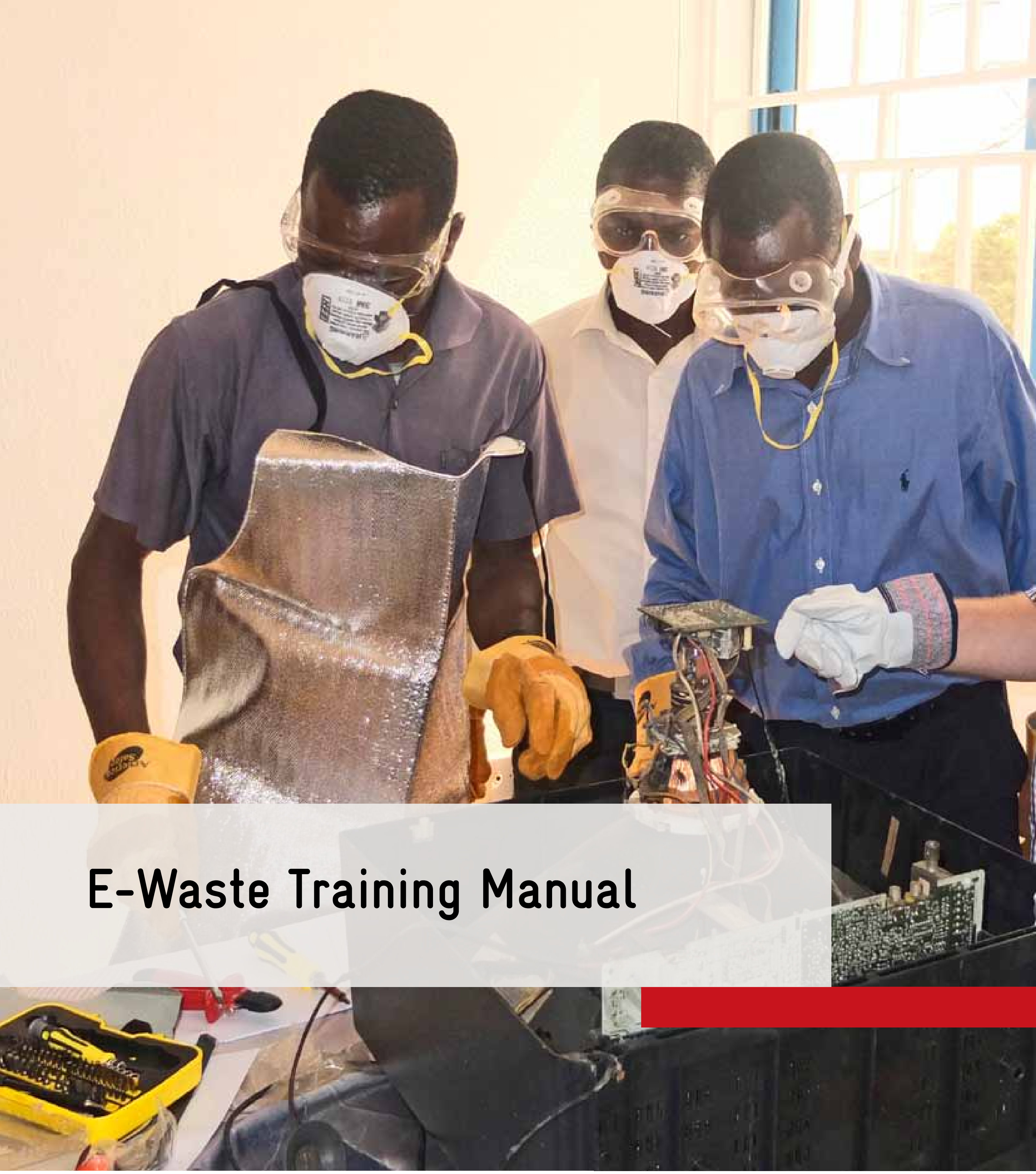

E-Waste Training Manual

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Environmentally Sound Disposal & Recycling of E-Waste (E-Waste Programme)
Supporting Ghana to introduce a sustainable e-waste management system

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Introduction

This training manual about safe and sound handling of electric and electronic waste (e-waste) was developed within the framework of the German Cooperation programme for "Environmentally Sound Disposal & Recycling of E-Waste" (E-Waste Programme, 08/2016 – 01/2020), with its objective to support the Ghanaian Ministry of Environment, Science, Technology and Innovation (MESTI) to improve the conditions for sustainable management of e-waste in Ghana.

Part of the programme includes capacity development for actors in the informal sector, promoting individual skills and organisational structures of those directly involved in the collection and resource recovery. In order to avoid health and environmental risks, the programme supports e-waste collectors and recyclers who are willing to change their methods.

To achieve this goal, a consortium of international experts (WRF – World Resources Forum, St. Gallen, Switzerland, DRZ – Demontage- und Recycling-Zentrum, Vienna, Austria, SAEWA – Southern African E-Waste Alliance, Cape Town, South Africa, RECLITE – Waste Electrical and Electronic Equipment Recycling, Germiston, South Africa, GWR - gemeinnützige Gesellschaft für Wiederverwendung und Recycling mbH) developed a training of trainers course specifically targeted at the situation at Old Fadama scrap yard in Accra, to be held at the newly adapted training facilities.

Local partners' contributions came from EPA – Environmental Protection Agency (providing assistance as to the e-waste related national legislation), NYA – National Youth Authority (spatial resources and contacts to relevant environmental groups), and Chance for Children (charity ready to take over the administration of following trainings).

As a basic manual for e-waste trainers, this publication assembles compact information about e-waste in theory (definitions, global and local implications), practical dismantling of different types of equipment, output fractions after manual dismantling, the management of a small scale recycling facility (including the calculation of business opportunities), and the organising of trainings. An annex comprises contacts and references as well as templates that can be used in future workshops.

We wish you successful trainings!

Content

Content

Content

1.

E-Waste: Global and Local Implications

1.1. Definitions, Types, Categories

WEEE or e-waste is often misunderstood as comprising only computers and related IT equipment. According to the OECD, e-waste is "any appliance using an electric power supply that has reached its end-of life". In this manual, WEEE and e-waste are used as synonyms, and include all the 10 categories of EEE (Table 1) as specified in Annex I of the EU WEEE directive [1] which has become the most widely accepted classification. It must be noted that the categories listed in table 1 were subject to a transitional period until August 2018. Since August 2018 all EEE shall be classified within the categories set out in Annex III of the EU WEEE directive (Table 2).

	Category
1.	Large household appliances
2.	Small household appliances
3.	IT and telecommunications equipment
4.	Consumer equipment and photovoltaic panels
5.	Lighting equipment
6.	Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
7.	Toys, leisure and sports equipment
8.	Medical devices (with the exception of all implanted and infected products)
9.	Monitoring and control instruments
10.	Automatic dispensers

Table 1: Categories of EEE covered by the EU WEEE Directive during the transitional period (until August 2018)

	Category
1.	Temperature exchange equipment
2.	Screens, monitors, and equipment containing screens having a surface greater than 100 cm^2
3.	Lamps
4.	Large equipment (any external dimension more than 50 cm) including, but not limited to: Household appliances; IT and telecommunication equipment; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3.
5.	Small equipment (no external dimension more than 50 cm) including, but not limited to: Household appliances; consumer equipment; luminaires; equipment reproducing sound or images, musical equipment; electrical and electronic tools; toys, leisure and sports equipment; medical devices; monitoring and control instruments; automatic dispensers; equipment for the generation of electric currents. This category does not include equipment included in categories 1 to 3 and 6.
6.	Small IT and telecommunication equipment (no external dimension more than 50 cm)

Table 2: Categories of EEE covered by the EU WEEE Directive after the transitional period (after August 2018)

1 European Union, (2012): Directive 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)

E-waste may contain precious metals such as gold, copper and nickel and rare materials of strategic value such as Indium and Palladium. These precious and heavy metals can be recovered, recycled and used as valuable source of secondary raw materials. ICT components, for example, contain a variety of metals for which recovery is economically attractive (Table 3).

Device	Au		Ag		Pd	
	(mg)	(ppm)	(mg)	(ppm)	(mg)	(ppm)
PC	316-338	21-23	804-2,127	54-142	146-212	10-14
Laptop	246-250	85-86	440	152	50-80	17-28
Tablet	131	215	26	43	no data	no data
Mobile phone	50-69	455-627	127-715	1,155-6,500	10-37	91-336

Table 3: Content of Au, Ag, and Pd in ICT devices

At the same time, e-waste also contains toxic and hazardous substances, for example, heavy metals such as mercury, cadmium, lead, and chromium, or Persistent Organic Pollutants (POPs), which can be found in plastic casings or in Printed Wiring Boards (PWB). Some of these substances have been regulated, and their use has been restricted for new equipment through the European RoHS [2] directive. Other substances have been banned, but are still allowed for certain applications (for instance, mercury in energy-saving lamps) and/or are still present in older equipment. E-waste and its components may therefore pose a significant health risk not only due to their primary constituents, but also as a result of improper management of by-products either used in the recycling process (such as cyanide for leaching gold) or generated by chemical reactions (such as dioxins through the burning of cables).

Due to its properties, WEEE is generally considered to be hazardous waste under the Basel Convention. It is included in Annex VIII to the Convention under the following entry for hazardous waste:

> "A1180 Waste electrical and electronic assemblies or scrap containing components such as accumulators and other batteries included on list A, mercury-switches, glass from cathode-ray tubes and other activated glass and PCB-capacitors, or contaminated with Annex I constituents (e.g., cadmium, mercury, lead, polychlorinated biphenyl) to an extent that they possess any of the characteristics contained in Annex III (note the related entry on list B B1110)." [3]

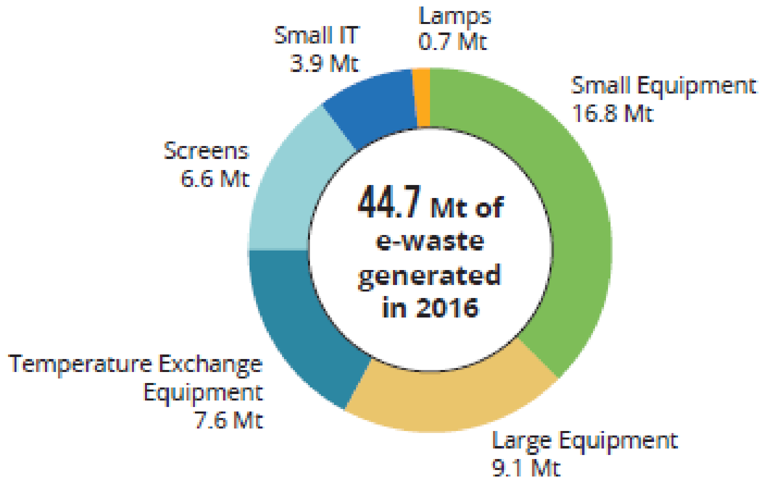
2 Restriction of Hazardous Substances Directive 2002/95/EC

3 UNEP, (2015). Technical guidelines on transboundary movements of electrical and electronic waste and used electrical and electronic equipment, in particular regarding the distinction between waste and non-waste under the Basel Convention. UNEP/CHW.12/5/Add.1/Rev.1.

