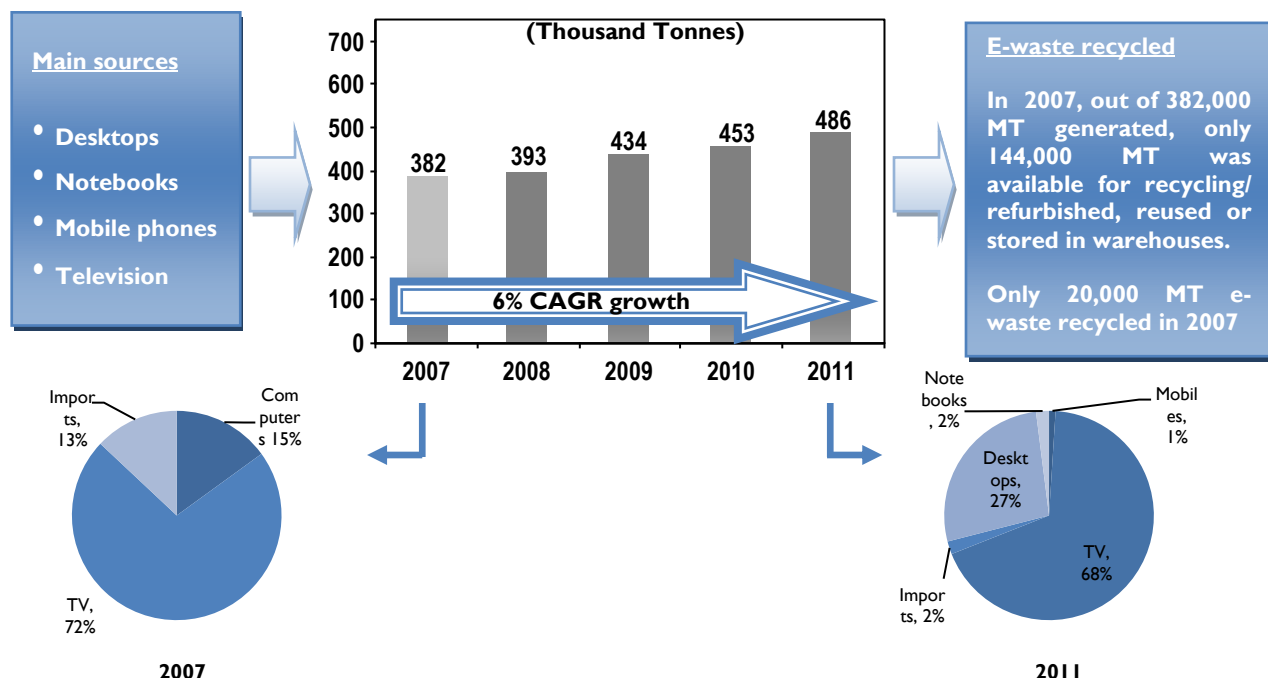
The growth rate of discarded electronic waste is high in India as well. In the last few years, India has emerged as an “Information Technology” giant. The consumer electronics market has also grown at a significant rate in India. Increasing market penetration, large replacement market and high obsolescence rates make e-waste one of the fastest growing waste streams in India and many other developing countries.

Based on the findings of national level e-waste inventORIZATION study for Gtz by IMRB, India generated around 3,32,000 tonnes of e-waste in 2007. Products covered in this inventORIZATION study included Computers (both Desktops and Laptops), Televisions and Mobile phones. It was found that around 50,000 tonnes of e-waste comes through imports besides 3,32,000 tonnes generated domestically. Due to factors like lack of proper collection systems, extended storage and second hand use, only 1,44,000 tonnes, out of 3,82,000 tonnes, is available for recycling.

Based on the estimates from individual e-waste streams, the total e-waste likely to be generated in the next few years is summarized in the figure below.

Figure 6: Forecast of e-waste generation in India, 2007 - 2011

(Source: IMRB primary study of Businesses & homes on disposal methods, 2007)



4.2 Indian Scenario – Policies & Regulations

Ministry of Environment and Forests (MoEF) of the government of India is responsible for environmental legislation and its control. In the year 2001 Gtz, in cooperation with MoEF, began to work on hazardous waste management in India.

In India, several environmental laws exist, which cover the management of hazardous waste such as The Batteries Management and Handling Rules, Hazardous Waste Management and Handling Rules, etc. However, the hazardous and solid waste rules in India do not make any direct reference to e-waste or its management.

In the last few years, realizing the growing concern of e-waste, a number of initiatives have been taken by the government agencies to arrange for e-waste management programs. The main bodies active in e-waste management in India are CPCB, SPCBs, Gtz and industry associations such as MAIT (Manufacturers' Association for Information Technology). These organizations are working under the guidance of MoEF.

As a result of these initiatives, the CPCB (Central Pollution Control Board) had set up a task force in 2007 to analyze the different aspects of e-waste covered in various environmental legislations in India and to draft guidelines for environmentally sound management of e-waste. In the beginning of 2008, the CPCB released guidelines for environmentally sound management of e-waste, which apply to all those who handle e-waste.

The E-Waste Guidelines are the first policy document dealing specifically with prevention, management, treatment, recycling, and disposal of e-waste in India.

These guidelines provide guidance to the manufacturers, recyclers, customers, generators, collectors, transporters, dismantlers, and enforcement agencies and prescribe procedures for handling e-waste in an environmentally sound manner

Apart from emphasizing on the need for adoption of environmentally sound technologies and methods for e-waste treatment and disposal, these guidelines also introduce certain internationally accepted principles and practices, such as restriction of the use of certain

hazardous substances (RoHS) in electrical and electronic equipment, extended producer responsibility and product take-back.

However, these remain voluntary guidelines only and they fail to provide sufficient guidance and enforceability to fully meet the need for specific regulations for e-waste management.

The guidelines have been found lacking when it comes to stipulating what must be done by different players such as vendors, recyclers and others.

In contrast, e-waste recycling laws in Europe make it obligatory on the producer to provide information on reuse centers, treatment facilities and recycling facilities besides stipulating the time period within which it must be done (within one year of putting any electrical/ electronic equipment on the European market).

Section 5

E-waste in KMA: Disposal Behavior and Quantum

5.1 Disposal Practices of Users in KMA

A quantitative survey was conducted among the users (both households and establishments) to understand their disposal behavior with focus on aspects such as:

- Obsolescence rates of different product categories under the scope of the study
- Reasons for disposal/replacement of those products
- Methods used for disposal
- Considerations while disposing

A total of 710 Households and 390 business establishments were covered in the survey. These sample sizes were calculated using statistical sample size calculators keeping in mind the population and $\pm 5\%$ error level.

While doing the survey the interviews were conducted in such a way that there is a significant representation of all the seven locations under the scope of the study.

Business establishments were covered for Computers, Printers and UPS and households were interviewed for all the seven product categories mentioned under the scope of the study i.e. Computers (Desktops and Laptops), Printers, UPS, Televisions, Refrigerators, DVD players and Mobile Phones.

In case of households, this survey was conducted among the users who have disposed off any of the above mentioned seven product categories in last two years. This qualification criterion was kept to get real time data as responses and thus to ensure the accuracy of findings of the study. In order to meet 710 such households, a total of 2473 contacts were made.

This section summarizes the disposal behavior of Households and Business establishments captured through these quantitative interviews.

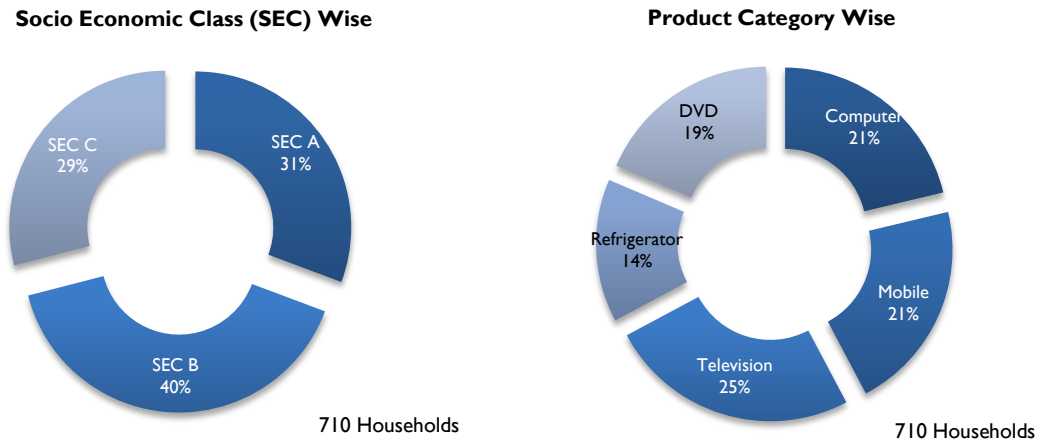
Disposal here refers to the products which have either been sold / donated / exchanged for new products.

Disposal Behavior of Households

Sample Details

Following two charts depict the socio economic class (SEC) wise and product wise coverage of the households. (Refer SEC classification grid in Annexure G)

Figure 7: Sample Size Break-up of Households



Obsolescence Rates

Unexpectedly, it was found that the obsolescence rate of the lower SEC i.e. SEC C was higher as compared to SEC A & B. This may be attributed to the fact that the lower classes have a tendency to buy cheaper goods. Life of such products is shorter as compared to branded products affordable to the upper class of the society. The obsolescence rates by SEC and product categories are summarized in the table given below.

Table 6: Disposal Behavior of Households – Obsolescence Rates

Product Category	Age in Months (In years in parenthesis)			
	Overall	SEC A	SEC B	SEC C
Mobile	33 (2.75)	37 (3.08)	35 (2.92)	28 (2.33)
Television	102 (8.50)	99 (8.25)	111 (9.25)	104 (8.67)
Refrigerator	130 (10.83)	140 (11.67)	125 (10.42)	119 (9.92)
Desktops	81 (6.75)	83 (6.92)	81 (6.75)	79 (6.58)
Notebooks	49 (4.08)	51 (4.25)	51 (4.25)	48 (4)
DVD/VCD	49 (4.08)	53 (4.42)	54 (4.50)	40 (3.33)
Printers	58(4.83)	59 (4.92)	57 (4.75)	--

Methods of Disposal

As it can be seen from the table below, more than 30% of the mobile phones, Televisions and DVD players were sold in the second hand market by the residential users. In case of computers, this percentage is even higher where 50% of the household computers reach the second hand market.

In case of refrigerators, more than half of the disposed refrigerators were exchanged for new ones. This also validates one of the finding from the qualitative study – ‘Refrigerator dismantlers (at Hazra Crossing and Bondel gate source most (almost 90%) of the old refrigerators from dealers and manufacturers’

It is interesting to note that a good percentage of disposed products were directly sold to the scrap dealers. This percentage was higher in case of televisions and DVD players, with almost 10% of such cases in each category.

Table 7: Disposal Behavior of Households – Methods of Disposal

Method of Disposal	Product Category				
	Mobile (149)	Television (177)	Computers (151)	DVD Players (132)	Refrigerators (101)
Given to relatives/friends	37%	24%	20%	30%	11%
Donated to driver/maid/other charity	0%	1%	1%	0%	0%
Thrown in dustbin / municipal waste	7%	1%	0%	2%	0%
Sold in second hand market	34%	31%	50%	34%	19%
Sold to scrap dealer	3%	11%	2%	9%	4%
Exchanged for new products	13%	28%	27%	15%	60%
Others	6%	4%	0%	10%	6%

It can be concluded from the above that sales in the second hand market and exchanges for new products were the two most commonly adopted routes for disposal across all the product categories. Dealers and manufacturers can be the focus of formalization initiatives and formal recyclers to fulfill the planned recycling capacities.

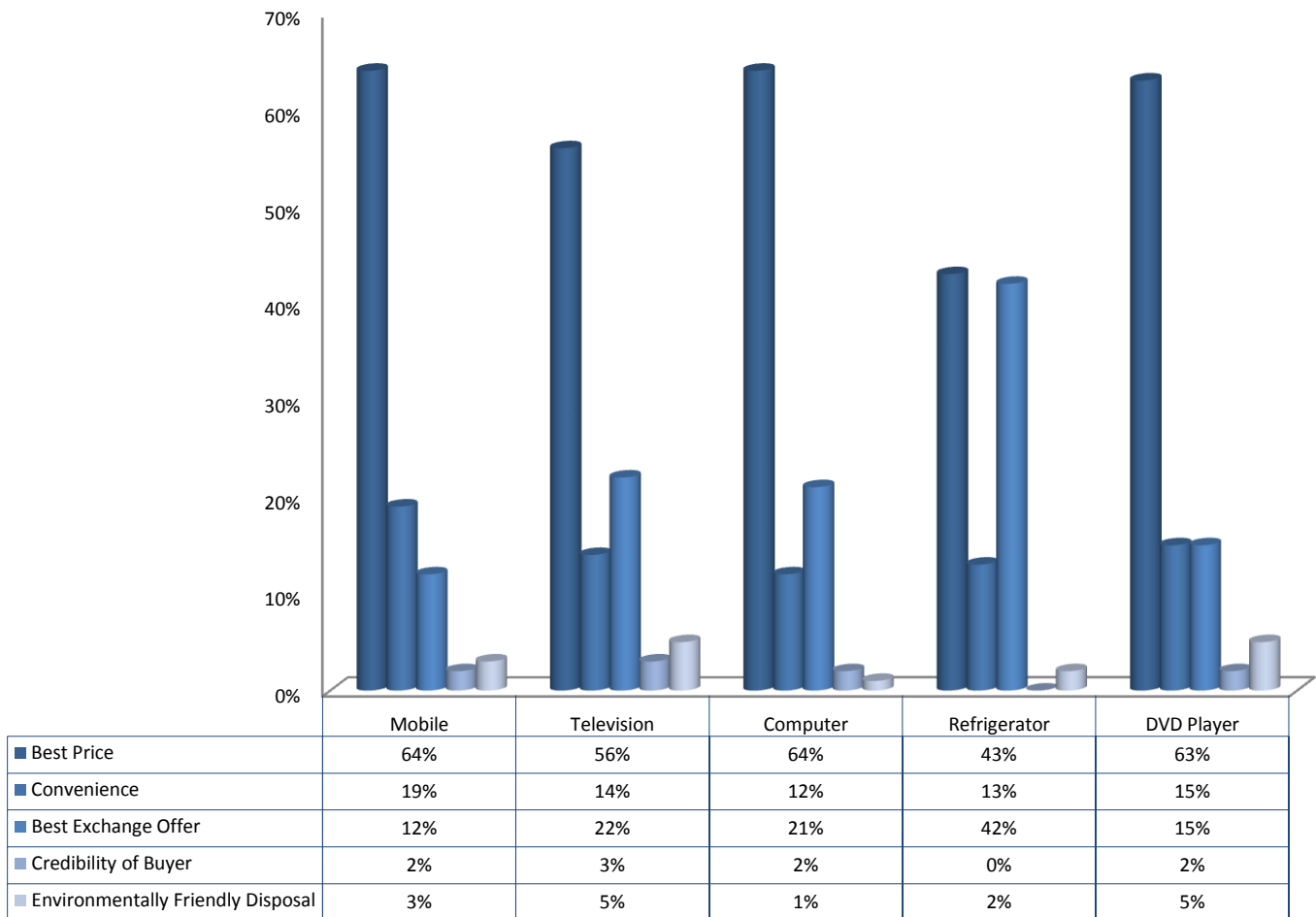
Considerations while Disposal

Price (Best Price/Best Exchange offer) and convenience were the most important factors of consideration for most of the residential users while disposing their old products.

Percentage of households wanting environmentally safe disposal of their old goods is very low. Low awareness levels may be one of the reasons.

However, it is interesting to note that when a similar kind of survey was conducted in Delhi in 2007, the percentage of households wanting environmentally safe disposal of their old products was even lower.