1.2. Global Generation, Consumption and Implications

Across the world, in both developed and developing countries, the generation of e-waste is increasing constantly [1]. The latest Global E-Waste Monitor [2] states that the annual generation of e-waste has grown to 44.7 Million Metric Tonnes globally. This amounts to 6.1 kilogram of e-waste generated by each individual, which is expected to increase to 6.8 kg by 2021.

Estimates of e-waste totals per category in 2016

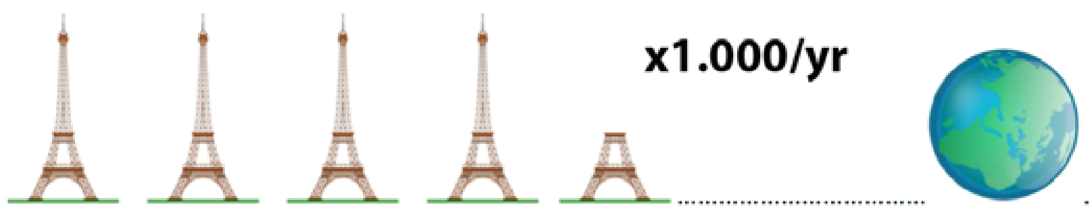


The global quantity of e-waste in 2016 is mainly comprised of Small Equipment (16.8 Mt), Large Equipment (9.1 Mt), Temperature Exchange Equipment (7.6 Mt), and Screens (6.6 Mt). Lamps and Small IT represent a smaller share of the global quantity of e-waste generated in 2016, 0.7 Mt and 3.9 Mt respectively.

UNU Global E-Waste Monitor Report (2017)

Global e-waste generation

In more visual terms: The current generation of 44.7 million tons of e-waste is equivalent to almost 4,500 Eiffel Towers added to the planet EVERY YEAR



1 https://learning.climate-kic.org/courses/e-waste-mooc/ewaste-course/e-waste-challenge/1-1-the-e-waste-tsunami
2 United Nations University: Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann,P., (2017)

The currently existing consumption behaviour highly contributes to the increasing e-waste volumes. This is spurred on by manufacturers who sometimes deliberately develop products that are designed to break down quickly, are fast getting technically outdated [3] or are perceived to be old-fashioned by the consumer [4] after a short while of being in use. Every type of electrical and electronic equipment tends to have a specific average useful life-span before it becomes e-waste. A washing machine is not as quickly and frequently replaced as a laptop or a mobile phone.

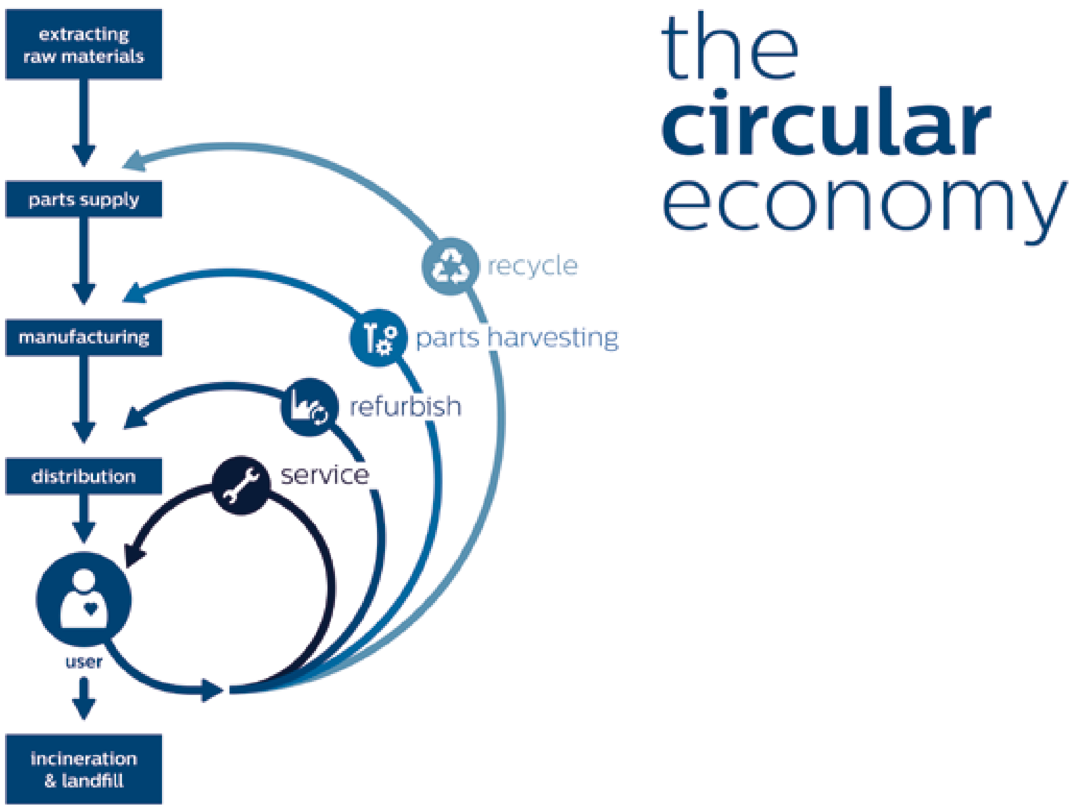
UNU Global E-Waste Monitor (2017)

Generally speaking, the life span of EEE is continually decreasing. Still, there is a marked difference in the frequency electronic and electrical equipment is becoming e-waste depending on the world regions. From the e-waste generation numbers provided according to continents [5] it is evident that residents of countries driven by "emerging economies" are much more thrifty, responsible and inventive on how to maintain and prolong the useful life-time of electronics [6]. It is therefore no wonder that Ghana boasts a vibrant, growing and generally very skilled e-waste repair and refurbishment sector. The latter includes many self-taught but over the years highly-specialised individuals who are experts in their field and capable to extend the useful lifespan of electronics for decades.

Extending the life of EEE has a positive impact to the environment as the extraction of natural resources, the generation of waste and the consumption of energy can be minimised compared to producing a new device.

3 https://storyofstuff.org/movies/story-of-electronics/
4 The term to describe a real or perceived state of electronic/electrical equipment getting dysfunctional, being aged or unmodern to the point that replacement is required is called "obsolescence". There is mounting evidence that often manufacturers of goods deliberately "build" this into a product as demonstrated in the movie for the design of lightbulbs: https://www.youtube.com/watch?v=_aczWRC14ds
5 Baldé, C.P., Forti V., Gray, V., Kuehr, R., Stegmann, P., (2017)
6 UNU estimates that in 2016, domestic e-waste generation in Africa was approximately 2.2 Mt (out of 44.7 Mt globally), which amounts to 5% of all e-waste generated and means each African generates about 1.9 kg e-waste on average.

The model of Circular Economy supports this approach by keeping the prioritization of maintenance and recovery of function in mind. Servicing of functional equipment retains most value of the technical nutrient because it avoids e-waste from being generated in the first place. Refurbishment gives e-waste a second lease of useful work life, and any functional parts that can be harvested are of higher value and importance than any recovery of materials that forms part of what we actually refer to as "recycling" of e-waste. Incineration and landfilling should be ultimately entirely avoided in a Circular Economy or at least only be used as the very last resort. Rethinking however already starts at design and production level (e.g. sharable, long-lasting, upgradable, repairable, non-toxic products) and offers the emergence of many services and future products.



https://sustainablecomputing.umich.edu/knowledge/life-cycle.php

Life Cycle of a Computer:

The annual life cycle burden of a computer is 5,600 MJ (megajoules), however, only 34% of life cycle energy consumption occurs in the use phase. The rest of the energy is needed for the mining, manufacturing, packaging, and transportation processes that are required in making a computer. An average computer is made up of over 30 different minerals which are mined and extracted from the earth. Some of these minerals are silica, iron, aluminium, copper, lead, zinc, nickel, tin, selenium, manganese, arsenic, and cadmium - all non-renewable resources in our life time.

It takes 245 kg of fossil fuels, 22 kgs of chemicals, and 1500 litres of water to manufacture one desktop computer. Ultimately, 80-85% of all electronic products are discarded in landfills or incinerators releasing toxins into the air and soil.

However, at some point EEE reaches the end of its life. At this stage it is important to keep in mind that the metal concentrations of Au, Ag, and Pd in ICT devices often exceed the concentrations found in natural ores by up to 50 times (UNU 2012). This highlights the relevance of e-waste as a secondary resource to secure and stabilise future supply chains. Consequently, inefficient treatment of WEEE may lead to a systematic loss of secondary materials.

Hence, the appropriate handling of e-waste both prevents environmental and health issues and contributes to more sustainable use of raw materials.

Compared to annual production volumes, the demand for metals used in EEE reaches significant levels (Table 4).