Figure 8: Disposal Behavior of Households – Most Important Consideration while Disposal

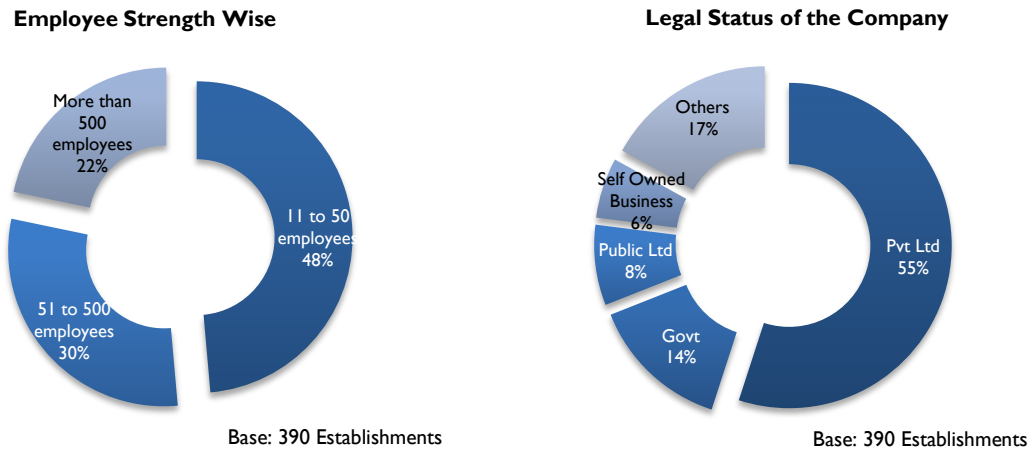


Disposal Behavior of Business Establishments of KMA

Sample Details

Following two charts show the breakup of sample size of business establishments by employee strength and legal status of the company.

Figure 9: Sample Size Break-up of Business Establishments



Obsolescence rates and Reasons for Disposal

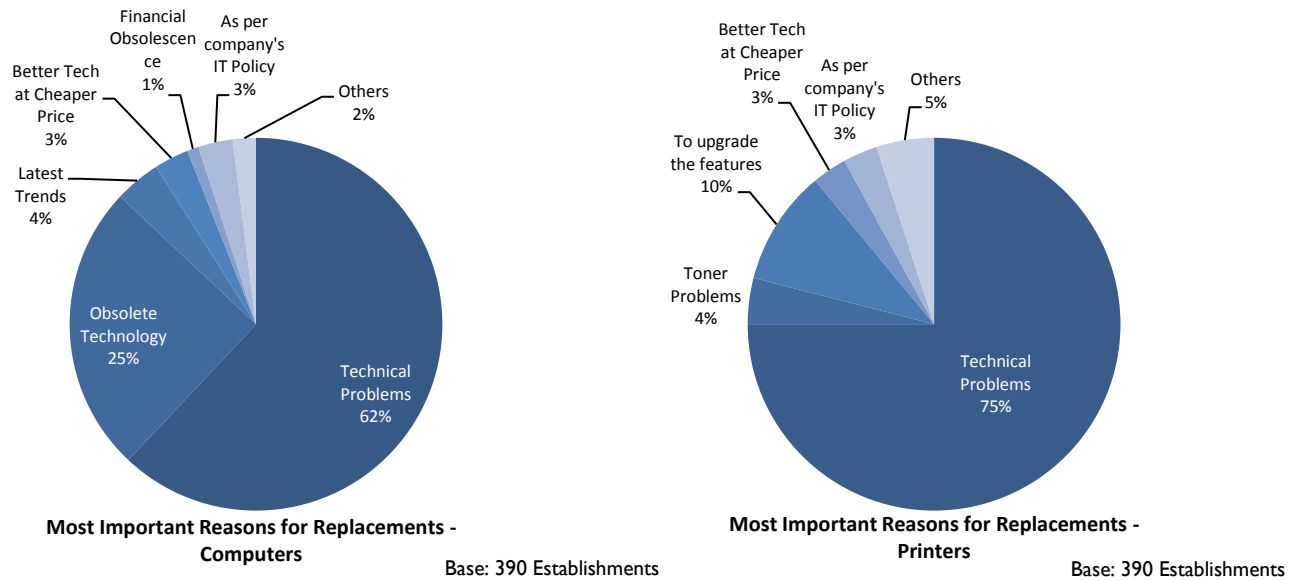
The obsolescence ages of IT products in business organizations are decreasing every year. Both Computers as well as Printers are disposed (sold / exchanged for new products / donated etc) within five years of purchase.

Pie charts given below summarize the most important reasons for disposal / replacements of IT products by business establishments.

Table 8: Disposal Behavior of businesses – Obsolescence Rates

Computers	Desktops	Laptops
Age in Months (In years in parenthesis)	58 (4.83)	51 (4.25)
Printers	Inkjet Printers	Laser Printers
Age in Months (In years in parenthesis)	56 (4.67)	57 (4.75)

Figure 10: Disposal Behavior of Business Establishments – Key Reasons for Replacements

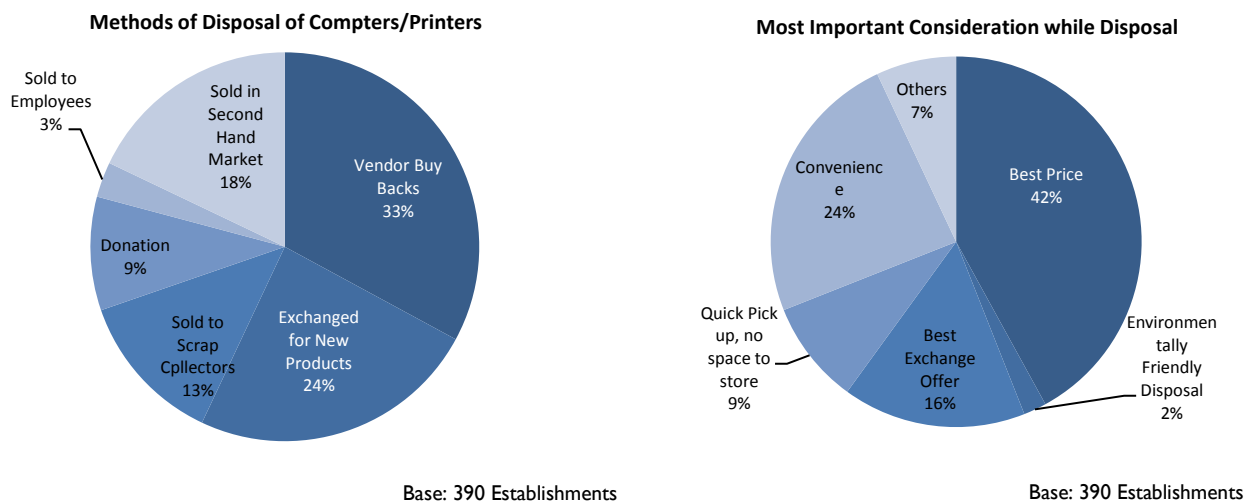


Methods of Disposal and Considerations during Disposal

More than 50% of replacements of computers and printers happen through Vendor buy backs and Exchange schemes. Around 30% of the old IT goods of business establishments directly enter the e-waste stream through sales to second hand market and scrap dealers.

Half of the establishments have Price as the most important consideration while replacing their old computers/printers.

Figure 11: Disposal Behavior of Business Establishments – Methods and Considerations during Disposal



Levels of Awareness about Hazards of E-waste

To gauge the levels of awareness among the business establishments, following question was asked to the respondents from this segment: “Have you heard about problems due to disposal of electronic and electrical equipments? Please check one of the following options based on your level of understanding.”

The responses to this question are summarized in the table given below. It was observed that a significant proportion of organizations – around 20% are still not aware of the issues related to e-waste disposal.

Table 9: Awareness levels of Business Establishments

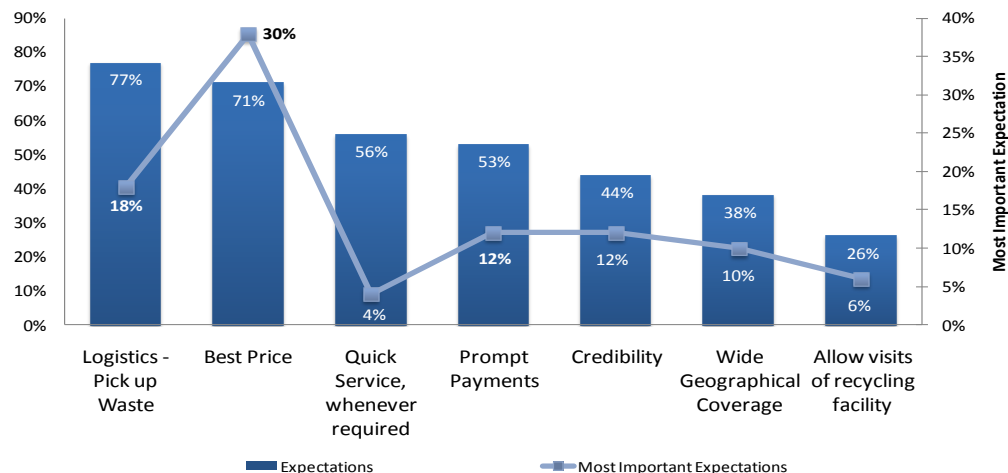
E-waste Awareness Levels	2009 - Kolkata	2007 – Delhi
Have a very good understanding of the problem	17%	15%
Have some understanding of the problem	39%	38%
Have only a brief understanding of problem	25%	40%
Do not know about this problem	19%	7%

Expectations of Organizations from a Formal Recycling Company

When organizations were asked about their expectations from a formal e-waste recycling company, “Logitics and Best Price offer” came out as the most important expectations.

Prompt pickups of waste and prompt payments for their waste are the next two important expectations from a formal recycling company.

Figure 12: Expectations of Business Establishments from a formal recycling company



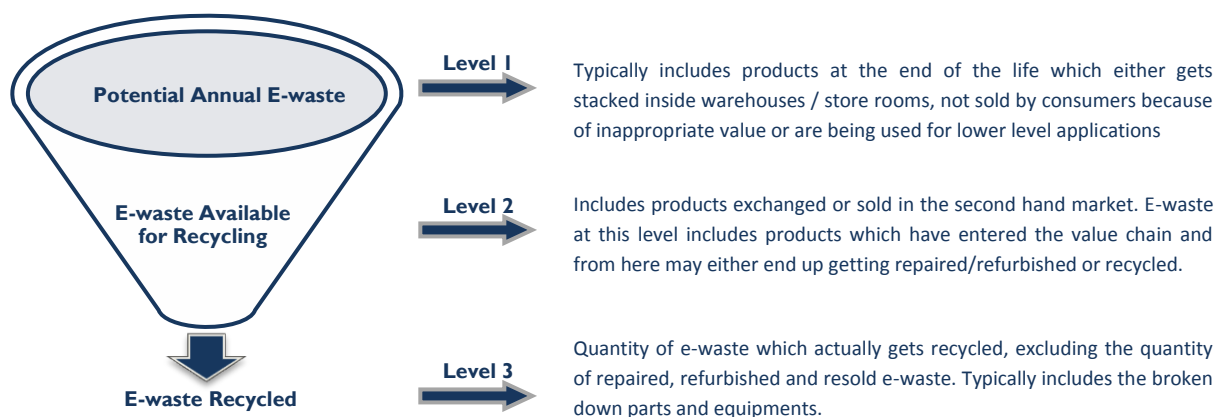
5.2 E-waste Quantities in KMA

These obsolescence ages captured through the primary survey among the users were used as an input for e-waste quantity estimation. 'Input and Obsolescence method' was adopted to arrive at the e-waste quantities of different product categories. This input and obsolescence methodology was developed during the 'National Level E-waste Assessment study' conducted in 2007. Inputs from industry experts like Gtz and MAIT were obtained to validate the methodology.

Details of this methodology and steps followed for estimating the e-waste quantities for KMA are as follows.

It was found that most of the used electronic products are either relocated or given to relatives/ friends for further use. Also, because of lack of proper collection systems, households and institutions are unsure of the actions to be taken with their old computers or televisions. This results in storage of these products inside their warehouses and store rooms for a long period of time. Even when the products are sold or exchanged, many are refurbished and resold and possibly some useful parts are recycled through repair shops. As unorganized recycling involves many legal and jurisdiction issues, the unorganized players are not open to any kind of research or study on this subject. Therefore, for accuracy and better understanding of e-waste production in India, a funnel approach was adopted to arrive at actual quantities of e-waste at three levels:

Figure 13: Pictorial Representation of Funnel Approach used for E-waste Estimation



Level 1: Estimation of Potential Annual e-waste: The quantity of e-waste generated at this level was calculated by applying input and obsolescence method to all the products categories under the scope of this study. Input refers to the sales of product and obsolescence refers to the average number of years after which the product is disposed of by the customer. Input/sales figures were obtained from databases available with respective industry associations and already published reports for different product categories. The following table briefly describes the steps followed for this estimation.

Table 10: Steps in estimation of Potential Annual e-waste

Process	Desktops	Notebooks	Printers	Televisions	Mobiles	Refrigerators	DVD Players
Step 1: Annual Sales by segment	Source of Data						
	MAIT – ITOPs	MAIT – ITOPs	MAIT -ITOPs	CEAMA	COAI, AUSPI	CEAMA	CEAMA
Step 2: Obsolescence age applied for estimation of Potential Annual e-waste:	Replacement Age						
	Business Establishments: 5 Years Households: 7 Years	Business Establishments and Households: 4 Years	Business Establishments and Households: 5 Years	9 Years	3 Years	11 Years	4 Years
Step 3: Conversion of number of units of e-waste in tones by applying weights of the product categories	Unit Weight						
	27.2 KG	3.4 KG	6.5 KG	25 KG	0.1 KG	35 KG	5 KG

Level 2: Estimation of e-waste Available for Recycling: Quantity of e-waste at this level was derived on the basis of inputs from expert interviews and channel member insights. Informal sector e-waste intermediaries were also interviewed.

Level 3: Estimation of e-waste Recycled: This quantity of e-waste at this level was estimated on the basis of interviews with formal recyclers, informal recyclers and experts.

Before moving on to the findings related to the e-waste volume, following are the key assumptions associated with this estimation the e-waste quantities:

- Current obsolescence rates (captured from primary survey) have been considered as standard rates for forecasting the e-waste quantities for future as well.
- Disposal of all components and sub-components have been assumed along with the disposal of the main product category. Given that continuous disposal cycle of different components will balance out the volumes in the overall estimation over years, this assumption holds valid.
- Weights of the product categories have been assumed to be standard over years.
- The estimated e-waste volumes may vary with changing market situation. For e.g. change in product compositions or changing industry regulatory scenario.

The next few pages summarize the findings from the assessment. **It was estimated that KMA generates around 26000 tonnes of potential e-waste annually, of which 9290 tonnes is available for recycling and only 2000 tonnes gets recycled.** The detailed product wise break-up and forecasts

Figure 14: E-waste generation in KMA in 2010

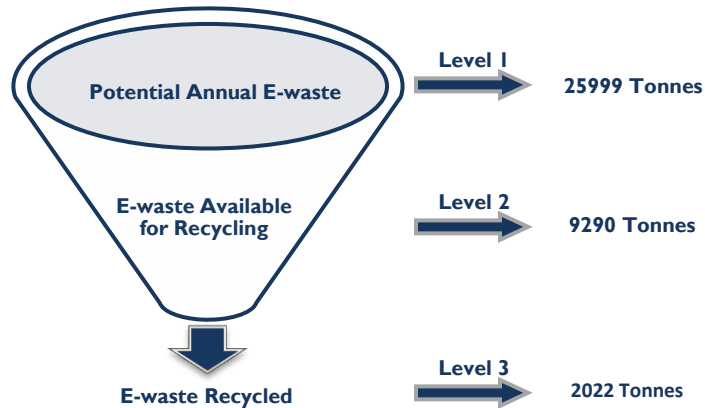


Figure 15: Potential Annual E-waste in KMA – By Type of Product Categories

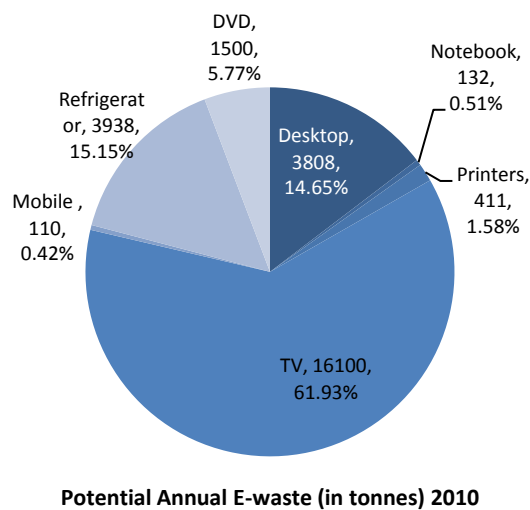


Table 11: E-waste at Three Levels of Funnel – By Type of Product Categories (Unit in Tons)

Product Category	Potential Annual E-waste	Available for Recycling	E-waste Recycled
Desktop	3808	1714	857
Notebook	132	59	30
Printers	411	185	92
TV	16100	4830	483
Mobile	110	55	3
Refrigerator	3938	1772	354
DVD	1500	675	203
Total	25999	9290	2022

*Refer Annexure I for e-waste volumes by number of products for all product categories

Figure 16: E-waste from Desktops – Break-up by User Segment (in Tonnes and Percentage)

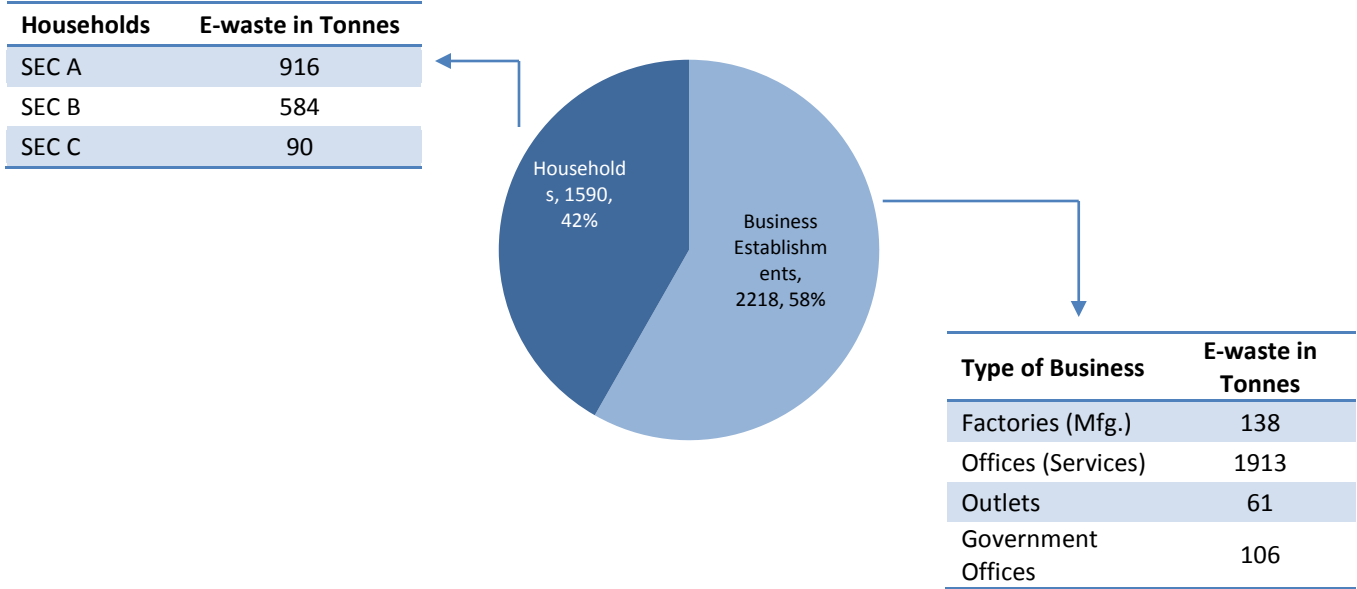


Figure 17: E-waste from Desktops – Forecasts for Next Ten Years (in tonnes)

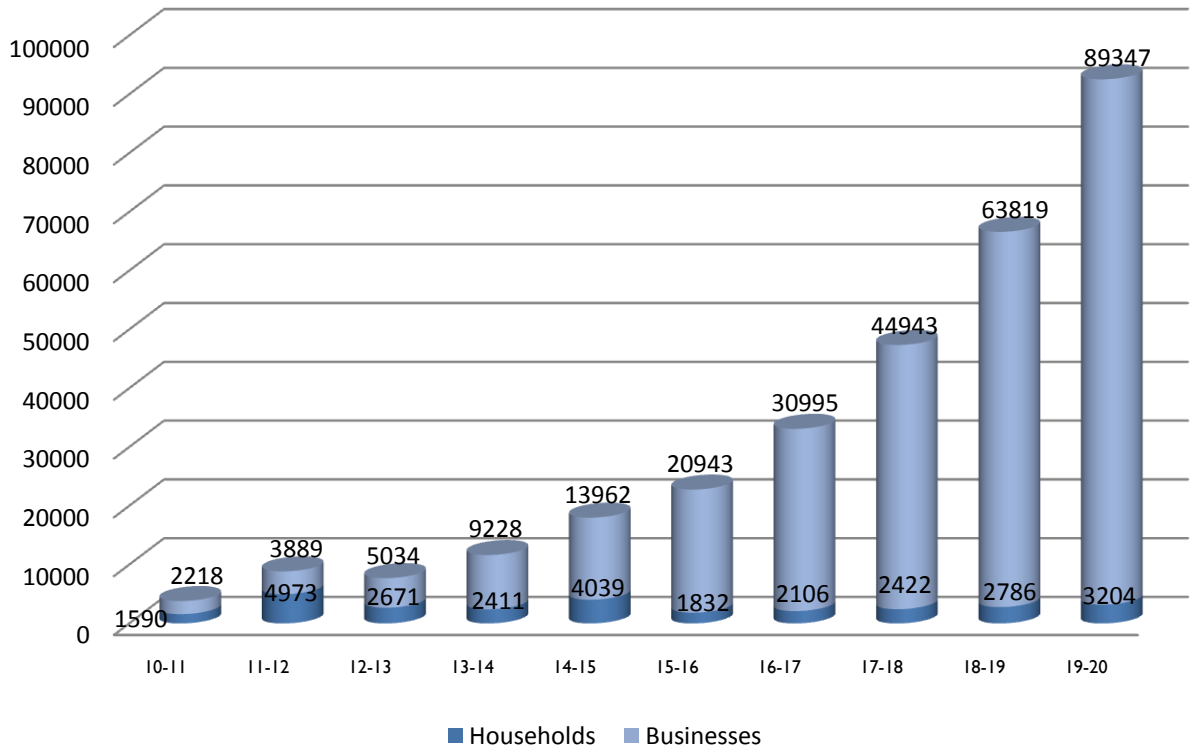


Figure 18: E-waste from Notebooks – Break-up by User Segment (in Tonnes and Percentage)

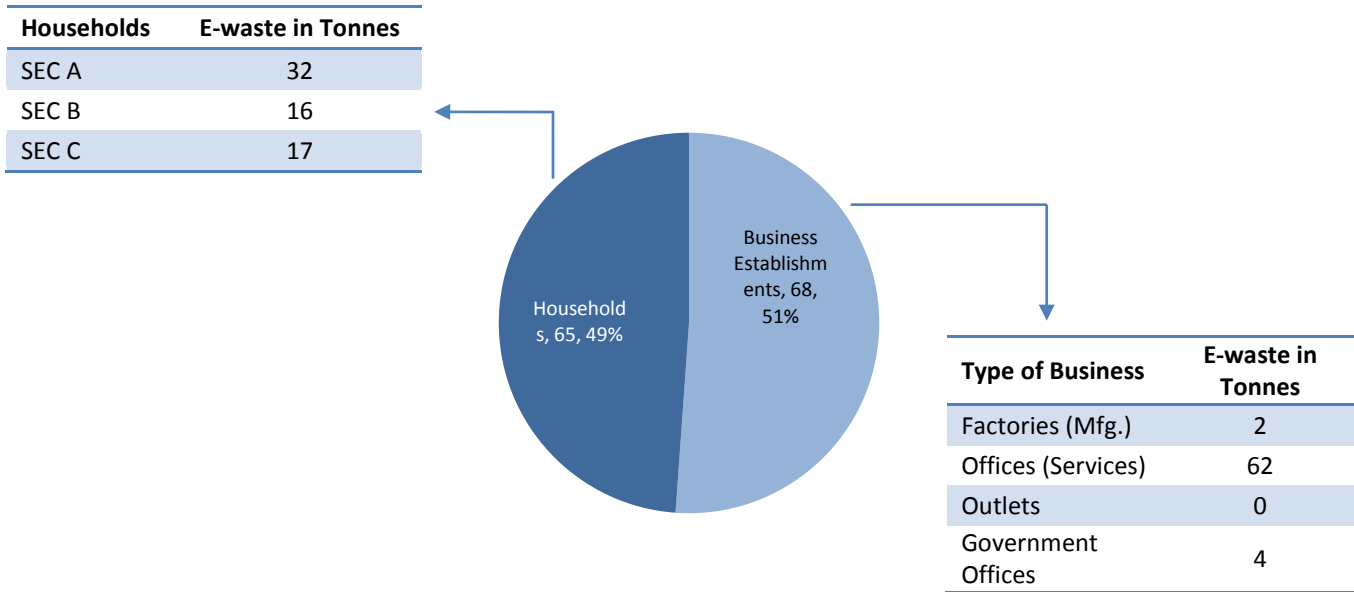


Figure 19: E-waste from Notebooks – Forecasts for Next Ten Years (in tonnes)

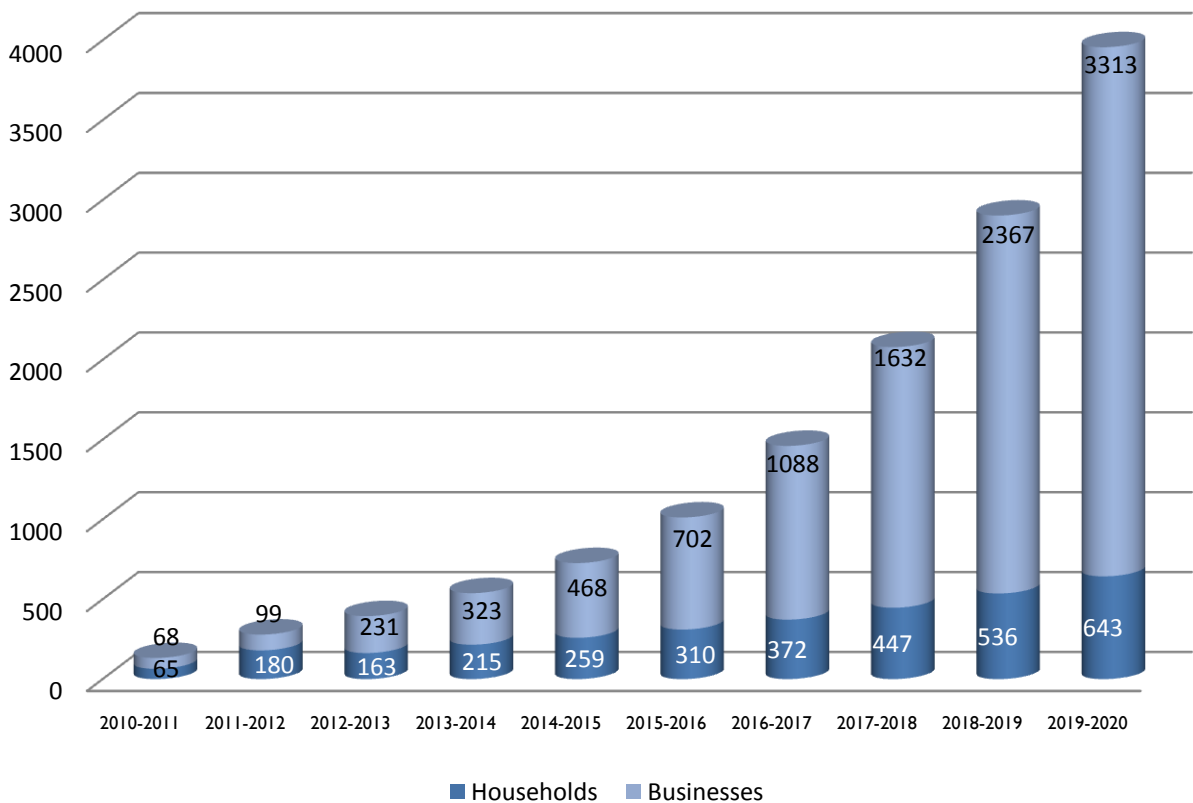


Table 12: E-waste from Printers – Forecasts for Next Ten Years by Type of Printer

Year	Total Potential Annual E-waste (in Tonnes)	Inkjet Printers	Laser Printers
2010-2011	411	378	33
2011-2012	405	247	158
2012-2013	454	267	186
2013-2014	385	163	221
2014-2015	418	177	241
2015-2016	451	186	265
2016-2017	488	196	291
2017-2018	526	205	321
2018-2019	562	210	353
2019-2020	603	216	388

The above mentioned figures of e-waste from IT products have been calculated using the market size data from IMRB's ITOPs (IT Office Products & Services) study. This study is conducted for MAIT, covering 14,000 households and 10,000 business establishments across 22 cities of India. Since last twelve years, this survey is conducted every six months for estimating the market size of IT and office products.

All the IT product categories (Desktops, Notebooks and Printers) have a combined share of 4351 tonnes in the e-waste generation in the current year i.e. 2010. However, this figure of e-waste only from IT products is expected to go up to 97110 tonnes by 2020.

The quantity of e-waste from Desktops is inclusive of the weight of peripherals like keyboards, mouse and UPS as well. During the study it was found that UPS batteries replacements, especially in case of business establishments happen through vendor buy back schemes. This may be attributed to the "Battery Management and Handling Rules – 2001" which mandates all the manufacturers to ensure environmentally safe disposal and recycling of their batteries. However, as there is a significant presence of grey market and unbranded products in India, a major proportion of UPS may end up entering in the unorganized e-waste stream rather than being recycled by authorized recyclers. Thus, weight of UPS has been taken into consideration in calculations.

Estimate of current and forecasted E-waste quantities from Consumer Electronics are summarized in the table below.

Table I3: E-waste from Consumer Electronics – Forecasts for Next Ten Years (in Tonnes)

Year	Mobile Phones	Televisions	Refrigerators	DVD Players	Total
2010-2011	110	16100	3938	1500	21648
2011-2012	203	17938	4638	1800	24579
2012-2013	169	19250	5250	2100	26769
2013-2014	220	20563	5906	1860	28549
2014-2015	286	22313	6475	2046	31120
2015-2016	310	24500	6799	2251	33860
2016-2017	388	26250	6738	2476	35852
2017-2018	485	30188	7350	2674	40697
2018-2019	485	32375	8488	2888	44236
2019-2020	582	33688	10325	3119	47714

The above mentioned figures of e-waste generated from consumer electronics have been calculated by using the market size data maintained by the respective industry associations and by applying the obsolescence ages captured through the primary survey conducted in KMA.

In case of TV, Refrigerators and DVD players, the data was provided by CEAMA (Consumer Electronic Appliances Manufacturers Association).

In case of mobile phones the data of GSM and CDMA subscribers was collated from COAI and AUSPI respectively. This subscribers' data was used to calculate the net additions in terms of mobile handsets after applying an appropriate correction figure on the subscriber base suggested by industry experts.

To conclude this section, a graph and a table summarizing the forecasts for next ten years (for the entire product categories combined) is shown below.