Metal	Primary production* (t/y)	By-product of	Demand for EEE (t/y)	Demand/ production (%)	Main applications
Ag	20,000	Pb, Zn	6,000	30	Contacts, switches, solders...
Au	2,500	(Cu)	300	12	Bonding wire, contacts, integrated circuits...
Pd	230	PGM	33	14	Multilayer capacitors, connectors
Pt	210	PGM	13	6	Hard disks, thermocouples, fuel cells
Ru	32	PGM	27	84	Hard disks, plasma displays
Cu	15,000,000		4,500,000	30	Cables, wires, connectors...
Sn	275,000		90,000	33	Solders
Sb	130,000		65,000	50	Flame retardants, CRT glass
Co	58,000	Ni, Cu	11,000	19	Rechargeable batteries
Bi	5,600	Pb, W, Zn	900	16	Solders, capacitors, heat sinks...
Se	1,400	Cu	240	17	Electro-optic devices, copiers, solar cells
In	480	Zn, Pb	380	79	LCD glass, solders, semiconductors
Total			4,670,000		

*based on demand in 2006; acronyms: PGM= Platinum Group Metals; CRT= Cathode Ray Tube; LCD= Liquid Crystal Display

Table 4: Important metals used for EEE

Looking further into the recycling, e-waste is truly the "Kinyonga" (Chameleon) amongst all waste streams as it changes its composition and appearance constantly. What can be found in a batch of e-waste is depending at any given time on many factors. It includes its place of origin, type of generator and most importantly the time when it was generated.

This makes it very challenging for recyclers to secure sufficient volumes of certain e-waste types over an extended period that can warrant investment costs linked to set-up of required treatment technologies.

Types of electrical and electronic equipment (and/or their peripherals to drive them) that currently experience the strongest growth in numbers are (including but not limited to):

- Lithium Ion Batteries (a key enabler for the switch to Electric Vehicles)
- LED lighting/smart street lighting - modular and multi-functional systems for cities
- Laser lighting (huge growth in the automotive industry)
- Off-grid solar equipment
- Photovoltaic (PV) cells

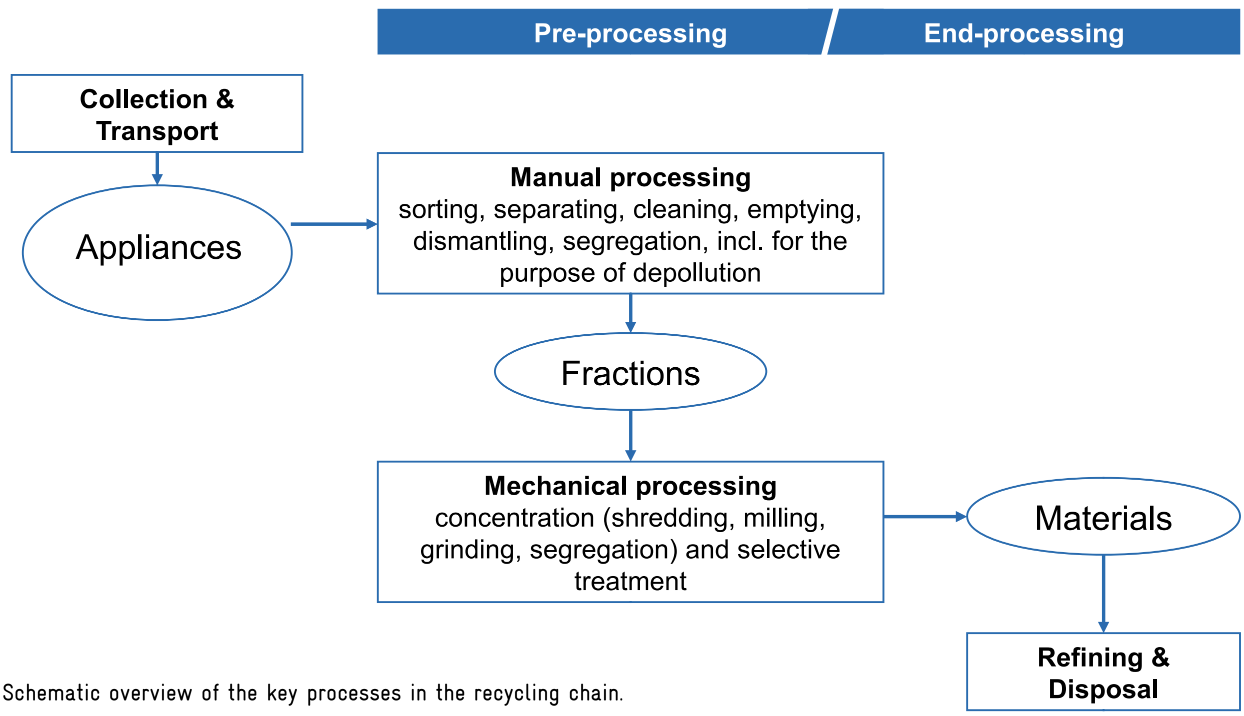
1.3. Recycling Chain

The recycling chain for WEEE consists of three main subsequent steps:

1) collection
2) pre-processing (incl. sorting, dismantling, mechanical treatment)
3) end-processing (incl. refining and disposal)

Usually for each of these steps specialized operators and facilities exist. The material recovery efficiency of the entire recycling chain depends on the efficiency of each step and on how well the interfaces between these interdependent steps are managed. If for example, for a certain material the efficiency of collection is 50%, the combined pre-processing efficiency is 70% and the refining (materials recovery) efficiency 95%, the resulting net material yield along the chain would be only 33%.

Concepts and processes applied in the recycling chain can vary considerably from each other in



Schematic overview of the key processes in the recycling chain.

different regions and countries with individual strengths and weaknesses. The main differences can be found between OECD countries with a prevailing formal sector and developing countries with a dominant informal sector. The graph below compares the recycling efficiency between a common formal system in Europe and the informal sector in India for the overall gold yield out of printed wiring boards. While both scenarios indicate similar (low) overall metal recovery efficiencies, both have their weaknesses and strengths in different steps of their respective recycling chain. An analysis of strengths, weaknesses, opportunities and threats (SWOT analysis) for a formal vs. an informal system is summarized in the table below.

System	Collection	Pre-processing	End-processing	Net yield
Formal e.g. Europe	60% formal take-back system	25% mainly mechanical processes	95% integrated smelter	15%
Informal e.g. India	80% individual collectors	50% manual sorting and dismantling	50% backyard leaching	20%

Recycling efficiency between a common formal system in Europe and the informal sector in India for the overall gold yield out of printed wiring boards

	Formal scenario	Informal scenario
Strengths	Access to state-of-the-art end-processing facilities with high metal recovery efficiency	High collection efficiency Efficient deep manual dismantling and sorting Low labor costs gives advantage of manual techniques over mechanical technologies in the pre-processing steps
Weaknesses	Low efficiency in collection Often low efficiency in (mechanized) pre-processing steps	Medium efficiency in dismantling and sorting Low efficiency in end-processing steps coupled with adverse impacts on humans and the environment
Opportunities	Improvement of collection efficiency Technology improvement in pre-processing steps	Improvement of efficiency in the pre-processing steps through skills development for dismantling and sorting Implementation of alternative business models, providing an interface between informal and formal sector
Threats	"Informal" activities in the collection systems	Bad business practice (bribery, cherry picking of valuables only, illegal dumping of non-valuables, etc.) Lacking government support (no acceptance of informal sector, administrative hurdles for receiving export licenses, etc.)

SWOT analysis of the e-waste recycling chain in formal vs informal scenarios

1.4. From Worst to Good Practice

What is a Worst Practice and why does this exist

According to the definition developed as part of the Guidance Principles for the Sustainable Management of Secondary Metals (ISO IWA 19), Worst Practices are described as: '…practices that are known or suspected to have severe (typically multiple) negative impacts on the environment, workers/community health and safety, and quality and quantity of recovered secondary metals, when applied by any economic operator in any of the processes concerned (collection, manual and mechanical processing, metallurgical processing and disposal).'

These undesirable practices are globally widespread and typically take place in economic environments and political climates that show an absence of control mechanisms (such as legislative enforcement of minimum standards to ensure the protection of both human health and environmental systems integrity). Individuals and local communities might be forced to engage in Worst Practices in subsistence activities [1] due to the lack of other local income opportunities and despite their often-tangible negative human health impacts.

Poor education and lack of training also contribute to engaging in risky practices in the informal sector (typically without sufficient protection for the workers or the receiving environment). Often there is a complete lack of awareness found in people engaged in any aspect of the described Worst Practices and, as a result, there is little understanding on how badly these practices can harm the environment and, ultimately, anyone involved in such unsound activities (workers) or involuntarily affected by them (e.g. neighbouring communities).

Some economic operators are also broadly applying Worst Practices in conducting their unofficial business activities [2] and profiteering from ill-gotten economic gains.

While prevalence can be observed in the informal sector (UBA and SA) in developing and emerging economies, Worst Practices can also occasionally be found in the otherwise 'formal sector' described by official business activities [3], e.g., if control mechanisms are not in place.

Enabling conditions to move away from Worst Practices

To this end it is of great importance to rather develop financial incentives and source the required funds (and other support mechanisms) to motivate and encourage Good Practices (in parallel to combating the described Worst Practices).

To raise awareness and strengthen their capacities to move away from Worst Practices, workers engaged in SA, UBA and OBA and their leadership need also support with targeted capacity building and coaching programmes.

Selected Worst Practices described in the following sub-chapters aim to provide guidance on how to overcome Worst Practices and on options for improvement.

1 Subsistence activities (SA) – activities that can be found in both the formal and the informal sectors, and are conducted by economic operators (mostly individuals and families) who earn a wage that is barely sufficient to support or maintain themselves and is below the minimum tax threshold required per national laws and regulations to pay taxes.

2 Unofficial business activities (UBA) – activities that are conducted by economic operators not constituted as legal entities, with income above the living wage as well as the minimum tax threshold and that purposely desire to bypass national and/or local laws and regulations.

3 Official business activities (OBA) – economic activities that are conducted by economic operators constituted as legal entities and, thus, are subject to government regulation, taxation and observation.

Criteria used to select Worst Practices

The following Worst Practices were selected for this document because they:

- occur in secondary metals recovery from any waste and end-of-waste that contains metals
- are globally widespread (mostly among economic operators involved in SA and UBA), often in emerging and developing economies
- are known for their severe (typically multiple) negative impacts on the environment, workers/community health and safety, and on the quality and quantity of metals recovered.

The description of the full set consisting of five clusters of practices of major concern and nine Worst Practices can be found in the publication 'From Worst to Good Practices in Secondary Metals Recovery (Karcher et al., 2018)'.