Figure 20: Total Potential Annual E-waste (in Tonnes) – Forecasts

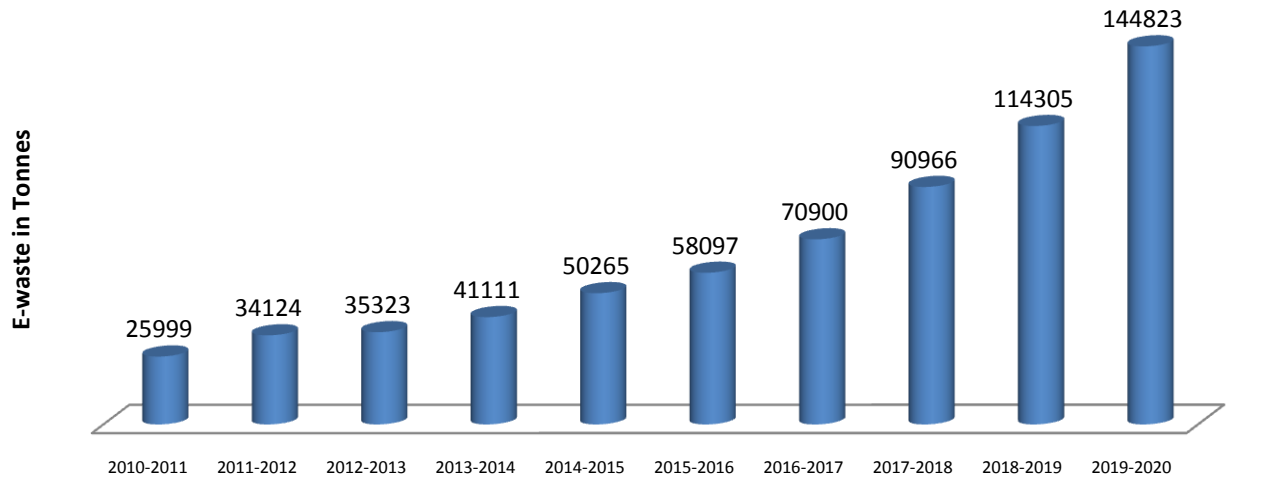


Table 14: Break-up of E-waste (in Tonnes) Forecasts by Product Categories

Year	10-11	11-12	12-13	13-14	14-15	15-16	16-17	17-18	18-19	19-20
Total E-waste (Tonnes)	25999	34124	35323	41111	50265	58097	70900	90966	114305	144823
Percentage Contribution from all the Product Categories										
Desktop	14.65%	25.97%	21.81%	28.31%	35.81%	39.20%	46.69%	52.24%	58.27%	63.91%
Notebook	0.51%	0.82%	1.12%	1.31%	1.45%	1.74%	2.06%	2.29%	2.54%	2.73%
Printers	1.58%	1.19%	1.29%	0.94%	0.83%	0.78%	0.69%	0.58%	0.49%	0.42%
TV	61.93%	52.57%	54.50%	50.02%	44.39%	42.17%	37.02%	33.30%	28.32%	23.26%
Mobile	0.42%	0.59%	0.48%	0.54%	0.57%	0.53%	0.55%	0.53%	0.42%	0.40%
Refrigerator	15.15%	13.59%	14.86%	14.37%	12.88%	11.70%	9.50%	8.11%	7.43%	7.13%
DVD	5.77%	5.27%	5.95%	4.52%	4.07%	3.87%	3.49%	2.95%	2.53%	2.15%

Share of IT products (mainly Desktops) in e-waste generation is expected to increase considerably. Current share of IT products of around 15% is expected to go as high as more than 50% in next five years and almost 70% by 2020. Share of mobile phones is insignificant in the overall potential e-waste generation and considering the fact that mobile phones in e-waste get cannibalized in repair and refurbishments, an even lower quantity, (almost insignificant) will be available for recycling in case of mobiles.

Section 6

E-waste Recycling in India and KMA

6.1 E-waste Recycling Practices of India

E-waste recycling in India is undertaken by two different types of recyclers –

1. Formal, also known as organized recyclers
2. Informal, also known as unorganized recyclers

The latter is responsible for recycling major proportion of e-waste processed in India. According to the national level e-waste assessment study conducted in 2007, 95% of the e-waste is recycled by the unorganized sector.

Formal Recyclers in India

As a result of concerted efforts by many stakeholders, e-waste management in India has slowly become more organized although it has still a long way to go given the widespread penetration of informal sector. India can now claim to be home of a few companies which are following at least environmentally sound practices in dismantling e-waste and then sending it to approved processing centres. Given the interest in this sector, more companies are slated to come up with state of art facilities to recycle the burgeoning e-waste generation.

Most of the e-waste recycling plants of the formal sector are concentrated around Western and Southern India. Chennai, in addition to being a vibrant IT hub, is also to a major port. This enables recyclers to import considerable quantities of discarded computers for processing. Bangalore on the other hand is the Silicon Valley of India. It is also a trend-setter where several initiatives on e-waste recycling have been experimented (involvement of corporate sector for voluntary waste collection, involvement of informal recyclers in a community initiative etc.). Mumbai, being the leading commercial city of India has a large corporate sector presence. This has led to growth of a few formal recyclers in this city.

Delhi, the national capital has a sizable representation of government departments. In addition, private sector hubs like Gurgaon (largely IT), Faribadad, NOIDA and Ghaziabad (Industrial belts with some presence of IT sector) generate sizeable quantities of e-waste each year. However, the presence of a large and entrepreneurial informal

sector in Delhi, which acts as the e-waste recycling hub of India, has been a factor for lack of a good formal recycling facility in the northern region. Realizing these lacunae, Delhi NCR government has already taken initiatives to rope in the private sector for setting up e-waste recycling plants. It has floated an Expression of Interest (EOI) inviting private firms to take up developmental projects related to collection and storage of the e-waste, dismantle, and segregate or extraction of valuable metals, reuse, recycling or treatment and final disposal. In addition to the initiatives of Delhi Government, a private sector recycling company has been set up in Roorkee to take care of the e-waste being generated from Delhi and NCR.

List of CPCB registered E-waste reprocessors in India is as follows. Some of these companies are already operational and some are yet to start their operations.

- E-Parisara Pvt. Ltd
- ASH Recyclers
- SIMS Recycling Solutions
- TESSAM Recyclers
- AER Worldwide
- Ultrust Solutions
- INAA Enterprises
- Attero Recycling
- Ecorecycling Ltd
- Polygenta ESPL
- Waste Re-Energy
- EarthSense Recycling
- Greenscape Eco Management
- MGA & Associates
- TiC Group
- Ramky Group
- IL&FS Waste Management

This above mentioned list is a partial one. A few more companies will join in the Indian e-waste recycling industry by the end of this year.

Current operations of formal recycling companies in India are limited only to pre-processing of the e-waste material where the crushed e-waste with precious metals is sent to smelting refineries outside India. Analysis of state-of-art technologies in vogue across the world

indicates that formal sector in India still has a long way to go in adopting international standards.

A couple of companies (Attero Recycling and Waste Re Energy) have already taken initiatives towards building these capabilities but their viability is uncertain due to following reasons:

- Very high capital investments
- Involvement of unorganized sector
- Lack of Raw material (e-waste to be processed) for the organized sector
 - In this regard, there has been a key development in the Indian e-waste industry. To ensure sustainability of high tech and high capital investment plants, MoEF granted permission to one of the e-waste recycling companies to import e-waste from US and UK.

Informal Sector

Indian E-waste recycling is presently concentrated in the informal (unorganized) sector. Operations of the informal sector are mostly illegal and processes are highly polluting. In terms of recycling, the informal sector of India gets engaged in dismantling, sale of dismantled parts, valuable resource recovery, export of processed waste for precious metal recovery.

In the unorganized sector, it is commonplace to find crude dismantling operations using tools like hammer, chisel, screw driver including open burning of wires to extract precious metal like copper, gold, platinum, silver etc., Some of the processes involve soaking of circuit boards in open acid bath followed by manual scrapping to extract copper and precious materials with the residue thrown into open drains.

Such unchecked activities carried out without proper protection to workers is hazardous not only to labourers involved but also to environment. In addition, the country loses out on precious metal recovery as unorganized sector is able to recover only 25% of metal as against possible efficiencies of over 95-99% in organized sector.

The organized sector is unable to grow due to lack of availability of e-waste for processing. The unorganized sector has better reach in collection due to the ubiquitous spread of scrap collectors and is also able to offer better prices for the e-waste. They can afford to do so as they do not pay taxes and employ low cost labour in crude working conditions with minimum investments in equipments.

A detailed description of the functioning of the unorganized sector is given in the next section of this report while presenting the findings regarding the e-waste recycling in Kolkata Metropolitan Area.

6.2 E-waste Recycling in KMA

Kolkata being the heart of eastern India is a home for many institutions and commercial establishments. Kolkata Metropolitan area (KMA) is responsible for significant share in the overall sales of electronics, IT products and mobile phones. Thus, KMA also becomes a significantly big generator of e-waste.

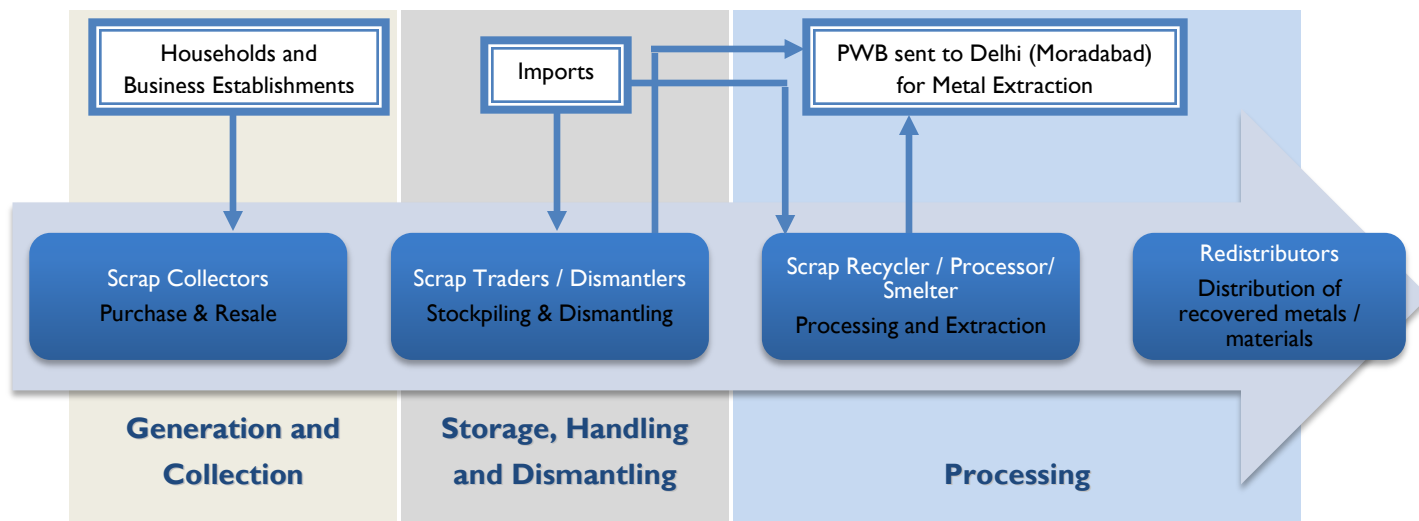
Currently there isn't any formal recycling company in Kolkata Metropolitan Area or West Bengal. Therefore, 100% of the e-waste recycling / processing which is today taking place in Kolkata Metropolitan Area is undertaken by the unorganized sector.

The study of KMA's unorganized e-waste recycling industry was conducted using Primary Research Methodology where each and every area under the scope of the study was visited to identify the prevalent e-waste recycling practices. Stakeholders at various levels of e-waste trade were met and interviewed by the research team during these field visits.

Details findings about the e-waste trade chain, stakeholders and recycling processes at each level of the trade chain, business economics and geographical presence of the unorganized e-waste recycling industry of KMA are given below.

Figure 21: E-waste Industry Trade Chain

(Source: IMRB primary field study in Kolkata Metropolitan Area)



The e-waste trade chain can be broadly classified into three stages – Generation, Storage & Handling and Processing.

1. Generation and Collection: Many different categories of stakeholders purchase, use, and then discard electronic waste and thus act as e-waste generators e.g. manufacturers, households, institutions and commercial establishments. Collection of this e-waste is critical to the e-waste trade chain and is currently done by the unorganized sector.

2. Storage, Handling & Dismantling: The next stage after collection is the handling and dismantling services. Here collected electronics are consolidated and sorted to determine what equipment can be refurbished or reused as whole units and what equipment must be disassembled for further processing.

3. Processing: After being handled, it is then processed for either feedstock for new production or for refurbishment into new equipment. Outputs from activities at this stage include scrap commodities such as glass, plastics, and metals – the primary elements from which all electronic hardware is made.

Details of stakeholders and their roles at each of these above stages with specific focus on KMA's e-waste industry are as follows.

Collection - Scrap Collectors



Refrigerators collected by a scrap dealer at Richie road (Hazra Crossing) – collected from dealers and manufacturers

Presence of scrap collectors is not limited to specific locations / clusters. They are present across all locations and converge at specific clusters for trading of collected scrap. Most of these scrap collectors don't deal in exclusive product categories. For e.g. a scrap collector will usually pick the entire junk of offices (including the electronic waste) and then segregates and sells to respective traders/dismantlers

Types of scrap collectors

- Small Scale/Door to door scrap collectors – They pick up waste from households. Contribution of this category of scrap collectors to e-waste stream is insignificant (as most of the e-waste find its route in the recycling chain through second hand markets)
- Large Scale/Professional scrap collectors – They collect waste from offices (through auctions), second hand and repair shops and from small scale scrap collectors
- Exclusive e-waste Scrap Collectors – These scrap collectors are usually found near the e-waste recycling clusters. They are at fixed locations, unlike the above categories – people come and sell their scrap instead of door to door collection



Computer scrap sold by a large scale scrap dealer at Chandni market

Roles / Functions performed

Stakeholders at this level are involved in most crucial function, i.e. Collection. They also get involved in segregation for reselling to specialized stakeholders

Sometimes, large scale collectors forward integrate and get involved in second level handling / dismantling / repair, depending upon factors like quantum of waste, number of helping hands, location of operation etc.

Handling and Dismantling - Scrap Traders and Dismantlers

Scrap traders and dismantlers mostly deal in selected product categories, thus this category of stakeholders are exclusive in nature. Collection of scrap by traders can be from following sources

- Scrap collectors
- E-waste generators – directly from institutions / offices (not from households)
- E-waste manufacturers – old products of exchange schemes from dealers, defective lot of manufacturing
- Importers – located in Kolkata and Delhi



Components for Resale at Chandni Market

Role in trade chain

Key role at this stage is Manual Dismantling. Scrap collected from above mentioned sources is checked for reselling/reuse/repair. Scrap which can be directly sold for reuse is sold to second hand market. Scrap which has some defective parts is repaired and then sold in second hand market. Scrap which cannot be repaired is further disassembled/dismantled –

- Functional components of such scrap are used for refurbishments/repair of other products. Sometimes loose functional components are also sold in the market.
- Rest of the components are sold to respective processors

Next level in the trade chain is processing which is a specialized job. Thus, the components are sold accordingly. For e.g. PWBs are sent to Delhi for metal extraction, plastic cabinets are sold to plastic recyclers in Topsia -Tiljala belt



TV Dismantling in progress at Chandni Market

Location of Scrap Traders

Dismantlers/traders of almost all the electronic products (under the scope of this study) are present in Chandni and Fancy market. Only in case of refrigerators the dismantling/handling is not being done in Chandni. Hazra crossing (Richie road) is the hub for refrigerators dismantling. Apart from Hazra crossing, some of the scrap traders dealing in refrigerators are present in Bondel gate. Multiple lots of Refrigerators scrap were also found in Ghusuri area of Howrah.

However, it is important to note that Howrah doesn't have presence of e-waste specific clusters. Large scale scrap processors dealing in scrap from multiple industries are present in Ghusuri and Bajrangbali market of Howrah.

Presented below is a case study of a dismantler situated in Chandni area of Kolkata.