Clusters of practices of major concern	Worst Practices
Unsound collection practices	A. Poor housekeeping during collection: handling, logistics and facilities
Unsound transportation and trading	B. Non-compliant trading and poor housekeeping in transportation
Dangerous manual dismantling practices	C. Unsafe manual dismantling
Inefficient mechanical processing	D. Low-quality segregation during mechanical processing
Inefficient and dangerous metallurgical processing	E. Low-tech, unsound 'smelting' and 'off-burning'
	F. Amalgamation
	G. Other low-tech, unsound chemical leaching
Unsound disposal	H. Open burning
	I. Open dumping

Case: Trading and Transportation

Worst Practice

Illegally traded e-waste amounts to about 75% posing serious risks to health. A wide range of actors mainly engaged in official business activities (OBAs) or unofficial business activities (UBAs) can be involved in non-compliant trading and transportation locally, nationally and internationally: producers, distributors, traders (importers and exporters), consumers, collectors, refurbishers, waste brokers, shipping companies, shipping agents, terminal operators, environmental inspectors, customs officials, police officers, organised crime groups, recyclers, downstream vendors, and final disposal service providers. Examples of non-compliant trading include, but are not limited to:

- Selling on processed fractions to a down-stream vendor who is operating in a non-compliant and dangerous manner, with dire consequences to worker safety and the receiving environment
- Violating the applicable global (Basel Convention) or local (WEEE Directive) legislation that limits and prescribes the modus operandi for acceptable trading and transportation practices
- Non-existent or incomplete documentation of accurate shipping records and/or forgery of the relevant export and import permits, where the latter are typically obtained by bribing of officials
- Trading of cargo that is deliberately falsely labelled and wrongly declared to avoid local costly and legally prescribed waste treatment obligations (such as safety disposal costs) and import duties
- Improperly packaged cargo that does not comply with the required minimum standards set by international transportation regulations in order to avoid costs
- Utilisation of equipment, facilities and transportation vessels that are unsound and unsafe to use with regards to structural integrity and the technical standard required, such as unroadworthy trucks and unseaworthy ships
- Utilisation of fly-by-night types of transportation services that typically employ an untrained, unprotected workforce operating in a non-compliant (e.g. unlicensed), unprotected (accident-prone) and uninsured manner.

Worst Practice: Mixed and non-labelled scrap exported from Europe to Nigeria non-compliant with the Basel Convention ©Empa

Good Practices

The following key points describes some requirements to transform any unsound-trading-and-transportation-type Worst Practices into Good Practices.

1. **Identify, report and take action on non-compliance**
   Requirements include trading and transportation obligations linked to a specific actor in the value chain or to the specific nature of materials transported, traded and/or transferred (e.g. through transboundary shipments and restrictions thereof as stipulated by the Basel Convention).
   Any non-compliant trading and/or transportation activity identified and practised by any actor anywhere along the entire value chain of secondary metals recovery, at any scale and in any location observed, needs ultimately to be reported to the relevant parties and stopped.
   The Economic Operator concerned has to rectify and replace this activity with a compliant practice, and document it towards the establishment of a compliance check list to be used for future compliance monitoring and evaluation.

2. **Implement a chain-of-custody scheme**
This is a regular verification of compliance forms part of a verifiable, traceable and transparent list of checks and balances measures that support chain-of-custody schemes. A certification system could be established that supports the monitoring of compliance of outgoing quantities of material (including monitoring, measurement and documentation) for specific accounting periods, and that then balance all these with the corresponding outgoing shipping records for the same quantities and materials (guidance can be found in the e-Steward Standard and ISO IWA 19:2017).

3. **Make sure to duly document and maintain shipping records**
Workers' skills need to be developed on how to produce verifiable records of incoming and outgoing shipments or transfers of any secondary metals containing waste or materials, which should include a complete data set for all shipping logs, invoices, bills of lading or waybills, other commercially accepted documentation of transfers, and the corresponding acknowledgements of receipt from receiving facilities
Workers should also learn how to fill in and keep track records of weights of materials and/or piece/unit counts, dates, particulars of the consignee (typically the buyer who is the receiver) and consignor (the seller or donor initiating the transition), and verifiable contact information for the entity that transfers shipment (the freight forwarder is thereby assuming the role of an intermediate consignee).

4. **Ensure proper packaging**
Workers have to safely separate, consolidate and contain such materials and wastes, in a manner that prevents leaching, leakage, spills, dispersal, and the release of vapours, fumes, particulates, dust, liquids, and/or other forms of dangerous materials. Workers should use containers that:
- Protect human health and the environment during storing and shipping of each material
- Meet the packaging and shipping requirements of respective downstream processors

5. **Classify and label properly**
For the exact classification of secondary metal-containing wastes, different classification systems exist. The Basel Convention uses a system with Y, A and B codes (waste classification codes) for hazardous and non-hazardous wastes as well as hazardous characteristics. Other waste classification systems used worldwide are the OECD Waste Lists and the European Waste Catalogue (EWC).
It must be noted that waste classification codes do not always have a corresponding entry in the goods nomenclature of the World Customs Organization Harmonized System (WCOHS), which serves as the global system for customs authorities. In these cases, concerned economic operators will find guidance in the E-waste Inspection and Enforcement Manual (2012) which lists classification systems for various types of e-waste (as a prime source of secondary metals), and their corresponding customs codes. Concerned economic operators should know how to accurately and visibly label containers according to their contents and packaging type, and prevent container damage, collapse, and contamination.

Good Practice: Proper identification of materials in particular to segregate hazardous components ©WRF

6. **Hire only authorized transporters**
   Only logistic service providers with all the legal authority and adequate insurance or financial guarantees to cover costs in the event of an accident or injuries can be considered for the transportation of any secondary metals-containing materials.
   It needs to be pointed out that safe end-use treatment facilities (offering the required treatment standards by operating according to the necessary, highly specified and sophisticated technologies) might not be available in every country or even on every continent from where secondary metal-containing waste/material stream originates. Such materials might therefore have to be exported to a foreign pre-authorised facility with the best available technologies. In these cases, it is recommended to establish and utilise a fast-track mechanism as part of the trading channel.

Case: Manual Dismantling Practices (Fridges)

Worst Practice

Worldwide about 173,000,000 units of cooling appliances are discarded annually (Magallini, 2018) not always following proper dismantling for metal recovery. A typical domestic refrigerator contains on average 32 kg of steel, 1.3 kg of copper and 2.2 kg of aluminium. It also contains about 0.3 kg of refrigerants which need to be cautiously separated, which is equivalent to 661 kg CO_2 or a 2,160 km journey in a diesel car.

Worst Practice occurs when there is a forced opening of refrigerators (by smashing and/or breaking the plastic or metalencasing structures), instead of using safer devices to facilitate their controlled opening (e.g., a screwdriver) and breaking and crushing the inside parts without wearing PPE and without the proper separation and containment of hazardous constituents being released. By doing so, extremely harmful gases such as Freon R-12, HCFC R123a, and Isobutane R600a are released to the atmosphere. These gases can be on average 3000 times more damaging than CO_2 and contribute significantly to global warming as well as depletion of the ozone layer. For example, a single kilogram of Freon R-12 has the same impact on global warming as 10,900 kg of CO_2.

In addition, a refrigerator's foam insulation contains 'blowing agents' (which is a type of gas used to make cellular or spongy products contained in the foam insulation in fridges) which escape into the atmosphere when the housing (the white outer casing of the refrigerators) is dismantled. The foam insulation is highly flammable and is often burned deliberately as a means to control the temperature of the fire.

On average by implementing good recycling practices, 485 kg of CO_2 equivalent per refrigerator can be avoided. This is equivalent to the emissions from a 1,600 km diesel car journey (Safaei et al., 2018).

Worst Practice: Open burning of a refrigerator at Agbogbloshie ©Empa

Good Practices

A good practice starts with used refrigerators being returned by the general public to authorized collection centres and facilities, and if not existing, stored in proper centres. Before any treatment, fridges need to be separated based on the type of refrigerant gases they contain. Good practice includes tools fit-for-purpose, personal protective equipment and training, for workers could avoid personal injury. All this together ensure a higher quantity and quality of metals

The average recovery efficiency of these cooling system gases is up to 70% which can then be safely collected and either properly disposed of or reused in the manufacture of new refrigerators. Similarly, the foam insulation and oil- and additives-based lubricants can be carefully removed and re-used or disposed of properly.

Importantly, if good practice is not followed it may negate all the environmental gains of buying energy efficient refrigerators in the first place.

For more information refer to chapter 2.11.

Good Practice: Extraction of cooling gases before fridge dismantling for recycling (Ghana) ©WRF

Case: Treatment of cables to recover copper

Worst Practice

Worst form of recovering copper involves burning off waste cables in open fires that incinerates the outer insulating plastic covering leaving copper as a residue which is then collected. Copper is then recovered as the desired product.

Insulation makes as an average 38% of cables and is composed of Polyvinyl Chloride or PVC (66.3%) and Polyethylene (31.2%) as well as other materials (2.5%). By burning the insulation dioxins and mercury (Hg), as well harmful Chlorine (Cl) compounds, such as Polychlorinated Biphenyls (PCBs), and about 1.6 kg of CO_2-eq per kg of recovered copper are released (Safaei et al., 2018).

Worst Practice: Open cable burning containing copper ©Empa

Good Practices

There exist three key treatment processes to recover copper from cables: the first uses manual or mechanical processes to strip cables and wiring to recover copper; the second involves heat recovery, and the third uses chemical processing. The type of treatment largely depends on the specifications of the cable (e.g. diameter, copper purity and homogeneity, the cable volumes) and the available budget.

Manual or mechanical processing, that is stripping and mechanical granulation of cables, is the most widely used method. This is due to its simplicity (which allows its application for a wide range of cables) and its relatively low cost. In addition to recovering copper with minimum loss, the cables' plastic insulation can also be recovered safely.

Residues are disposed of safely. This not only avoids the incineration emissions but can also save a considerable amount of raw material to produce new plastic insulation. In addition, using manual and mechanical processing, the copper recovered maintains its physical properties and composition, whereas in open burning, the surface layer of copper oxidizes. As a result, the recovered metal has an inferior quality and subsequently fetches a lower price when sold compared to copper recovered via a manual or mechanical granulation process.

The second process, heat recovery, is where cables are incinerated in high temperature kilns with proper emission controls and the heat is captured for use. Provided optimal operational conditions exist this can largely prevent the formation and release of most hazardous toxins and the calorific value contained within the cable waste can provide a source of heat energy for a variety of purposes.

The third good practice option involves chemical treatment. This option, if properly managed can be an efficient process that is particularly suitable when the composition of waste cables is mixed and contains a range of different metals. Using this process, waste cables are submerged into a series of chemical solutions. Copper is then extracted in a fractionated process using further techniques such as: displacement, crystallization and electrolysis of the leaching solution to isolate the metal. However, this process needs to be carefully managed and monitored to achieve positive net environmental benefits.

Above all, these three processes can only be recommended as good practices if workers and the environment are protected and therefore have to take place a safe fit-for-purpose work environment with all the activity based required personal protective equipment and safe working precautions for workers in place.

For more information refer to chapter 3.14.

Good Practice: Cable stripper avoiding air pollution ©Empa

Case: Recycling of Printed Wiring Boards

Worst Practice

Do not practice wet chemical leaching: it may be tempting to extract precious metals such as gold or silver immediately with wet chemical processes. Such processes include dissolving the metals in acids and precipitating them with cyanide salts or mercury. All these processes are highly hazardous and must be conducted by professionals in a laboratory. In addition, recent studies have shown that such processes are selective (they only act on one metal) and inefficient (they only allow to extract the apparent metals).

Worst Practice: Leaching of PWBs ©Empa

Another potentially hazardous practice is to de-solder certain components on a PWB by heating the solder. If this process is not performed under controlled conditions (heat regulation), very hazardous substances are released (e.g. dioxins, gaseous lead).

Breaking off parts should only be done when they are pasted or too difficult to remove.

Good Practices

If possible, always remove parts by unscrewing or dislodging. Wear goggles and gloves when components are broken off.

Immediately store different fractions in their respective containers and work on one material at a time. For example, first remove all aluminium parts and store them in the aluminium container. In a second step remove all the ferrous parts and store them in the relevant container. And so on. Doing so will avoid mixing up materials and thus grant for better sales value.

The best alternative for recovering value from PWBs is to sell them to precious metal refineries and smelters (see chapter 3.8.).

Best Practice: Depollution of PWB ©DRZ

International Organization for Standardisation (ISO) International Workshop Agreement (IWA) (2017), Guidance Principles for the Sustainable Management of Secondary Metals Secretariat of the Basel Convention (2012), E-waste Inspection and Enforcement Manual, available at http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-EWASTE-MAMUAL-INSPEnforcement.English.pdf

Magallini, F. (2018). Refrigerators production and end-of-life disposal. Internal report available at the Sustainable Recycling Industries programme

Safaei, A., Symeonidis, A., Valdivia, S., Ottiger, F. (2018). Life Cycle Assessments of Selected Worst Practices in Secondary Metals Recovery and Recommendations to Move Towards Good Practices, available at https://www.sustainable-recycling.org/wp-content/uploads/2018/09/LCI-Worst-Practices_180831_.pdf

Karcher, S., Valdivia, S., Schluep, M. (2018), From Worst to Good Practices in Secondary Metals Recovery (SRI, 2018), available at https://www.sustainable-recycling.org/from-worst-to-good-practices-in-secondary-metals-recovery/

United Nations Office on Drugs and Crime (UNODC) (2013), Transnational Organized Crime in East Asia and the Pacific, chapter 9: Illicit trade in electrical and electronic waste (e-waste) from the world to the region. Available at: https://www.unodc.org/documents/toc/Reports/TOCTA-EA-Pacific/TOCTA_EAP_c09.pdf

Awareness raising and training to address any Worst Practice

a. Raise awareness and inform

The aim of awareness-raising activities is to contribute to a change in working patterns and to improve the understanding of the value-chain actors and economic operators concerned about the risks and multiple negative consequences, direct and indirect, of non-compliant trading and transportation practices.

Manufacturers need to understand that it is in their interests to ensure that their end-of-life and metal-containing wastes are processed and subsequently traded through a compliant chain of service providers in order to maximise and optimise recovery efficiencies.

Workers need to understand that (no matter where they are located in the value chain and from which global location they operate), it is their intrinsic human right to be fully insured, fairly paid and to work in and with appropriate, licensed facilities and transportation means. This includes that the required environmental, health and safety (EHS) measures, such as personal protective equipment (PPE), are firmly in place where the concerned activity is conducted.

Workers need freely accessible information that explain potential risks and proper measures to be taken into account.

Awareness-raising campaigns should also include civil society, represented by not-for-profit organisations, to ensure citizens are given the opportunity to put pressure on national decision-makers to increase their efforts to tackle this environmental crime.

The ISO Guidance Principles for the Sustainable Management of Secondary Metals provide directions on sustainability criteria to protect workers and the environment when implementing these practices (IWA 19:2017).

b. Train your workforce on hazardous materials management

As part of the training required for Economic Operators handling wastes containing metals with any (potential) hazardous components or materials, need to know that individuals might be involuntarily or accidentally exposed to danger. Such detailed descriptions should include the exact nature and appearance of concerned wastes, materials or components and the inherent environmental, health and safety risks involved in handling such items as well as the appropriate protection mechanism required.

Therefore, clear instructions must be provided according to the relevant practical technical and, if required, legal reporting formats. Proper training needs to be in place, e.g., in the form of illustrated operational standard procedures and in the relevant local language, to inform workers handling such materials on the safest practices to do so. This would include how to avoid any contamination of non-hazardous fractions, and the mixing of clean materials destined for processing.

Awareness raising of waste-pickers and municipality representatives in Lima (2016) ©WRF

1.5. Health and Safety

Workers engaged in e-waste treatment are exposed to hazardous substances in e-waste through water, air, soil, dust, and food. This exposure can even put lives at risk, especially of those involved in Worst Practices (see chapter 1.4).

Preliminary research on short- and long-term effects of exposure to hazardous e-waste substances shows a correlation with the levels of chemicals and metals in human-derived biological samples. The toxicity of individual substances found in e-waste is well documented, however, the toxicity of mixtures of substances is less clear. Certain population groups, e.g. children, are more vulnerable given the sensitivity of their developing systems. The timing of exposure also may indicate the expected duration of certain resulting health effects of exposure.

According to Atiemo et al. (2016) and Sepúlveda et al. (2010), the burning of e-waste to recover metals releases heavy metals such as lead, mercury, cadmium and others, halogenated compounds, polybrominated diphenyls ethers (PBDEs), and dioxins. Moreover, the uncontrolled manual dismantling of used lead-acid batteries (ULAB) releases nickel, lithium and lead. Health impacts associated to these substances have been of particular interest for occupational health research.

Also, according to Chen et al. (2011), cumulative exposures are predictably high where informal recycling sites have operated for more than a decade. For example, rice and dust samples collected from homes close to e-waste sites had concentrations of lead, cadmium, and copper that were nearly twice the maximum permissible concentrations (Zheng et al. 2013). An exposure of contaminated food such as rice combined with inhaling lead through house dust puts workers and people living close to the areas and especially children at high risk for neurotoxicity and adverse developmental effects (Zheng et al. 2013).

See in Table 1 a more detailed list of chemicals and heavy metals released from e-waste and routes of exposure.

Changes in lung function, thyroid function, hormone expression, birth weight, birth outcomes, childhood growth rates, mental health, cognitive development, cytotoxicity, genotoxity are some adverse health effects of exposure to e-waste.

Also, carcinogenic and endocrine disruption effects are possible which could lead to long-term impacts due to anomalies in the neuro, reproductive and intellectual development, and attention problems.

Significant negative correlations between forced vital capacity, a measure of lung function, and blood chromium concentrations have been reported. This was observed, e.g., in a group of boys aged 8 to 9 years exposed to chromium concentration substances from an e-waste recycling facility in the town they live.

Dismantling e-waste can also directly lead to injury.

On a very basic, human level, attention to the enforcement of treatment measures for those exposed to hazardous e-waste materials is urgent. Monitoring and surveillance, especially of informal e-waste recycling operations, is essential.