Case Study – A Dismantler/Scrap Trader

- Location – Chandni Market
- Number of years in industry – 8 years
- Type and Volume of products handled
 - Deals in computers and computer peripherals
 - Deals on an average of 2 computers per day (50-60 computers per month)
- Activities undertaken –
 - Dismantling
 - Repair and Refurbishment
 - Uses old components for assembling a new computer
 - Sells faulty components (which cannot be repaired) to scrap collectors / recyclers
- Procurement
 - From Imports
 - Importers based out of Delhi, Kolkata and Hyderabad
- Key business economics -
 - Sources an old computer at INR 5000 (average sourcing price)
 - Sells a repaired computer between INR 5300 – 5600; average earning per computer – INR 450
 - Average earning per month – INR 25000 to 30000 (own profit after paying salaries – INR 12000 to 15000)
- Skill level and Manpower
 - Has done a six months course of repairing computers
 - Has two employees – unskilled labors only for support functions; plans to train his employees for computer repairing through the same six months course





Stripping of wires for copper extraction at Keshav Sen Street

Processing – Recyclers/Processors/Melters

This category of stakeholders is involved in the third or final level processing of e-waste. The non-repairable components of e-waste extracted by dismantlers are processed/recyclers at this level.

Role in the trade chain

- Extraction of sub-components from components
- Shredding – reduction of size of metals like copper, aluminum and other material like plastic cabinets – in order to make it suitable for recycling/smelting
- Smelting – recycling various materials for making new products



Aluminium Smelting at Rajarhat

Key activities which take place at this level of e-waste trade are stripping wires for copper, IC's extraction from PWB, surface heating of PWB, Gold extraction from pins and comb, acid bath of PWB, Plastic Shredding, and Smelting of metals like copper, aluminum.

One of the key findings related to e-waste processing is that stakeholders involved at this level of trade develop expertise in one or two activities which becomes their core competency. Thus, all the recyclers/processors might not be able to process e-waste completely.

It was found that activities related to precious metal extraction from PCB are not undertaken in Kolkata. The PCBs are sent to Delhi and Moradabad for metal recovery. Not only from the Kolkata's e-waste recycling industry, printed circuit boards from other cities of India also reach Delhi for metal extraction.

Another unique feature observed for Kolkata's e-waste processing/recycling industry is that most of the businessmen involved in this third level processing of e-waste were not dependent solely on e-waste. Due to e-waste reselling to Delhi, not much quantities of e-waste is available in Kolkata for recycling. It was observed that copper melters not only recycle the copper from e-waste, but from other sources as well.

Most of the metal traders outsource the metal smelting process on job work basis.

Presented below are two case studies to develop a better understanding of role of stakeholders at this level.

Case Study – Copper Melter

- Location – Tarak Pramanick Road / Girish Park
- Number of years in industry – More than 20 years
- Key Activities
 - Only involved in copper smelting
 - Job work for metal traders
- Works in a small closed room (without ventilation) – room has a small furnace where the copper is melted and converted into copper bricks which are further sold to metal traders
- Dimensions of the room and the furnace - 300 Sq ft area with height not more than 12 ft. The furnace is 46inch x 58 x 43 (width, depth and height). The entire furnace is built of 7 inch insulated brick with coating of mud
- Is paid INR 5000 per month, runs a family of four members
- No other employees, family supports, mostly works himself



Case Study – Dismantler and Copper Extractor

- Location – Keshav Sen Street
- Number of years in industry → 20 years
- Key Activities
 - Dismantling of computers, doesn't deal with other products
 - Wire stripping for copper extraction
- Procurement – from Chandni market, directly from offices (mainly government offices) through tenders
- Skill level and Manpower
 - Owner is literate, participates in tender/auction
 - Has 3 employees → migrants from poor states like Bihar
 - Semiskilled, uneducated
- Owner earning – not revealed; his employees earn around 100 – 120 rupees per day



Material Flows to Delhi and Moradabad

It was found during the field survey of Kolkata's recycling hotspots that one of the key activities related to e-waste recycling doesn't take place anywhere in Kolkata or West Bengal. This activity is metal extraction of PWBs. Like most of the other cities, PWBs from KMA reach Delhi and Moradabad (a small town of UP near Delhi) for metal extraction.

This was validated by visiting the concerned areas in Delhi and Moradabad.

In case of Delhi, the areas where PWBs from all across the India are processed are Seelampur and Shastri Park. During the visits in these two areas, it was confirmed by the workers that they receive e-waste from Kolkata and other cities like Bangalore and Mumbai.

Process – The PWBs are either sold directly or through intermediaries. In the former process, Scrap recyclers of Kolkata visit Delhi to sell the PWBs on per Kg basis. Similarly, when a melter from Delhi wants to extract metal from PWBs, he goes to different cities and buys PWBs.

In case of intermediaries, a margin (ranging between 5 – 10%) has to be kept aside by the melters. Thus this process is a less preferred one. Intermediaries get involved when large volume of scrap from multiple recyclers has to be transported to Delhi.

Mentioned below are two case scenarios of melters based in Delhi and Moradabad who receive material from Kolkata –

Case I – Irshaad Hussain, Moradabad

- Three brothers – all are partners and in the same business of scrap recycling
- Deal in all categories of copper scrap and in e-waste as well
- One of the partner travels very often to buy scrap from other parts of India
- Receive scrap from Kolkata, Mumbai and Chennai
- In case of Kolkata, the material is bought from Chandni market

Case II – Hazi Irshad, Seelampur

- Deals in electronic scrap only and employs around 30-35 workers
- One of the key big recyclers present in Seelampur market
- Mostly buys scrap through intermediaries
- Receive scrap from Kolkata, Bangalore, Chandigarh and Jaipur
- Buys in bulk – lots of PWBs weighing between 1 ton to 2 tonnes
- Processes some material and sends the rest to Moradabad

Geographical Mapping of e-waste industry in Kolkata

Snow Ball (Reference) Sampling methodology was used to identify/map the locations of informal e-waste recycling industry. The field study was started from the areas which were already identified in the previous reports. From the workers in those areas, references about their business intermediaries and locations of those intermediaries were asked. This process ensured mapping of all the locations wherever e-waste recycling is taking place in KMA.

During the field visits, stakeholders of all the three levels of e-waste trade were interviewed – Scrap collectors, Dismantlers and Recyclers.

Areas under the scope of the study included Kolkata, Howrah, Salt Lake City, South Dum Dum, Uluberia, Kalyani and Barasat. It was found that e-waste dismantling and recycling activities are taking place only in Kolkata and Howrah. In rest of the places, e-waste trade is limited to the collection stage. E-waste of the entire KMA is brought to the hub, i.e. Kolkata. In case of Howrah also, there aren't any stakeholders who are exclusively dealing in e-waste; they work on waste received from multiple sources including factory/construction/railway waste.

In order to ensure accuracy of the above said conclusion, concerned officials of municipalities for rest of the areas under the scope of the study were contacted for confirmation. The municipalities also confirmed absence of e-waste recycling activities in all the locations except Kolkata and Howrah.

Activity wise geographical mapping of e-waste industry of KMA is shown in the figure below.

Figure 22: Geographical Mapping of E-waste Industry in KMA

(Source: IMRB primary field study in Kolkata Metropolitan Area)



Scrap Traders/Dismantlers

- **Kolkata**
- For computers and peripherals, mobile phones, DVD VCD, TV - Chandni Market Princep Street, Grey Street
- Second hand mobile hub - Khidderpore-Metiaburuz area
- For refrigerators - Hazra Crossing, (Richie Road), Bondel gate, Rifle Range Road
- **Howrah** (Quantum of e-waste processed here is insignificant as compared to other metal wastes)
- Ghusuri – For televisions, DVD VCD players
- Bajrangbali – For all kind of metal wastes



Scrap Recyclers/Processors

- **Kolkata**
- Copper Extraction – Keshav Sen Street, Hazra Crossing, Kankurganchi-Kapdapara-Phool Bagan belt
- Copper Smelting – Tarak Pramanick Road / Girish Park
- Aluminum extraction and smelting – Rajarhat Surrounding areas/villages - Dashdron is an adjacent village where the units are located (Raja Bazaar is also a hub for Al recycling, but does not deal with Al from e-waste)
- Plastic Shredding and Recycling – Topsia Tiljala Belt (Only a couple of recyclers work on plastic from e-waste)
- **Howrah**
- Ghusuri and Bajrangbali market of Howrah are hotspot for metal scrap recycling (largely metal scrap from construction sites, factory waste like ingots)

Pyramid Structure of the E-waste Recycling Industry

Mentioned below is another important characteristic of the unorganized e-waste recycling industry of Kolkata Metropolitan Area.

Based on the study of Delhi and Mumbai industry, it was observed that the unorganized e-waste recycling industry follows a pyramidal structure. Highest number of scrap collectors are involved at the lowest level and very low numbers of e-waste recyclers/melters at the topmost level.

This pyramid structure was observed in case of KMA as well. In fact, in case of KMA, intermediaries/stakeholders involved at the uppermost level i.e. recyclers/melters are even lesser. One of the reasons behind this is that some of the third level activities of e-waste recycling are not undertaken in Kolkata.

During the field visits and interviews with the unorganized recycling industry of Kolkata, stakeholders were asked about the approximate number of people involved at each of the three levels. Based on the responses received and overall understanding of the industry, the number of people involved in this industry in KMA region was estimated. These numbers are shown in the pyramid below.

Figure 23: Pyramid Structure of e-waste industry & Estimate of number people involved in KMA



Section 7

Conclusions and Recommendations

7.1 Key Conclusions on KMA's e-waste Industry

Generation Stage – Users' Disposal Behavior

- In case of obsolescence rates, not much of a difference was observed across different socio economic classes of KMA.
- Average Obsolescence ages by user segment and product categories are summarized below:
 - Household Users
 - Desktops – 7 years
 - Notebooks – 4 years
 - Mobile Handsets – 3 years
 - Televisions – 9 years
 - **Refrigerators – 11 years**
 - DVD players – 4 years
 - Business Establishments
 - Desktops – 5 years
 - Notebooks – 4 years
 - Printers – 5 years
- In case of business establishments, technical problems and obsolete technology were found to be key reasons for replacement of their IT products.
- Selling in second hand market and exchanging for new products are the most commonly adopted methods of disposal among users of KMA.
- Major consideration of users at the time of disposal of their old electronic or IT products is the monetary benefit.
- Business Establishments of KMA were also checked on their awareness levels about e-waste problems and it was found that the awareness is still low and needs improvement.
- Logistics support and prompt service (in terms of waste pick-ups and payments) are the key expectations of users from a formal recycling company.

After considering all these factors it has been estimated that KMA region generates around 26000 tonnes of potential e-waste annually (in 2010-11) and the projected amount would touch the figure of 144823 tonnes during 2019-20.

Processing Stage – Key characteristics of KMA's e-waste recycling industry

- It was found that unorganized e-waste recycling industry (dismantling/recycling activities) is only present in Kolkata and Howrah region of KMA
- Kolkata e-waste recycling industry is scattered. Here stakeholders of the informal e-waste recycling industry are present in small clusters scattered in and around Kolkata. Unlike Delhi / Mumbai, there aren't cases of large population of a village working only on e-waste (Like Shastri Park or Seelampur of Delhi)
- Recycling of PCBs which is one of the key activity in e-waste recycling business and involves maximum risk to the environment and health of the workers does not takes place anywhere in KMA or West Bengal. PCBs are sent to Delhi and Moradabad for metal extraction.
- In case of KMA's e-waste recycling industry, it was observed that stakeholders present at the third level of the trade chain, i.e. melters, aren't exclusive e-waste recyclers. They instead depend on waste from multiple sources.
- Unlike Delhi and Mumbai's e-waste recycling industry, most of the business owners at the third level of e-waste processing outsource the metal smelting process on job work basis.
- Geographical mapping of KMA's e-waste recycling industry
 - Locations of Dismantlers - Kolkata
 - Chandni Market , Princep Street , Grey Street, Hazra Crossing, Bondel gate, Khidderpore-Metiaburuz area, Rifle Range Road
 - Locations of Dismantlers – Howrah
 - Ghusuri and Bajrangbali
 - Location of Scrap Recyclers
 - Keshav Sen Street, Hazra Crossing, Tarak Pramanick Road / Girish Park, Rajarhat, Raja Bazaar , Topsia Tiljala Belt, Kankurganchi-Kapdapara-Phool Bagan belt

7.2 Way Forward - Recommendations

Because of the absence of stringent e-waste laws and regulations the industry has been working in an informal manner in India for many years now.

As compared to most developed countries, India is still at a nascent stage of e-waste generation. Given this, it is probably the right time to build a strong foundation for a sound e-waste recycling ecosystem that not only takes care of the current problems but also insulates us in the future when e-waste volumes will start burgeoning out of control.

After assessing the KMA's recycling industry, it can be concluded that the industry is present at basic levels. The environmental and occupational risks associated here are not as high as the risk levels of same industry in places like Delhi or Mumbai where the industry is already ripe and wide spread. So, it would be appropriate to target the stakeholders for improvisation now.

Considering this, formalization should be the initial focus of the West Bengal State Government. This initiative should be two pronged –

1. **Improvising the processes of existing informal industry** and limiting their presence till Collection and Dismantling stage
2. **Integrating a formal recycling company with the informal sector** for taking over the hazardous recycling processes

1. **Improvisation of informal industry** – First step towards meeting this objective is to create awareness among the trade stakeholders about following concerns –

- Potential Health and Environment Risks
- Use and importance of protective gear
- Advantages of integration/formalization by illustrating Bangalore case study of informal recycler converting into a professionally run organization

This awareness creation may then be followed by an appropriate training program with the identified stakeholders.

2. **Integration with a formal recycling company** - The informal sector currently plays a vital role in collection, segregation and dismantling of e-waste. This role needs to be nurtured to complement the formal recyclers as supply chain partners and formal recyclers should take on the hazardous and higher technology recycling processes. The same should be done with a clear definition of operations that are suitable for informal and formal sectors, standard and transparent pricing to ensure fair distribution of value across the stakeholders; best recycling technologies to enable extraction of maximum value with minimal losses as well as legal intervention

For a successful implementation of this system, it is important for the formal recyclers to make sure that the best technologies are adopted to recover the maximum value. If not feasible currently, the long term focus of the formal recyclers should be to develop a mechanism for integrated smelting plants, so that the precious metals and the value recovered out of the same remains within the boundaries of the nation. Currently, cost of establishment of these plants is prohibitively high but R&D efforts can be directed to suitably adapt a few processes to recover the high value adding materials within India. This will ensure greater profitability for e-waste recyclers.

Intermediaries and facilitating bodies like NGOs should be consistently involved in preparing/educating the people in informal sector for integration with the formal one. Example of efforts to integrate informal sector can be found in some programmes undertaken in Bangalore.

The following valuable real life examples of integration of informal and formal sector in Brazil for solid waste management serve as live models to be adopted for integration of informal sector in other industries as well:

- ASMARE Waste Picker Cooperative of Brazil - Collects source-separated materials at schools, businesses, residences, office buildings. Members receive training and earn up to 6 times the minimum wage. ASMARE is now a model for other cooperatives
- COOPAMARE Waste Picker Cooperative of Brazil - Collect 100 tons of recyclables / month, at a cost lower than the city recycling program. Members earn US \$ 300 / month, twice the minimum wage (half of labor force earns less than US \$150)

In addition to the above mentioned actions suggested to reduce the environmental and health risks, following initiatives are recommended to develop system which is sustainable and successful in long term.

1. **Awareness creation:** Need for creating awareness is critical for establishing a successful recycling industry. Given the low awareness regarding harmful effects, greater efforts are required on the part of government and voluntary bodies to make this knowledge widespread. Customers (both businesses and homes) are unaware of the negative impacts of disposing the e-waste to informal recyclers and look at it merely as an opportunity to earn money. It is important to educate the users/e-waste generators about the potential risks of unsafe disposal of e-waste.
2. **Defining Roles for major stakeholders:** Extended Producer and Consumer Responsibilities
 - a. **Extended Producer Responsibility:** There is a clear need for well defined collection models and take back schemes. Different models can be adopted depending upon the product categories. For e.g. For big and heavy hazardous household waste (AC, refrigerator, washing machines), a one day drop off cum exchange event can be sponsored by the producer, where consumers can exchange them for a discount. Formal recyclers can then take these products by paying appropriate and standard price to the producers (also bearing the logistics cost) for recycling at their facilities.
 - b. **Consumer Responsibilities:** It should be made compulsory for businesses units to dispose off their IT waste only to formal recyclers. Initially this model can be implemented in a more voluntary manner, more as a part of Corporate Social Responsibilities. Later on, depending upon the success of the preliminary phase, it can be made mandatory for all the commercial users to include an annual contract agreement with the formal recycler in the city or nearest to the city for disposal and recycling of their IT waste.