Injured child dismantling a compressor (2018) ©WRF

Chemical classification of e-waste components and sources and routes of exposure

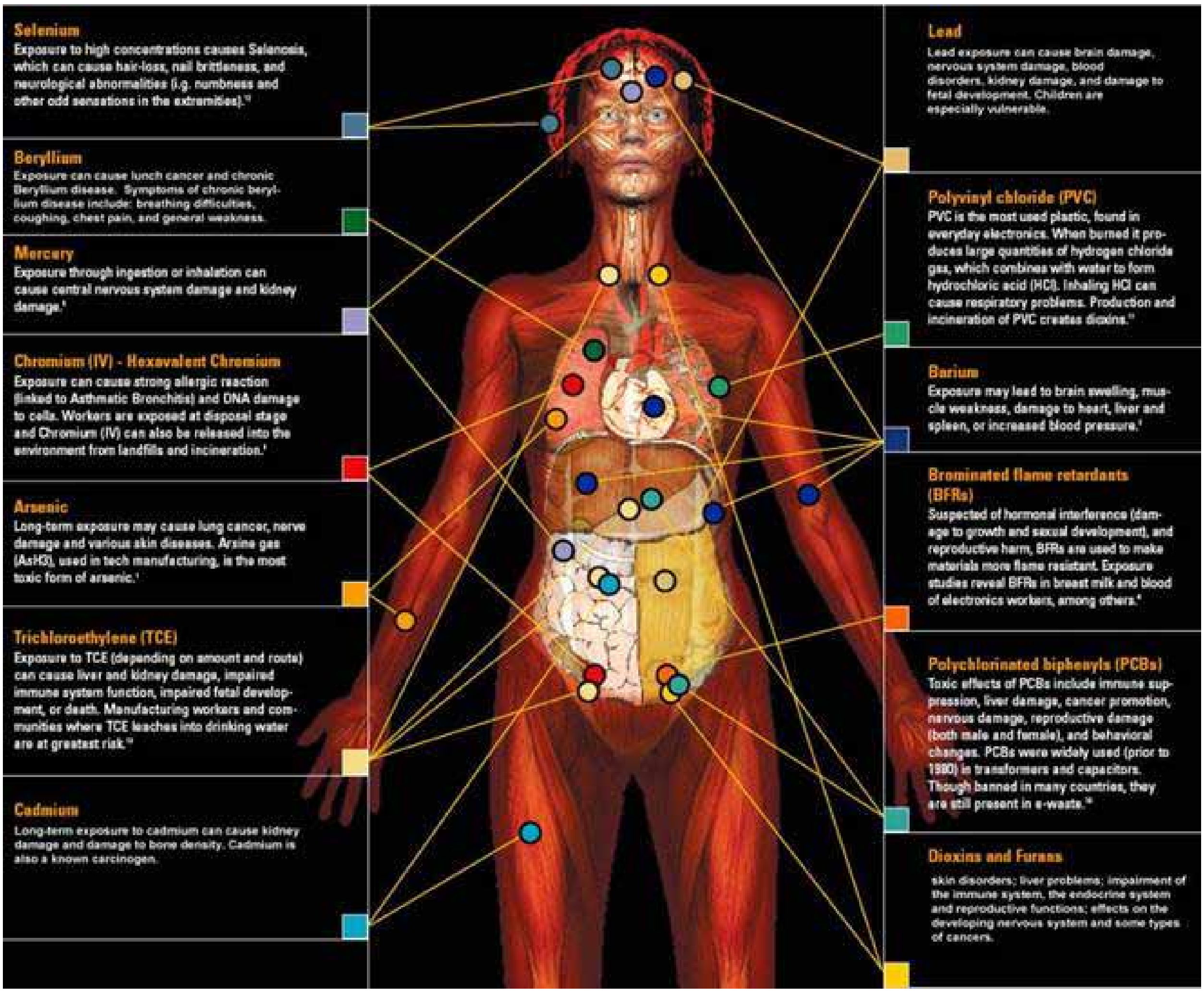
	Component of electrical and electronic equipment	Ecological source of exposure	Route of exposure
Persistent organic pollutants (POPs)			
Brominated flame retardants Polybrominated biphenyls	Fire retardants for electronic equipment	Air, duct, food, water, and soil	Ingestion, inhalation, and transplacental
Polychlorinated biphenyls	Dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lighting, ceiling fans, dishwashers, and electric motors	Air, dust, soil, and food (bio-accumulative in fish and seafood	Ingestion, inhalation or dermal contact, and transplacental
Dioxins			
Polychlorinated dibenzodioxins and dibenzofurans	Released as combustion byproduct	Air, dust, soil, water, and vapour	Ingestion, inhalation, dermal contact, and transplacental
Dioxin-like polychlorinated biphenyls	Dielectric fluids, lubricants and coolants in generators, capacitors and transformers, fluorescent lighting, ceiling fans, dishwashers, and electric motors		
Perfluroalkyls	Perfluroalkyls Fluoropolymers in electronics	Water, food, soil, dust, and air	Ingestion, dermal contact, inhalation, and transplacental
Polyaromatic hydrocarbons			
Acenaphtene, acenaphtylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(e)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(j)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, phenanthrene, and pyrene	Released as combustion byproduct	Release das combustion byproduct, air, dust, soil, and food	Ingestion, inhalation, and dermal contact
Elements			
Lead	Printed circuit boards, cathode ray tubes, light bulbs, televisions (1.5-2.0 kg per monitor), and batteries	Air, dust, water, and soil	Inhalation, ingestion, and dermal contact
Chromium or hexavalent chromium	Anticorrosion coatings, data tapes, and floppy disks	Air, dust, water, and soil	Inhalation and ingestion
Cadmium	Switches, springs, connectors, printed circuit boards, batteries, infrared detectors, semi-conductor chips, ink or toner photocopying machines, cathode ray tubes, and mobile phones	Air, dust, soil, water, and food (especially rice and vegetables)	Ingestion and inhalation
Mercury	Thermostats, sensors, monitors, cells, printed circuit boards, and cold cathode fluorescent lamps (1-2 g per device)	Air, vapour, water, soil, and food (bioaccumulative in fish)	Inhalation, ingestion, and dermal contact
Zinc	Cathode ray tubes, and metal coatings	Air, water, and soil	Ingestion, and inhalation
Nickel	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, dermal contact, and transplacental
Lithium	Batteries	Air, soil, water, and food (plants)	Inhalation, ingestion, and dermal contact
Barium	Cathode ray tubes, and fluorescent lamps	Ingestion, inhalation, and dermal contact	Ingestion, inhalation, and dermal contact
Beryllium	Power supply boxes, computers, x-ray machines, ceramic components of electronics	Air, food, and water	Inhalation, ingestion, and transplacental

Frazzoli et al. 2010

Overview of e-waste chemicals

Chemical	Mode(s) of action	Effects	Reference dose
PCDD/Fs	Significant bioaccumulation related to lipid solubility. Interaction with the AhR	Reproductive and neurobehavioral development Immune development Carcinogenicity	TWI: 14 pg WHO-TEQ/kg_{bw}
PBDEs	Significant bioaccumulation related to lipid solubility. Interaction with thyroid hormones. BFR may activate pathways related to nuclear receptors, as shown by the expression of the CYP isoforms CYP1A1, CYP2B and CYP3A, representing of, respectively, Aryl-Hydrocarbon (AhR, dioxin receptor), Constitutive-Androstane and Pregnane-X receptors	Reproductive development Neurobehavioral development Thyroid function. Hormonal effect levels in animals start from ca 1 mg/kg_{bw}, but effects on spermatogenesis, suggesting hormonal causes, have been observed at a low dose (60µg/kg_{bw}) of the PBDEs' congener BDE-99	TDI: 0,15 µg/ kg_{bw}
PCBs	Significant bioaccumulation related to lipid solubility Congeners with different modes of action: DL PCBs are similar to PCDD/Fs (interaction with AhR), though generally less potent; NDL PCBs show different properties concerning toxicity and persistence: interference with the metabolism of thyroid and estrogens, oxidative stress	Both NDL and DL PCBs may exert a variety of toxicological effects, including carcinogenicity, on multiple targets such as liver, thyroid, immune function, reproduction and neurobehavioral development DL PCB may act as tumor promoters in tissues, such as liver; different congeners may alter different pathways, such as the induction of oxidative stress and/or inhibition of apoptosis	TWI (DL PCBs): 14pg WHO-TEQ/ kgbw
PAHs (high molecular weight)	Genotoxic damage Oxidative stress Interaction with AhR	Carcinogenicity Mutagenicity Teratogenicity	
Al	Interaction with Ca cell-cell communication	Skeletal development and metabolism Neurotoxicity Foetal toxicity	TW1: 1 mg/kg_{bw}
As	Oxidative stress Interaction with glucorticoid receptor	Increased risk of diabetes and of cancer (skin and other tissues)	
Cd	Oxidative stress Interaction with essential elements as Ca and Se Agonist of ERα	Kidney damage. Renal toxicity Bone disease (osteomalacia and osteoporosis) Possibly reproductive damage, and lung emphysema	0,14-0,26 mg per day
Cu	Essential element*, may be toxic at high dose levels	Liver damage	Upper level: 5 mg per day
Cr(VI)	Cytotoxicity Oxidative DNA damage mRNA expressions of StAR, SF-1, 17β-HSD-117β-HSD-2, FSHR, LHR, Erα and ERβ Hypothalamic-pituitary-gonadal axis Oxidative stress	Carcinogenicity Reproductive functions Endocrine function	
Fe	Essential element*, may be toxic at high dose levels	Liver damage	Not established
Hg	Interaction with sulphur aminoacids Cell proliferation/differentiation/communication Interaction with Se Methylmercury can bioaccumulate	Neurobehavioral development of children (especially methylmercury) Anemia Kidney damage Chronic neurotoxicity	
Pb	Interaction with sulphur aminoacids Cell proliferation/differentiation/communication		
Se	Essential element*, may be toxic at supranormal dose levels. Interaction with sulphur aminoacids.	Hair loss Nail brittleness Cardiovascular, renal and neurological abnormalities	300 µg per day
Zn	Essential element*, may be toxic at high dose levels. Impaired Cu metabolism	Increased risk of Cu deficiency (anemia, neuro logical abnormalities)	Upper level: 25 mg per day

* Essentiality or toxicity of chemicals depends on chemical form, oxidation state an d sources and routes of exposure
(Adapted from Frazzoli et al. 2010)



Atiemo, A. et al. (2016). Baseline Assessment on E-waste Management in Ghana. Sustainable Recycling Industries. Accra/Ghana. Retrieved May 24, 2018, from sustainable-recycling.org/sampson_2016_sri-ghana/

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1.6. Legal Aspects

Extended Producer Responsibilities (EPR)

Early experiences in industrialized countries have shown that the average municipality is not adequately equipped and staffed in order to handle a complex waste stream such as WEEE. As a result, new approaches to ensure the responsible handling of such wastes had to be considered. Under the concept of Extended Producer Responsibility (EPR), producers accepted the end of life responsibility for their products. They initiated take back schemes either individually or collectively as part of a group of producers or as part of national oriented producer responsible organizations (PROs) to manage the material flows and the financing of unprofitable processing steps. National authorities started to address this concept in their waste regulations as well.

EPR is an environmental management strategy guided by the principle that "whoever designs, produces, sells, or uses a product takes responsibility for minimizing that product's environmental impact". Typically, key stakeholders along the entire lifecycle and value chain of a product are working together to ensure that it is taken care of environmentally responsibly in each distinct lifetime phase namely:

- Pre-consumer - prior to its use
- Consumer - during its use
- Post-consumer - after its useful lifetime

In most globally applied EPR systems, the product's manufacturer, distributor or brand owner takes on the challenge of developing a plan and implementing a program to collect and recycle (either themselves or via an agency [1]) their products once they reach end-of-life.

Producers can also choose to appoint an agency to carry out their duties under the plan. In addition, producers must report on the program's performance and consider the design of their products, making them easier to recycle.

While the detailed set-up of the chosen EPR system differs vastly between countries, the table on the next page outlines some of the generic key responsibilities that should be ideally assigned (as a minimum) to stakeholders of any EPR system.