Annexure

Annex A - List of products, which fall under the ten categories of e-waste as per the WEEE Directive

1. Large household appliances

- a. Large cooling appliances
- b. Refrigerators
- c. Freezers
- d. Other large appliances used for refrigeration, conservation and storage of food
- e. Washing machines
- f. Clothes dryers
- g. Dish washing machines
- h. Cooking
- i. Electric hot plates
- j. Microwaves
- k. Other large appliances used for cooking and other processing of food
- l. Electric heating appliances
- m. Electric radiators
- n. Other fanning, exhaust ventilation and conditioning equipment

2. Small household appliances

- a. Vacuum cleaners
- b. Carpet sweepers
- c. Other appliances for cleaning
- d. Appliances used for sewing, knitting, weaving and other processing for textiles
- e. Iron and other appliances for ironing, mangling and other care of clothing
- f. Toasters
- g. Fryers
- h. Grinders, coffee machines and equipment for opening or sealing containers or packages
- i. Electric knives
- j. Appliances for hair-cutting, hair drying, tooth brushing, shaving, massage and other body care appliances
- k. Clocks, watches and equipment for the purpose of measuring indicating or registering time Scales

3. IT and telecommunications equipment

- a. Centralized data processing
- b. Mainframes
- c. Minicomputers
- d. Printer units
- e. Personal computing:
- f. Personal computers (CPU, mouse, screen and keyboard included)
- g. Laptop computer (CPU, mouse, screen and keyboard included)
- h. Notebook computers
- i. Notepad computers
- j. Printers

- k. Copying equipment
- l. Electrical and electronic typewriters
- m. Pocket and desk calculators
- n. And other products and equipment for the collection, storage, processing, presentation or communication of information by electronic means
- o. User terminals and systems
- p. Facsimile
- q. Telex
- r. Telephones
- s. Pay telephones
- t. Cordless telephones
- u. Cellular telephones
- v. Answering systems
- w. And other products or equipment of transmitting sound, images or other information by telecommunications

4. Consumer equipment

- a. Radio sets
- b. Television sets
- c. Video cameras
- d. Video recorders
- e. Hi-fi recorders
- f. Audio amplifiers
- g. Musical instruments
- h. Other products or equipment for the purpose of recording or reproducing sound or image, including signals or other technologies for the distribution of sound and image than by telecommunications

5. Lighting equipment

- a. Luminaries for fluorescent lamps with the exception of luminaries in households
- b. Straight fluorescent lamps
- c. Compact fluorescent lamps
- d. High intensity discharge lamps, including pressure sodium lamps and metal lamps
- e. Low pressure sodium lamps
- f. Other lighting or equipment for the purpose of spreading or controlling light with the exception of filament bulbs

6. Electrical and electronic tools (with the exception large-scale stationary industrial tools)

- a. Drills
- b. Saws
- c. Sewing machines
- d. Equipment for turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making, holes, punching, folding, bending or similar processing of wood, metal and other materials
- e. Tools for riveting, nailing or screwing or removing rivets, nails, screws or similar uses
- f. Tools for welding, soldering or similar use

- g. Equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means
- h. Tools for mowing or other gardening activities

7. Toys, leisure and sports equipment

- a. Electric trains or car racing sets
- b. Hand-held video game consoles
- c. Video games
- d. Computers for biking, diving, running, rowing, etc
- e. Sports equipment with electric or electronic components
- f. Coin slot machines

8. Medical devices (with the exception of all implanted and infected products)

- a. Radiotherapy equipment
- b. Cardiology
- c. Dialysis
- d. Pulmonary ventilators
- e. Nuclear medicine
- f. Laboratory equipment for in-vitro diagnosis
- g. Analysers
- h. Freezers
- i. Fertilization tests
- j. Other appliances for detecting, preventing, monitoring, treating, alleviating illness, injury or disability

9. Monitoring and control instruments

- a. Smoke detector
- b. Heating regulators
- c. Thermostats
- d. Measuring, weighing or adjusting appliances for household or as laboratory equipment
- e. Other monitoring and control instruments used in industrial installations (e.g. in control panels)

10. Automatic dispensers

- a. Automatic dispensers for hot drinks
- b. Automatic dispensers for hot or cold bottles or cans
- c. Automatic dispensers for solid products
- d. Automatic dispensers for money
- e. All appliances which deliver automatically all kind of products

Annex B - Components in E-waste

	Metal	Motor \	Cooling	Plastic	Insulation	Glass	CRT	LCD	Rubber	Wiring / Electrical	Concrete	Transformer	Magnetron	Textile	Circuit Board	Fluorescent lamp (ineballast)	Incandescent lamp	Heating element	Thermostat	FR/ BFR – containing plastic	Batteries	CFC, HCFC, HFC, HC	External electric cables	Refractory ceramic fibers	Radioactive substances	Electrolyte Capacitors (over L/D 25mm)	
Large Household Appliances																											
Refrigerator	✓	✓	✓	✓	✓	✓			✓	✓						✓		✓	✓			✓	✓				
Washing Machine	✓	✓		✓		✓			✓	✓	✓				✓			✓	✓				✓				○
IT & Telecom Equipment																											
Personal Computer (Base & Keyboard)	✓	✓		✓						✓		✓			✓					✓			✓				
Personal Computer (Monitor)				✓			✓	✓							✓								✓				
Laptop		✓		✓				✓		✓		✓			✓	✓				✓	✓		✓				
Cellular Telephone	✓			✓		✓		✓							✓	✓				✓	✓						
Consumer Equipment																											
Television	✓			✓			✓			✓		✓			✓					✓			✓				

✓ Present in E-waste

○ Possible presence as a component

Annex C – Recoverable from Typical E-waste

From a Typical Personal Computer

Elements	Content (% of total weight)	Content (kg)	Recycling efficiency (%)	Recoverable weight of element (kg.)
Plastics	23	6.25	20	1.25069408
Lead	6	1.71	5	0.8566368
Aluminium	14	3.85	80	3.08389248
Germanium	0.0016	0.00	0	0
Gallium	0.0013	0.00	0	0
Iron	20	5.57	80	4.45453312
Tin	1	0.27	70	0.19188512
Copper	7	1.88	90	1.69614576
Barium	0.0315	0.01	0	0
Nickel	0.8503	0.23	0	0
Zinc	2	0.60	60	0.35979072
Tantalum	0.0157	0.00	0	0
Indium	0.0016	0.00	60	0.00026112
Vanadium	0.0002	0.00	0	0
Terbium	0	0.00	0	0
Beryllium	0.0157	0.00	0	0
Gold	0.0016	0.00	99	0.000430848
Europium	0.0002	0.00	0	0
Tritium	0.0157	0.00	0	0
Ruthenium	0.0016	0.00	80	0.00034816
Cobalt	0.0157	0.00	85	0.00362984
Palladium	0.0003	0.00	95	0.00007752
Manganese	0.0315	0.01	0	0
Silver	0.0189	0.01	0	0
Antimony	0.0094	0.00	0	0
Bismuth	0.0063	0.00	0	0
Chromium	0.0063	0.00	0	0
Cadmium	0.0094	0.00	0	0
Selenium	0.0016	0.00	70	0.00030464
Niobium	0.0002	0.00	0	0
Yttrium	0.0002	0.00	0	0
Rhodium	0	0.00	50	0
Mercury	0.0022	0.00	0	0
Arsenic	0.0013	0.00	0	0
Silica	24.8803	6.77	0	0

From a Typical Television

Material type	%
CFCs	0.20
Oil	0.32
Ferrous metals	46.61
Non-ferrous metals	4.97
Plastics	13.84
Compressors	23.80
Cables/plugs	0.55
Spent purfoam	7.60
Glass	0.81
Mixed waste	1.30
Total	100.00

From a Typical Refrigerators

Elements	%	PPM	Recoverable weight of element (kg)
Aluminium	1.2		0.4344
Copper	3.4		1.2308
Lead	0.2		0.0724
Zinc	0.3		0.1086
Nickel	0.038		0.013756
Iron	12		4.344
Plastic	26		9.412
Glass	53		19.186
Silver		20	0.000724
Gold		10	0.000362

Annex D – Occurrence and Risks associated with Hazardous substances in E-waste

S.No.	Hazardous substance	Use	Risk	Regulatory requirements with threshold quantities
1.	Short chain chloroparaffins, alkanese C ₁₀₋₃	Amounts less than 1% by weight of SCCP are present in mid chain chlorinated paraffin's (MCCP). Used as secondary plasticizer and flame retardant for PVC and chlorinated rubber in cable insulation	Very toxic to aquatic organisms. It may cause long term effects in the aquatic environment	Halogenated aliphatic compounds covered under schedule 2, B1 I $\geq 0.005\%$
2.	Antimony trioxide	The major use is as a flame retardant synergist in plastics etc. It increases the flame retardant effectiveness of halogenated flame retardant compounds thereby minimizing their level	Limited evidence of a carcinogenic effect	Antimony and antimony compounds Covered under Schedule 2 as A1 ($\geq 0.005\%$)
3	Beryllium metal	Chassis, rotating mirrors in laser printers; windows for X-ray generators and detectors for research and medical purposes. Benefits of use include; low density; high stiffness; high specific heat and lightweight rigidity for precision instrumentation	Very toxic on inhalation. It may cause cancer by inhalation. Beryllium component scrap is classified as non hazardous in the OECD, Basel and EU regime. However, it is recommended that beryllium metal components should be segregated from equipment at end of life and returned to the supplier for recycling	Beryllium and cadmium compounds Covered under Schedule 2 as A3 $\geq 0.005\%$
4	Beryllium oxide (Beryllia)	Used in heat sink electrical insulators for electrical and electronic systems and devices. It has the benefits of very high thermal conductivity; very high electrical resistivity; low loss factor; high breakdown factors, high breakdown voltage, and chemically inert. Beryllium ceramic components should be separated from equipment at end of life and returned to the supplier for recycling. Beryllia components should not be passed through crushing and shredding operations without proper controls, due to the risk of dust generation. Beryllia ceramic component scrap is classified as non-hazardous in the OECD, Basel and EU Waste Control Systems	Very toxic by inhalation. It may cause cancer by inhalation	Beryllium and cadmium compounds Covered under Schedule 2 as A3 $\geq 0.005\%$
5	Cadmium	Cadmium metal or powder may be used as part of the negative electrode material in nickel-cadmium (NiCd) batteries, as an electrodeposited, vacuum deposited or mechanically deposited coating on iron, steel, aluminum base materials, titanium	Very toxic by inhalation. It may cause cancer. Harmful to aquatic organisms	Cadmium and beryllium compounds covered under Schedule 2 as A3 $\geq 0.005\%$

S.No.	Hazardous substance	Use	Risk	Regulatory requirements with threshold quantities
		base alloys or other non-ferrous alloys, and as an alloying element in low-melting brazing, soldering and other specially alloys.		
6	Cadmium oxide	Cadmium oxide is utilized most often as part of the negative cadmium electrode in nickel cadmium and some silver cadmium military batteries. Cadmium oxide is also part of silver cadmium oxide (Ag-CdO) electrical contract alloys	May cause cancer by inhalation. Toxic by inhalation. Toxic if swallowed Danger of serious damage to health by prolonged exposure. Harmful if swallowed	Cadmium and beryllium compounds covered under Schedule 2 as A4 $\geq 0.0005\%$
7	Cadmium sulphide	Cadmium sulphide serves as the basis compound for a series of pigments and semiconducting compounds with a wide range of uses. Apart from its use in red, orange, and yellow pigments for plastics, glasses, ceramics, enamels and artists colours, cadmium sulphide is also used for phosphors in x-ray fluorescent screens, cathode ray tubes and electronic devices, smoke alarm photoreceptors, photographic exposure meters, and photovoltaic energy conversion systems.	Limited evidence of carcinogenic effect Toxic by inhalation. Toxic if swallowed. Danger of serious damage to health by prolonged exposure. Harmful if swallowed. It may cause long term effects in the aquatic environment	Cadmium and beryllium compounds Covered under Schedule 2 as A4 $\geq 0.005\%$
8	Chromium VI	Used as colorant in pigments (e.g. lead chromate) and as corrosion inhibitor (sodium dichromate) in circulating water systems e.g. absorption heat pumps and (industrial) heat exchanges in freezers and refrigerators. Chromium (VI) has historically been used by the electronics industry as an anti-corrosion treatment, as well as an electrical shielding material for certain sheet metals.	Toxic if swallowed / very very toxic by inhalation. It may cause heritable genetic damage. It may cause cancer by inhalation. Very toxic to aquatic organisms and may cause long term effects in the aquatic environment	Chromium (VI) compounds Covered under Schedule 2 as A5 $\geq 0.005\%$
9	Copper beryllium alloy	Used in electrical connector terminations, switch components, relay springs, electromagnetic radiation seals	Components in end of life electrical equipment can be recycled as part of the general copper recycle stream. There is generally no need for component extraction prior to equipment recycling. Toxic by inhalation	Beryllium and beryllium compounds covered under Schedule 2 as A3 $\geq 0.005\%$
10	Decabromodiphenylether	Used as a flame retardant in electrical and electronic plastics	Potential for forming brominated dibenzodioxins or furans (PBDD/F) in uncontrolled thermal processes, and possibility that higher PBDEs could debrominate to form the tetra	Halogenated compounds of aromatic rings covered under schedule 2 as A 16 $\geq 0.005\%$

S.No.	Hazardous substance	Use	Risk	Regulatory requirements with threshold quantities
			and penta BDEs found in marine environment food chain	
11	Lead	Used in batteries, solders, alloying element for machining metals, printed circuit boards, components, incandescent light bulbs, and weighting	Processing of metallic lead may give rise to lead compounds, which are all, classified as dangerous substances. The landfilling of WEEE has given rise to concerns over possible leaching of lead into the environment	Lead and lead compounds covered under Schedule 2 as B4 $\geq 0.5\%$
12	Lead oxide	Occurs in leaded glass in cathode ray tubes, light bulbs and photocopier pastes. Lead oxide is also used in batteries	May cause harm to the unborn child. Harmful by inhalation/harmful if swallowed	Lead and lead compounds covered under Schedule 2 as B4 ($\geq 0.5\%$)
13	Liquid crystals: commercially available liquid crystals (LC) are mixtures of 10 to 20 substances, which belong to the group of substituted phenylcyclohexanes, alkylbenzenes and cyclohexylbenzenes. The chemical substances contain oxygen, fluorine, hydrogen, and carbon. About 250 chemical substances are used for formulating more than thousand marketed liquid crystals	Liquid crystal mixture are used as electroactive layer in liquid crystal display (LCD). Today LCDs are a widely used components in electric and electronic (E&E) products as i.e. mobile phones, notebooks, automotive displays, electronic games, PC, monitors etc.	Press articles claiming that LCDs contain carcinogenic azo-dyes. More current articles talk about hazardous ingredients. Toxicological studies on a large number of single liquid crystals have been performed according to OECD Guidelines and EU regulations. So far no indications of carcinogenic potential and acute oral toxicity have been found	Not covered under schedule 1 and 2
14	Mercury	It is estimated that 22% of the yearly world consumption of mercury is used in electrical and electronic equipment. It is basically used in thermostats, (position) sensors, relays and switches (e.g. on printed circuit boards and in measuring equipment) and discharge lamps. It is used in data transmission, telecommunications, mobile phones batteries, and certain light sources.	Very toxic to aquatic organisms and may cause long term effects in the aquatic environment. Effects in humans are mainly affecting the central nervous system (CNS) as well as the kidney. Toxic by inhalation	Mercury and mercury compounds covered under Schedule 2 as A6 $\geq 0.005\%$
15	Mineral wool: [man-made vitreous (silicate) fibres with random orientation with alkaline oxide and alkaline earth oxide ($\text{Na}_2\text{O}+\text{K}_2\text{O}+\text{CaO}+\text{MgO}+\text{BaO}$) content greater than 18% by weight]		Limited evidence of carcinogenic effect irritating to the skin	Not covered under schedule 1 and 2
16	Octabromodiphenylether (OBSE)	Flame retardant in plastics used for electrical and electronic equipment	Possible risk of harm to the unborn child	Halogenated compounds of aromatic rings covered under Schedule 2 as A16 $\geq 0.005\%$
17	Polychlorobiphenyls: the level of 50 mg/kg (0.005%) should be the defining threshold	PCBs were extensively used in electrical equipment such as capacitors and transformers.	Very toxic to aquatic organisms and may cause long term effects in the aquatic	Halogenated compounds of aromatic rings covered under Schedule 2 as A 16