1 Such an agency is mostly called a Producer Responsible Organisation (PRO) but might also have other names such a Product Stewardship Council or Product Care Association

STAKEHOLDERS AND THEIR KEY ROLES AND RESPONSIBILITIES IN AN EPR SYSTEM				
Stakeholder Type:	PRODUCER	GOVERNMENT	RETAILER	CONSUMER
Required Elements in the EPR System				
LEGISLATIVE	Register with regulators as an EPR obligated party	Develop legislation that is built on Producer EPR, Retailer "Take-Back" and Consumer "Bring-Back" obligation	Obligation to "Take-Back" waste of the same type of product that is sold.	Obligation to "Bring Back" to any designated collection point (e.g. retailer, Municipal Drop Off)
	Report back to government on achievement of set EPR programme targets (as specified in the plan)	Where/when stakeholders in Producer EPR system as set out in the plan are not delivering the required results – utilise power of legal incentives or legal enforcement	Report back to Producer on sales of new product, volumes of end-of life product received via customers	
OPERATIONAL	Facilitate and/or finance collection and recycling of waste under EPR obligation	Create enabling environment for Producer to optimally fulfil the EPR obligation	May collect recycling fees at the point of purchase on behalf of the Producers	
INFORMATION-BASED	Inform/educate the public about the program and its achievements	Monitor the efficiency of the Producer run EPR scheme	May provide consumers with information – e.g EH&S features of the product, deposits required on purchase, refunds available	

Summary of Stakeholders and their generic roles and responsibilities

Global Development

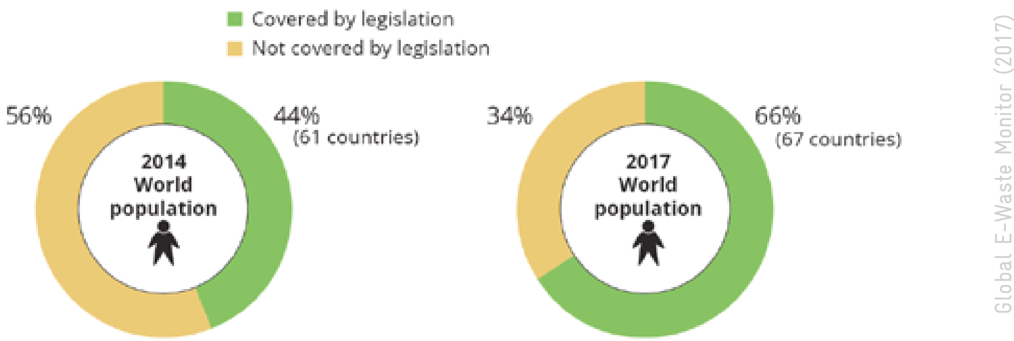
Formal WEEE management systems adhering to sustainability and extended producer responsibility principles were started around 25 years ago mainly in Europe. The European WEEE Directive [1] has set the global pace and standard in regulating WEEE management Figure 1 (next page). A sister directive with the WEEE is the RoHS Directive [2], which aims at reducing the environmental impact of EEE, by prohibiting certain types (and/or limit quantities) of specified hazardous material in defined products.

While the WEEE Directive aims at ensuring that measures for the responsible "end-of-pipe" treatment solution for WEEE is in place, the RoHS Directive clearly targets design improvements at the beginning of the EEE life cycle.

Both directives had to be transposed and therefore reformulated into national laws of European countries which enabled law-makers to accommodate national peculiarities but in turn increased the complexity for global producers to cope with dozens of deviations in the implemented procedures throughout the EU. Several European countries had started to implement WEEE management policies before the EU WEEE Directive came into force. One of the oldest legislative frameworks is the Swiss "Ordinance on the return, the taking back and the disposal of electrical and electronic appliances" (ORDEA). Its principles of defining stakeholders' obligation are presented in Figure 2 (next page).

In the US, 23 states have enacted some form of electronics recycling legislation. For example, some of these state laws established an electronics collection and recycling program and a mechanism for funding the cost of recycling under the EPR principle. Like in the USA, also in Canada and Australia the implementation of EPR mechanisms is voluntary by the industries, and is more precisely known as extended product responsibility to emphasize that the responsibility is shared for a product – the producer is not the only responsible party but also the packaging manufacturer, the consumer and the retailer. It is thought that the biggest challenge for USA, Canada and Australia is legislation and compliance, as current take-back initiatives have either come in late or are not comprehensive enough. Probably the biggest issue is that the current take back systems do not have a comprehensive product view and often only cover a few products. A more recent approach in Canada is to shift away from EPR to IPR (as for Individual Producer Responsibility) - where companies seek to provide municipalities (rather than on national government level) with a more hands-on support e.g. to facilitate the collection and recycling of WEEE in communities.

In recent years WEEE regulations based on EPR have also been established in a range of developing countries. The status of this development is changing continuously. Since 2011 a few African and Latin American countries have taken up EPR as a core principle in national WEEE legislation.



World Population (and number of countries) covered by e-waste legislation in 2014 and 2017

1 European Union, "EU Directive 2002/96/EC of the European Parliament and of the council of 27 January 2003 on waste electrical and electronic equipment (WEEE)." (2003).

2 European Union, "EU directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS)." (2003).

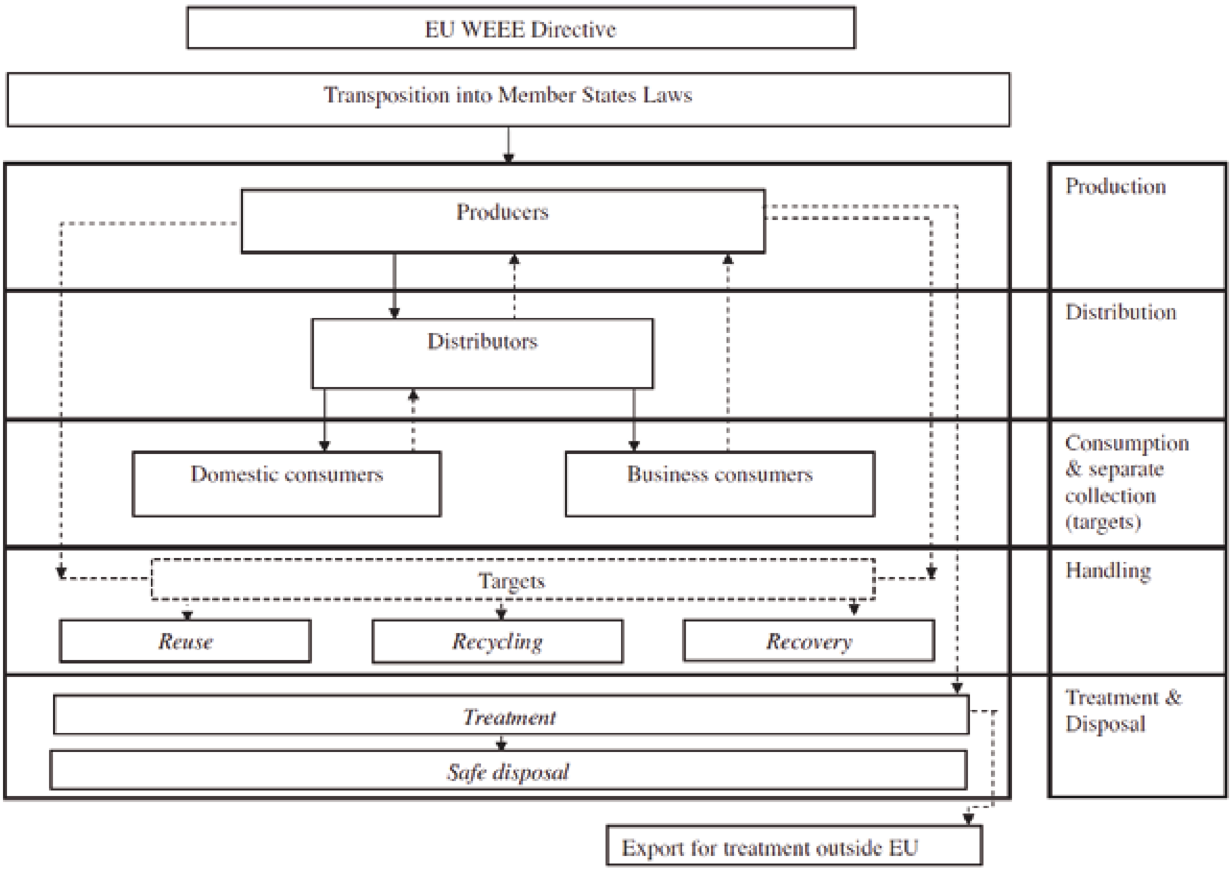


Figure 1: Simplified overview of the European WEEE Directive

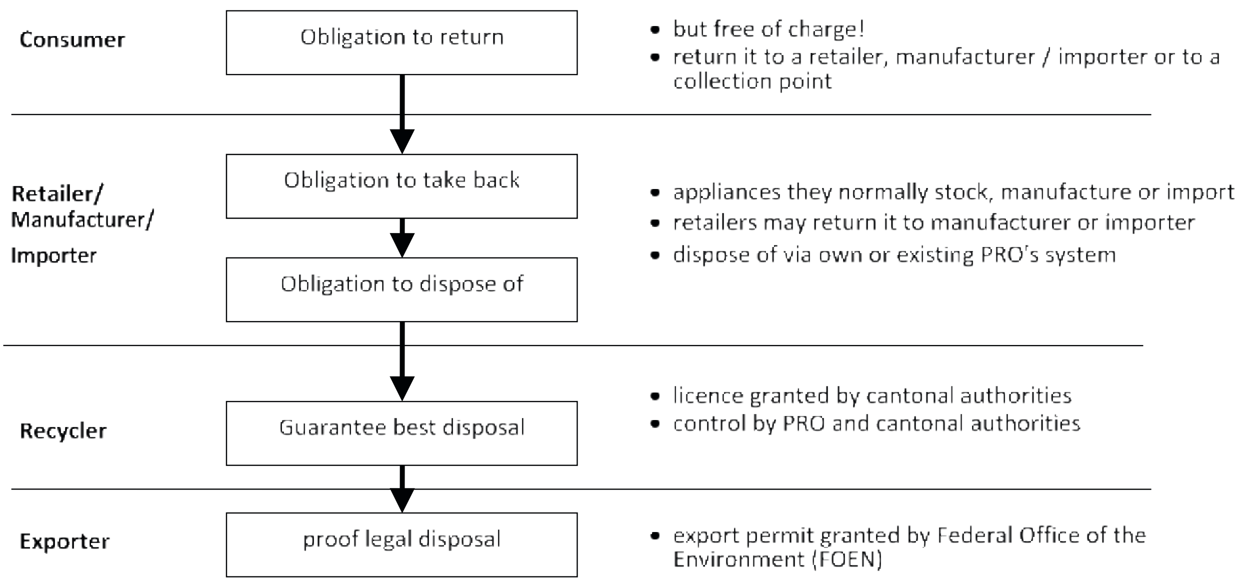


Figure 2: Schematic explaining the various stakeholders' obligations according to the Swiss WEEE legislation ORDEA

Internationally Binding Legislation

Apart from country-specific e-waste legislations, there are also some international legal agreements in form of "conventions" which also Ghana is a signatory of and which are related to the safe trading and handling of all materials contained in e-waste.