S.No.	Hazardous substance	Use	Risk	Regulatory requirements with threshold quantities
	concentration for wastes containing PCBs and PCTs above that concentration such waste should be considered as hazardous	Small capacitors include motor start capacitors and ballast capacitors. Motor start capacitors are used with single phase motors to provide starting torque, these capacitors can be found also in household electrical appliances including refrigerators, cookers, washing machines, air conditioners, dishwashers. Ballast capacitors are found within fluorescent, mercury and sodium lighting fixtures and neon lights, they weight up to 1.6 kg which 0.05 kg are PCBs (USEPA, 1987).	environment	= 0.005%
18	Polyvinyl chloride (PVC)		As with any material containing chlorine, potential for forming dioxins and furans in case of uncontrolled burning. Liberation of HCl gas during combustion. Recent health/environmental concerns have been raised about some additives used in PVC processing i.e. <ul style="list-style-type: none"> Heavy metals used as stabilizers Phthalate plasticizers, although these have been used for more than 40 years without any measurable impact on health and environment 	Halogenated aliphatic compounds covered under Schedule 2 as B11 >=0.5%
19	Refractory ceramic fibers: [Man-made vitreous (silicate) fibres with random orientation with alkaline oxide and alkali earth oxide (Na ₂ O+K ₂ O+CaO+MgO+BaO) content less or equal to 18% by weight]		May cause cancer by inhalation, irritating to the skin	Not covered under Schedules 1 and 2
20	Tetrabromobisphenol-A (TBBPA): TBBPA is the largest volume brominated flame etardant in production today. It is used as a reactive (primary use) or additive flame retardant in polymers, such as ABS, epoxy and polycarbonate resins, high impact polystyrene (HIPS), phenolic resins, adhesives and others. Its main use in E&E equipment is as a reactive flame retardant in printed writing boards		Perception of potential to form brominated dioxins/furans in thermal processes Perception of potential for endocrine modulating effects (harmone disruptor) The whole substances group of BFRs is listed in general on the Danish list of 'unwanted substances'	Halogenated compounds of aromatic rings covered under Schedule 2 as A16 ³ >=0.005%

Cadmium and cadmium compounds

Cadmium or Cd is an environmentally persistent element. Its atomic number is 48 and it has an average atomic mass of 112.41. Its density at 293.15 K is 8.65 g/cm³. It burns with a red flame to form cadmium oxide and is always divalent in compounds.

Occurrence in waste electrical and electronic equipment

Most of the cadmium in WEEE stems from Ni-Cd rechargeable batteries along with pigments and stabilizers in plastics (especially PVC). Cadmium plating is also used to prevent corrosion, and in addition, cadmium is used for chip resistance on circuit boards, in IR (infrared) detectors, semiconductors, fluorescent screens in cathode ray tubes, and solar cells.

Release during preparation and treatment

Cadmium is released as a result of landfilling as well as during mechanical and thermal treatment. Cadmium compounds may be leached out of landfills into the groundwater, while during the mechanical preparation (crushing and milling) of plastics, cathode ray tubes, and circuit boards, cadmium may be released with dust, later entering surface water and waste water. In factories in India and China with insufficient dust capture, cadmium concentration, sometimes exceeding 100 mg/kg, has been measured in the dust on the ground, while the sediment in waste water pipes has been found to contain as much as 83 mg/kg of the element (Bridgen, Labunska, and Santillo 2005). When waste is incinerated, cadmium accumulates in particular in fly ash (slag 30.8%, fine dust 48.4%, flue gas 20.8%; Wichmann, Sprenger, Wobst, et al. 2002).

Human intake

Cadmium enters the human body orally in the form of dust and vapour as well as via the food chain. Cadmium fumes are usually odourless.

Toxicity

Cadmium fumes and compounds are chronically or acutely toxic to humans. Cadmium accumulates in the liver and kidneys. In the event of acute poisoning, the symptoms include vomiting and pulmonary oedema; in the case of chronic poisoning, cadmium is carcinogenic and also damages the skeleton, bone marrow, and kidneys. Cadmium sulphate and cadmium oxide – which are used, for example, in electrical equipment for their luminosity – are carcinogenic. The WHO (World Health Organization) recommends that weekly intake of cadmium should not exceed 7 mg/kg body weight (Wichmann, Sprenger, Dettmer, et al. 2002).

Mercury and mercury compounds

Mercury or Hg has the atomic number 80 and an average atomic mass of 200.59. Since it has a melting point of -38.87°C , it is a liquid at room temperature. Its density at 293.15 K is 13.55 g/cm^3 . At room temperature, mercury has a high vapour pressure and is always divalent in compounds. Mercury is slightly corroded by oxidizing acids and forms light alloys with metals.

Occurrence in waste electronic and electrical equipment

Mercury is mainly found in dry batteries (as HgO [mercuric oxide]), thermostats, fluorescent tubes, and relays, and was formerly used in mercury tilt switches and mercury relays. HgI₂ (mercuric iodide) is used as a pigment.

Release during preparation and treatment

Mercury is mainly released during mechanical and thermal treatment as well as through leaching in connection with landfilling and mechanical-biological treatment. Mercury often occurs in gaseous form when WEEE is crushed owing to its high vapour pressure. Mercury leached by seepage water forms methylated mercury owing to microbial activities and then enters the human food chain via fish. When waste is incinerated, mercury accumulates in flue gas (slag 2.1%, fly ash 2.0%, flue gas 95.9% (Wichmann, Sprenger, Wobst, et al, 2002). AT WEEE factories in India and China, mercury concentrations of up to 460 mg/kg in the ground dust have been measured in connection with the recycling of circuit boards, as well as up to 5.9 mg/kg in connection with battery dismantling (Bridgen, Labunska, and Santillo 2005).

Human intake

In addition to oral and pulmonary intake, mercury can also enter the human body through the skin by resorption.

Toxicity

The impact of mercury on human health depends on its form (elementary, inorganic or organic). In the case of metallic mercury, the chronic effect of inhaling mercury fumes is harmful, although the acute toxicity of mercury is low. Even though the toxicity of inorganic mercury compounds increases with their solubility, it still remains below that of organic compounds, especially methyl mercury compounds (Harant 2002). The toxic impact of mercury is attributed to the substance's reactivity to free sulphhydryl groups in proteins.

The symptoms of mercury poisoning are relatively unspecific and include poor memory, head and neck ache, stomach and bowel complaints, as well as various neurological problems, especially in the central nervous system (for example, trembling hands). Advanced toxicity can lead to the loss of teeth, kidney failure, severe neurotrauma, and even death. Methylated mercury also causes embryotoxicity (Harant 2002; Wichmann, Sprenger, Dettmer, et al. 2002). The WHO recommends that the weekly human intake should not exceed 5 mg/kg body weight (methylated mercury: $<33\text{ mg./kg body weight}$). The maximum workplace concentration in Germany for mercury and inorganic mercury compounds in the air is 0.1 mg/m^3 (Wichmann, Sprenger, Dettmer, et al. 2002).

Lead and lead compounds

Lead or Pb has the atomic number 82 and an average atomic mass of 207.2. Its density at room temperature is 11.345 g/cm³. In compounds, lead is usually divalent, although sometimes it is tetravalent.

Occurrence in waste electrical and electronic equipment

Lead is used extensively in electrical equipment. Lead crystal is used in cathode ray tubes (in the form of PbO [lead oxide] as radiation shielding), lead rechargeable batteries (lead dioxide), as stabilizers in PVC insulation (lead PVC) and other plastics, soldering tin (usually tin-lead soldering alloys), pigments, and capacitor ceramics PbS (lead sulphate) is found in transistors, photoelectric cells, moisture sensors, and IR detectors (Blum and Schmidt 1996), while PbSe is sometimes contained in the LEDs of TV remote controls (Harant 2002).

Release during preparation and treatment

Lead emissions are mainly found in dust from combustion processes and after the mechanical treatment of WEEE. In landfills, lead may be leached out of lead crystal and lead rechargeable batteries. Following the extraction of metal in an acid bath (for example, soldering tin from circuit boards), high concentrations of lead remains in the waste water.

Following the dismantling and production of WEEE in Chinese and Indian factories, high concentrations of lead were found in factories and waste water. These levels reached 150-10 900 mg/kg in ground dust in India in connection with the manual dismantling of circuit boards. As much as 31300-76 000 mg/kg of lead was found in China. Meanwhile, 13 300-88 100 mg/kg of lead was measured in the ground dust in India at plants where batteries were removed and dismantled. The amount of lead contained in sediment from waste water channels at Chinese acid treatment factories was 4505-44 300 mg/kg, while the waste water in a waste water collection tank contained 3.66 mg/litre of lead (Bridgen, Labunska, and Santillo 2005).

Human intake

In addition to oral and pulmonary intake, lead can also enter the human body through the skin by resorption.

Toxicity

Lead and its compounds are poisonous. Symptoms of lead poisoning include nausea, vomiting, circulatory collapse, shock, acute liver failure, damage to the central nervous system (headaches, sleeplessness, depression, and coma), and even death. About 20-50 g lead is fatal (Blum and Schmidt 1996). However, owing to its low resorption, acute poisoning is only to be expected in connection with the intake of very high doses of lead (Harant 2002). Chronic lead poisoning is far more dangerous. Lead is only partly excreted in the urine, and about 95% of the resorbed lead is deposited in the bones, replacing calcium. Deposited lead can be remobilized from the bones, leading to lead diseases. Symptoms include tiredness, headaches, pale skin, deposition of lead sulphide on the edges of the gums, and damage to the central nervous system and the immune system. The half-life of lead in the human body is about 20 years. In Germany, the maximum workplace concentration in the air has been set at 0.1 mg/m³ (Wichmann, Sprenger, Dettmer, et al 2002).

Chromium

Chromium or Cr has the atomic number 24 and an average atomic mass of 51.99. Its density at 293.15 K is 6.93 g/cm³. With oxidizing acids, chromium forms a very resistant oxide film. Chromium occurs in the oxidation states of 0 to +6, and is an essential trace element for humans, as it is required for the glucose metabolism. In nature, chromium almost always occurs in Cr(III) and Cr(VI) compounds. Because chromates (salts containing the anion CrO₄²⁻) are able to migrate in cohesive soils, they pose a threat to the groundwater.

Occurrence in waste electrical and electronic equipment

Chromium is mainly used in chrome plating on the surface of plastic and metal, as a pigment in plastics (zinc chromate, lead chromate), in magnetic audio and data storage (as chromium VI oxide), in solar cells, and as an alloy component for solder and steel (Blum and Schmidt 1996; Harant 2002).

Release during preparation and treatment

Chromium is released during mechanical and thermal treatment and is also leached out of landfills. It is probably poorly thermally mobilizable and hence accumulates in fly ash (Jung, Matsuto, Tanaka, et al 2004; Wichmann, Sprenger, Wobst, et al, 2002). Chromium can, therefore, be assumed to be leached out of fly ash when landfilled.

Human intake

Human intake largely occurs orally via the food chain and by drinking chromium laden water, although pulmonary intake and intake via the skin (allergic reactions) also occur.

Toxicity

Chromium (III) compounds are only toxic in high doses. Chromates (chromium (VI) compounds) are between 100 and 1000 times more toxic than chromium (III) compounds, since they are easily able to penetrate human cell membranes (Blum and Schmidt 1996). Acute poisoning is rare but chronic poisoning is an occupational hazard that occurs more frequently, Chromium (VI) oxide and alkali metal chromates are particularly toxic to the human organism and have a caustic effect on the skin and the respiratory tract. Skin contact with chromates and dichromates causes eczema and growths. Chromium compounds tend to accumulate in the spleen, bone marrow, liver and lungs, womb, and testes. Typical effects of chromium poisoning include deposition of dust in the lungs and lung cancer (inhalation), caustic burns (chromium (VI) salts), and damage to the central nervous system, liver, kidneys (including acute kidney failure), and lungs (human intake of water-soluble chromium salts). Metallic chromium is harmless to the human body.

Polychlorinated biphenyls

PCBs consist of two phenyl rings joined by a simple carbon bond. These are synthetic products that do not occur naturally. Nowadays, PCBs are ubiquitous in the environment. They are physically characterized by low vapour pressures, thermal stability, high viscosity, and a retardant effect on flames (Harant 2002). PCBs also have lipophilic properties. Due to their tendency to accumulate in the environment, PCBs have been banned in Europe since the 1980s.

Occurrence in waste electrical and electronic equipment

PCBs are used in electrical equipment as insulating and cooling fluid in capacitors and transformers, softening agents in plastic, and dielectrics (insulators) in capacitors (Blum and Schmidt 1996).

Release during preparation and treatment

PCBs are mainly released during mechanical and thermal treatment.

Human intake

Human intake usually takes place via the food chain and breathing, although resorption through the skin is also possible.

Toxicity

PCBs have a low acute toxicity. In the event of chronic poisoning, they may accumulate in fatty tissue owing to their lipophilic properties. They cause chloracne, damage kidneys, liver, and central nervous system, and also accumulate in the liver and kidneys.

Brominated flame retardants

Flame retardants are chemicals that reduce materials inflammability and hence not only prevent them from burning but also limit the initial spread of flames. However, if fire does eventually break out, flame-proofing agents are powerless to stop it. The most common flame retardants are halogenated compounds that release halogen atoms at high temperatures. These halogen atoms intercept the radicals keeping the fire burning and so interrupt the chain reaction (Wichmann, Sprenger, Dettmer, et al. 2002).

In order to attain the desired inhibitory effect, flame retardants are added to the flammable polymers during production. A distinction is drawn between additive and reactive flame retardants. Additive retardants (which include PBB [polybrominated biphenyl]) are added to plastics (usually thermoplastics) before, during or after polymerization as softening agents or merely as additives. Reactive flame retardants include the frequently used TBBPA (tetrabromobisphenol A). This group is chemically installed in the polymer framework of duroplasts (polyester, epoxy resin, and polyurethane), making it very stable. The accumulation of flame retardant through migration or vaporization does not take place even over long periods.

PBBs are used in television and computer housing as well as textiles. These are characterized by high chemical stability. They are hardly biodegradable and accumulate in fatty tissue. PBBs are suspected to have toxic characteristics, leading to symptoms such as immune deficiency, liver damage, poor memory, and muscle weakness.

PBDEs comprise two phenyl rings connected by an oxygen bridge. These include a total of 209 individual compounds (congeners). In recent years, PBDEs have attracted attention owing to their high persistence and global distribution. They mainly reach the environment via waste incineration, recycling, and landfilling. The toxicological properties of PBDEs range from virtually inert to endocrine. As a rule, toxicity increases with decreasing bromination (Muller 2005; Wichmann, Sprenger, Dettmer, et al 2002b).

Other typical heavy metals and pollutants in waste electrical and electronic equipment

Arsenic

Arsenic or As is used in solar cells, diodes, and solid lasers, and is released from WEEE during mechanical and thermal treatment. Although metallic arsenic and low-soluble sulphides are not toxic, trivalent compounds (such as As_2SO_3) are highly toxic, and just 0.01-0.03 g of such a compound is fatal to human beings (Harant 2002). Human intake is pulmonary. In Germany, the maximum arsenic concentration allowed in the air in the workplace is 0.1 mg/m³. Following combustion, arsenic accumulates in the fly ash (45%) and fluidized bed ash (55%) (Jung, Matsuto, Tanaka, et al. 2004). Acute poisoning with arsine causes headaches, vomiting, a dazed state, feelings of anxiety and fever, followed by jaundice along with cardiac and liver damage. Chronic poisoning causes symptoms such as kidney and liver damage, vascular disorder, loss of blood pressure, and a metallic taste in the mouth. Over a longer period, arsenic is also carcinogenic (Blum and Schmidt 1996).

Asbestos

The term asbestos covers all naturally occurring fibrous minerals consisting of silicon dioxide, calcium, iron, magnesium or aluminum oxide, and magnesium silicate. The best known kind in electrical equipment is chrysotile. Since asbestos has outstanding thermal insulation properties, it is mainly used in irons, boilers, hairdryers, and toasters. Mechanical processes such as crushing and grinding dry asbestos cause the fibres (5-100 mm long, up to 5 mm thick) to be released into the air. If breathed in, these fibres can reach the lungs, where they cause chronic inflammation leading to lung cancer. WEEE containing asbestos should never be handled without sufficient protective gear. The use of asbestos has been banned in Germany since 1994.

Barium

Barium is used as a 'getter' in vacuum tubes. Barium carbonate and barium nitrate are used as sorbents for X-rays in cathode ray tubes (Harant 2002). In older devices, barium is found as white pigment (barium sulphate/ $BaSO_4$). Barium is leached out of cathode ray tubes in landfills and also released during the mechanical processing of WEEE containing barium. If emissions are insufficiently captured, barium accumulates in the ground dust at WEEE factories up to a level of 7200 mg/kg, while in the drainage pipes of waste water channels, it has been known to reach the levels of 41.75-4460 mg/kg (Bridgen, Labunska, and Santillo 2005). Water soluble barium compounds are poisonous and cause muscle cramps and cardiac trouble.

Chlorine

Chlorine exists in the natural environment as both poisonous chlorine gas (Cl_2) and chloride (Cl^-), which is essential for humans. Chloride is contained in residual waste in the form of salt adhesions and can, therefore,

be neglected in WEEE. Organic chlorine is found in PVC, flame retardants, and insulating materials, and in connection with the combustion of WEEE can lead to the formation of dioxins and furans.

Copper

Copper or Cu has the atomic number 29 and a density, at room temperature, of 8.92 g/cm³. Trace amounts of copper (about 1-2 mg daily) are essential for the human beings. Copper is characterized by excellent electrical conductivity and is one of the main components used in WEEE. Copper is used especially frequently in circuit boards, cables and wires, as well as copper alloys (for example, copper-tin and copper-nickel alloys). It is also employed in pigments (copper chromate).

Copper ions (Cu²⁺) are toxic to plants and bacteria. Although copper is an essential trace element for the human body, chronic inhalation of copper dust will induce poisoning symptoms such as allergies, liver damage, and breathing trouble. Moreover, a high copper load can lead to zinc deficiency in the body. Copper accumulates in the liver and kidneys. Copper dust on the skin leads to eczema while copper (I) oxide from semiconductors has a caustic effect on the mucous membrane following inhalation (Blum and Schmidt 1996). In Germany, the maximum concentration of copper in the air allowed in the workplace is 1 mg/m³.

In factories where circuit boards are manually dismantled and solder recovered, studies found 168-6805 mg/kg copper in ground dust in India and as much as 4100-25 400 mg/kg in China. Meanwhile, 229-15 200 mg/kg copper was found in sediments from waste water collection tanks in Chinese factories where WEEE was treated with acid (Bridgen, Labunska, and Santillo 2005).

Polychlorinated and polybrominated dibenzodioxins and dibenzofurans

Dioxins are six-membered heterocyclic compounds with two oxygen atoms in the 1,4 position. Furans are heterocyclic compounds with one oxygen atom and four carbon atoms in a five membered ring. Both occur in condensed ring systems, for example, polychlorinated dibenzodioxins. Dioxins and furans are not deliberately used in the production of WEEE. They result during the incomplete combustion of fuels containing chlorine (for example, PCBs) as a result of de novo synthesis. In landfills, for example, PCDD (polychlorinated dibenzop-dioxin)/furans can be leached out of correspondingly contaminated waste. Dioxins and furans are highly toxic and extremely persistent in nature. Their toxicity largely depends on the number and position of the Cl and Br atoms.

Poisoning causes severe rash ('chloracne'). Other effects of chronic poisoning include damage to the central nervous system and liver, as well as the formation of carcinomas.

Zinc

Although small quantities of zinc are essential for the human body, larger amounts are somewhat toxic. Zinc is used in zinc-carbon batteries, in soldering tin (Zn/Sn alloys), LEDs, and capacitors. Human intake of high doses of zinc (for example, in connection with the mechanical processing of WEEE) can cause irritation of the mucous membrane and fever.

Annex F – Details of some of the key processes in e-waste recycling

Recycling of Printed Circuit Boards

The printed circuit boards contain heavy metals such as antimony, gold, silver, chromium, zinc, lead, tin and copper. According to some estimates, there is hardly any other product for which the sum of the environmental impacts for raw material, industrial refining and production, use and disposal is as extensive as for printed circuit boards. The methods of salvaging material from circuit boards are highly destructive and harmful as they involve heating and open burning for the extraction of metals. In fact, only a few materials are recovered even after such harmful methods for extraction are used.



The recycling of circuit boards, drawn from monitors, CPU, disc and floppy drives, printers, etc. involves a number of steps.

1. First, there is manual removal of gold-plated pins and the few ICs that can be reused. The core of each motherboard has a flat laminated gold plate.
2. These laminated parts are cut down and sold to gold-smiths for gold recovery. Subsequently, pre-heating is done to remove resalable components like ICs, condensers, bearings (pulleys) from floppy drive and hard drive. Pre-heating involves putting the motherboard on a burning stove. Low heat is maintained to loosen only the chemical bond between solder and plastic.
3. At this stage, resalable chips, condensers, etc. are plucked out from these pre-heated plates. The pre-heated circuit boards are then bought by other dealers for recovery of solder (which consists of lead and mercury). The method of solder recovery is very rudimentary. A burning kerosene gas kit is placed in a small water tub to store molten lead. The circuit boards are simply put on top of the stove; tongs are used on all sides. The lead extracted due to heat application goes into a water tub – it floats due to low density.
4. After de-soldering, the circuit boards go for roasting or acid bath to recover copper from them. Copper retrieval is done through two processes:
 - a. **Open burning** – After separating all remaining components, motherboards are put for open pit burning to extract the thin layer of copper foils laminated in the circuit board. After charring, it is distilled through a simple froth floating process. The ash content is washed out and copper, with some carbon impurity, goes to another recycling unit. Defective IC chips and condensers, which do not have a resale market, are also burned in small enclosures with chimneys, to extract metallic parts.
 - b. **Acid Bath** – In this process, the collected mother boards are dipped in the acid for few hours. The acid, along with motherboard, is heated in a big container to formulate crystal copper sulphate. Then, acid iron chips are added and sludge containing copper is extracted which is further put into ion exchange process to recover copper from it.



Both methods, open burning and acid bath, are fraught with occupational health risks to workers as well as people living in surrounding areas. Circuit boards are charred only to extract copper and copper acts as a good catalyst for dioxin formation. This happens particularly because brominated flame retardants, which are one of the constituents of circuit boards, are incinerated.

Monitors

Monitors are much sought after by scrap dealers as they contain good quantity of copper yoke, besides circuit board and the picture tube. The first step in monitor recycling involves physical removal of plastic casing, picture tube (cathode ray tube), copper yoke and plates.

The intact and functional CRT is resold for regunning. These re-charged tubes are used for the manufacture of colour and black and white televisions for local brands. Regunning is possible only for those monitors whose terminal pin (diode pin) of electron gun has not broken in the process of removing yoke from gun. The success ratio of the regunning process is 4:1. If it becomes defective, it is broken down to recover iron frames from the glass funnel. The iron frames are found only in colour CRTs and not in black and white monitors. The glasses and iron frames from picture tubes are given to waste traders or dumped into the municipal bin.

Due to large scale recycling of CRTs, India doesn't have huge waste stocks. The dispersed nature of the e-waste trade and market might be a reason for not having such obvious display of waste.

Copper yokes and Metallic Transformers

The copper and yoke core recovered from yoke coils found around the picture tube end is sold to copper melters and re-winders. Apart from the yoke, copper and metallic core is also recovered from transformers mounted on the circuit board of the computer. The circuit tray also contains a number of condensers of different sizes. Depending upon their condition and demand, they again enter the secondary market for reuse. If they are defective, they are sold along with the motherboard.



Copper extraction from wires

Two kinds of processes are being followed for extraction of copper from wires. These are as follows:

- ❑ Manual drawing of wires for copper
- ❑ Extraction of copper by burning the wire

Manual drawing of wires for copper:

In this process, the edge of wire is cut with a knife. With the help of pliers, the copper is extracted from PVC. The process results in extraction of copper which is sold to copper melters. PVC is used for plastic graining.



Extraction of copper by burning the wire:

The general practice for material recovery from wire is simply to put it in fire either in closed or open drums. This is obviously harmful to workers involved and to the environment.



Plastic Chipping and Melting and Graining

The plastic casings of monitors are made either of PVC (polyvinyl chloride) or ABS (acrylonitrile-butadiene styrene). PVC was used more commonly in the early models of computers. Now, computer manufacturing companies have shifted to ABS plastic in the production of monitors. Though both types of plastics are currently being recycled in Delhi, the PVC wires cannot be recycled. This is due to the high percentage of silicate being added for making it fire retardant. The silicate plastic often ends up at kilns as an alternate source of energy. The plastic casing is recycled into EBS or High Impact Plastic. These kinds of plastics are frequently used in manufacturing toys.



Aluminum Extraction from Capacitor

In this process, capacitors are burned in a closed drum and the residual aluminum is extracted for recovery. An alternate way, which is not very popular due to tediousness involved, is manually cutting the capacitor to extract the aluminum film.

Gold Extraction from Chips and Pins

In this process, the gold plated pins are heated with sulphuric acid which results in extraction of gold flakes. The gold flakes and gold plated chips are then heated in a container named 'Kodali' with mica and silver added as ingredients. Mica then absorbs gold and copper and forms liquid. Impurities are removed. In an enclosure colloquially called 'adda,' heated air is blown resulting in mica evaporation, leaving behind gold and silver in solid form. The silver laden gold is once again heated in the *kodali* to liquefy the material. Now, acid (Aqua Regia) is added into this liquid and the sludge containing gold settles at the bottom. This sludge is separated from rest of the acid containing silver. The extracted sludge is once again heated in the *kodali* and rest of the impurities evaporate, leaving behind gold. On the other hand, the acid laden silver is added with rusted iron chips. Silver settles in the form of sludge which is also heated in the *kodali* leaving behind silver after evaporation of acid. The above process is generally done in enclosed workplace resulting in high exposure to dioxins etc during burning of gold plated chips and mica vapor.



Annex G – Socio Economic Classification of Households

Socio Economic Classification (SEC) of Households is done on the basis of Education Level and Occupation of the Chief Wage Earner of the Household. The grid used for this classification is shown below.

SEC A	1/2	SEC B	3/4	SEC C	5
SEC D	6	SEC E	7/8		

Occupation/ Education		EDUCATION							
		Illiterate	School Upto 4 yrs	School 5-9 yrs	Ssc/ Hsc	Some college but Not Grad	Grad/ post grad (gen)	Grad/ post grad (prof)	
O C C U P A T I O N			1	2	3	4	5	6	7
	Unskilled worker	01	8	8	7	6	6	6	6
	Skilled worker	02	8	7	6	5	5	4	4
	Petty traders	03	8	6	6	5	5	4	4
	Shop owners	04	6	6	5	4	3	2	2
	Businessmen/ industrialists								
	- None	05	6	5	4	3	2	2	1
	- 1-10	06	5	4	4	3	2	2	1
	- 10+	07	3	3	2	2	1	1	1
	Self-employed professionals	08	6	6	6	4	3	2	1
	Clerical/salesmen	09	6	6	6	5	4	3	3
	Supervisor level	10	6	6	5	5	4	3	2
	Officers/executives								
- Junior	11	5	5	5	4	3	2	2	
- Middle/ senior	12	3	3	3	3	2	1	1	

Annex H – Input/Sales figures (including forecasts) used for E-waste Quantity Estimation

(All figures in number of units and for KMA region)

Desktop Sales		
Year	Business Establishments	Households
2004-2005	64747	182819
2005-2006	81530	98200
2006-2007	142986	88635
2007-2008	185065	148477
2008-2009	339267	67339
2009-2010	513300	77440
2010-2011	769951	89056
2011-2012	1139527	102414
2012-2013	1652314	117776
2013-2014	2346286	135443
2014-2015	3284801	155759

Notebook Sales		
Year	Business Establishments	Households
2004-2005	1010	15640
2005-2006	17806	10704
2006-2007	19889	9465
2007-2008	29023	28167
2008-2009	67768	27917
2009-2010	94654	33501
2010-2011	137249	40201
2011-2012	205873	48241
2012-2013	319103	57890
2013-2014	478655	69467
2014-2015	694049	83361
2015-2016	971669	100033

Television Sales	
Year	Sales in number of Units
2001	644000
2002	717500
2003	770000
2004	822500
2005	892500
2006	980000
2007	1050000
2008	1207500
2009	1295000
2010	1347500
2011	1400000

Refrigerator Sales	
Year	Sales in number of Units
1999	112500
2000	132500
2001	150000
2002	168750
2003	185000
2004	194250
2005	192500
2006	210000
2007	242500
2008	295000
2009	325000

DVD Sales	
Year	Sales in number of Units
2006	300000
2007	360000
2008	420000
2009	372000
2010	409200
2011	450120
2012	495132
2013	534743
2014	577522
2015	623724
2016	673622

Annex I – E-waste Volume in number of Units

E-waste Volume in number of Units from different Product Categories and Segments							
Year	Desktops	Notebooks	Printers	Mobiles	DVD	Televisions	Refrigerators
2010-2011	140003	38819	63154	1100801	300000	644000	112500
2011-2012	325805	81749	62352	2025708	360000	717500	132500
2012-2013	283265	115637	69837	1694405	420000	770000	150000
2013-2014	427902	157847	59217	2202727	372000	822500	168750
2014-2015	661777	213080	64318	2863545	409200	892500	185000
2015-2016	837290	296870	69335	3102174	450120	980000	194250
2016-2017	1216967	428300	75001	3877717	495132	1050000	192500
2017-2018	1741370	609691	80901	4847146	534743	1207500	210000
2018-2019	2448700	851293	86491	4847146	577522	1295000	242500
2019-2020	3402577	1160361	92840	5816576	623724	1347500	295000

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- The eWaste Guide, a knowledge base for the sustainable recycling of eWaste at <http://www.ewaste.ch>
- US Environmental Protection Agency at <http://www.epa.gov>

Glossary

- ABS: Acrylonitrile-butadiene styrene
- BFR: Brominated Flame Retardant
- CED: Covered Electronic Devices
- CRT: Cathode Ray Tube
- DGFT: Directorate General of Foreign Trade
- HCFC: Hydrochlorofluorocarbons
- ITOPs Study: IT and Office Products Study
- MT: Metric Tonnes
- PCB: Printed Circuit Board
- PCBs: Polychlorinated Biphenyls
- RoHS: Restriction of Hazardous Substances
- LCD: Liquid Crystal Display
- PVC: Polyvinyl Chloride
- UNEP: United Nations Environment Programme
- PBB: Polybrominated biphenyls
- PBDE: Polybrominated Diphenyl Ethers
- TAC: Technical Adaptation Committee
- WEEE: Waste Electrical and Electronic Equipments