The Basel Convention

The overarching objective of the Basel Convention is to protect human health and the environment against the adverse effects of all types of hazardous wastes which also includes any e-waste (unless the latter is depolluted).
The key aims and provisions of the Basel Convention include:

- the reduction of hazardous waste generation and the promotion of environmentally sound management of hazardous wastes, wherever the place of disposal;
- the restriction of transboundary movements of hazardous wastes except where it is perceived to be in accordance with the principles of environmentally sound management; and
- a regulatory system applying to cases where transboundary movements are permissible.

The Bamako Convention

The Bamako Convention bans the import of any type of hazardous waste into Africa and further demands a tight and restriction-oriented control of transboundary movement and management of hazardous wastes within Africa. Bamako Convention ratified countries declare untested or non-functional electronic equipment to be a "hazardous waste". Ghana has not ratified the Bamako Convention but indicated in 2017 via an email from the Ghana EPA to the Basel Action Network (BAN) "that it is in the process to do so and that it already conforms to its rules".

1.7. Ghana Context

Development

Ghana has been in the news for its informal treatment of e-waste and related adverse effects on humans and the environment since a decade. One of the first reports published was "Poisoning the poor - Electronic waste in Ghana" from Greenpeace in 2008. Since then Ghana has drawn the attention of the public and policy makers on international and national Ghanaian levels. Various international development cooperation projects were launched with the aim to improve the situation, among others the Basel Convention e-waste Africa project, the German funded Best of two Worlds projects, activities funded by the Nordic Fund and Pure Earth and the Swiss-funded Sustainable Recycling Industries (SRI) programme. All these activities have led to advances in Ghana in various areas related to the e-waste issues, including a sound basis for understanding the baseline conditions, the launch of a (lose) national stakeholder group, a national e-waste strategy, (technical) capacity building with formal and some informal players, the introduction of recycling standards and the introduction of an e-waste bill. Over the years more formal recyclers appeared, while the informal sector seems to have grown at the same time as well. The latest overview of this development and a good summary about available e-waste reports and studies can be found in the 2016 SRI report "Baseline Assessment on E-waste Management in Ghana" [1]. The main steps of this development are summarized in the table below.

Year	Main activities and results
2008	Greenpeace study "Poisoning the poor - Electronic waste in Ghana"
2009 - 2011	Basel Convention e-waste Africa project with the launch of various baseline studies and a national e-waste strategy (Empa, Öko-Institut, Basel Convention Regional Center Nigeria)
2010	First registered formal e-waste recycler in Ghana starts operations
2013	First draft of a "Hazardous and Electronic Waste Control Bill"
2012 - 2015	Best of two worlds project (Öko-Institut)
2015	Launch of the Sustainable Recycling Industries project (WRF, Empa, Öko-Institut, Sofies)
2016	Adoption of the Hazardous and Electronic Waste Control and Management Act (Act 917)
2017	Start of the German Technical Cooperation (GIZ) e-waste Ghana project
2018	Mandatory Technical Guidelines on Environmentally Sound E-waste Management in Ghana
2018	Intensive and trustful co-operation on business model development and informal sector support by GIZ e-waste Ghana project

Main activities and results related to the e-waste issue in Ghana.

1 Atiemo et al. (2016), Baseline Assessment on E-waste Management in Ghana. Sustainable Recycling Industries. Accra/Ghana. https://sustainable-recycling.org/sampson_2016_sri-ghana/

Development

The past comprehensive inventory of e-waste volumes in Ghana has been done almost ten years ago under the Basel Convention e-waste Africa project [2,3]. Although these numbers are almost ten years old they still reflect the correct order of magnitude for Ghana. It can be assumed that numbers are higher today. The EEE imports into Ghana in 2009 added up to 215,000 tons and a per capita import of 9 kg. About 30% comprised of new products and 70% second hand EEE. Around 15% of the second-hand imports were estimated to be unsellable (i.e. would not respond to power, broken or outdated), a significant portion of which was destined directly to informal recycling. Another 20% of the imports can be serviced (repaired/refurbished) to get them functioning. Due to high amounts of second-hand imports, Ghana has a high availability of second hand EEE that can be purchased at comparatively low prices. This makes these products available for a larger share of the population, compared to other countries, and gives many Ghanaians the possibility to benefit from EEE in their everyday life. On the other hand, second hand products have a shorter lifespan compared to new products, which leads to a higher e-waste generation per year. The equipment that arrives already in broken condition is added to the internally generated WEEE and thus again increases the large amount of e-waste generated. A comparison of these numbers with other West African countries can be seen in the following table:

Country	Year	Imports of EEE		EEE in use		E-waste generated	
		tonnes/ year	thereof used EEE	tonnes	kg/inhabitant	tonnes/ year	Thereof collected
Benin	2009	16,000	30%	55,000	6.32	9,700	N/A
Côte d'Ivoire	2009	25,000	48%	100,000	4.8	15,000	N/A
Ghana	2009	215,000	70%	984,000	41.0	179,000	172,000
Liberia	2009	3,500	10%	17,000	4.6	N/A	N/A
Nigeria	2010	1,200,000	35-70%	6,800,000	44.0	1,100,000	N/A

Quantitative data for imports, EEE in use and e-waste generated in West African countries in 2009 [2].

2 Secretariat of the Basel Convention, "Where are WEee in Africa? Findings from the Basel Convention e-Waste Africa Programme," Geneva / Switzerland, (2011).

3 Y. Amoyaw-Osei, O. O. Agyekum, J. A. Pwamang, E. Mueller, R. Fasko, and M. Schluep, "Ghana e-Waste Country Assessment", Green Advocacy, Ghana & Empa, Switzerland, Accra, Ghana, (2011).

Key challenges

Despite all activities and achievements over the past decade many key challenges remain, among others:

- Although the Act 917 has been adopted, challenges for its implementation lie ahead and are currently unclear. In particular, Act 917 represents a framework legislation that needs to be complemented by specific implementing regulations in order to make it operational. By today, one implementing regulation (L.I. 2250, 2016) and one Technical Guideline have been passed, while fund management procedures and issues around lawful use of the envisaged e-waste fund are still widely undefined.
- At the same time, the level of the levies foreseen for this e-waste fund are defined by Act 917 and it is unclear whether the current levels reflect the true costs of sound collection and treatment of the various e-waste types. Informal recycling activities, mainly practiced at the Old Fadama scrap yard (better known as Agbogbloshie), are still ongoing and in fact seem to have grown over the last decade. This includes processes with adverse effects for humans and the environment, such as open burning of cables. These activities are also related to general social issues, such as informality per se and the use of child labor for certain activities.
- Although many new formal recyclers have appeared, most of them are not fully compliant with legal standards. Their processes are often technically not optimized due to the lack of knowledge and access to required infrastructure and technology. In addition to that, economic viable options for connecting to downstream markets are not available for all e-waste fractions.
- In addition, formal recyclers need to compete with the informal sector, who externalize many costs through unsound processes and hence get an unfair advantage when accessing waste materials by being able to pay higher prices. Therefore, formal recyclers cannot access enough volumes to justify investments for more efficient and professionalized operations.
- To improve this situation formal and informal economic operators would need to cooperate, which is either not established or happening in an unsound, and not transparent way in some cases, e.g., by also involving third party middle men who create the link to the actual e-waste collection sources. Such cooperation would also demand for strategies to improve the situation of the most vulnerable individuals and to formalize activities in the long term. Such strategies are currently not in place.

1.8. National Legislation

Overview

In August 2016 the Ghanaian Parliament has passed the Hazardous and Electronic Waste Control and Management Act, which is a major backbone and reference point for all regulatory developments and e-waste related initiatives of the last three years. Since then one implementing regulation (L.I. 2250, 2016) and one Technical Guideline have been passed. Hence as of today the national legislation with respect to e-waste is comprised of three key documents:

- Hazardous and Electronic Waste Control and Management Act 2016 (Act 917)
- Hazardous, Electronic and other Wastes (Classification), Control and Management Regulations, 2016 (L.I. 2250)
- Technical Guidelines on Environmentally Sound E-waste Management in Ghana

Act 917

The Hazardous and Electronic Waste Control and Management Act (here referred to as Act 917) consists of 2 parts: Part one on the "control and management of hazardous wastes and other wastes" and part two on "electrical and electronic waste".

Part one translates the provisions of the Basel Convention into national law. This means that hazardous waste may only be imported into Ghana or exported from Ghana when following the "prior-informed-consent procedure" of the Basel Convention. Transboundary movements of hazardous waste not in-line with these procedures are illegal. The First Schedule also entails categories of wastes to be controlled with Part 1 of this Act. As the list is identical with Annex I of the Basel Convention, Ghana's definition of hazardous waste is in-line with international consent.

Part two of Act 917 specifically addresses the management of electrical and electronic waste. Main elements of this part are provisions to collect an "electrical and electronic waste levy" (also referred to as "advanced eco levy") from manufacturers and importers of new and used EEE. The levy is destined to go into an "Electrical and Electronic Waste Management Fund" with the objective "to provide finance for the management of electrical and electronic waste and reduce the adverse impacts of electrical and electronic waste on human health and the environment".

L.I. 2250

The Legislative Instrument 2250 on Hazardous, electronic and other wastes (classification) control and management regulations (commonly referred to as L.I. 2250) was passed by the Parliament in 2016 and provides various specifications for Act 917. According to Article 1 the purpose of L.I. 2250 is to:

a) regulate the classification, control and management of waste;

b) establish a mechanism and procedure for the listing of waste management activities that do not require a Waste Management Permit;

c) prescribe requirements for the establishment of take-back systems;

d) prescribe requirements and timeframes for the management of wastes listed in the First Schedule;

e) prescribe general duties of waste generators, waste transporters and waste managers; and

f) prescribe requirements for the disposal of wastes.

Technical Guidelines

The Technical Guidelines contain principles and specific management requirements for collection, transport, storage and recycling of e-waste. The requirements are widely derived from acknowledged international standards (e.g. CENELEC). Though, a major difference between the Technical Guidelines and international standards is the Ghanaian approach of introducing 5 level of tiers.

The background of this tier-approach is the policy intention that all operators involved in waste and e-waste management shall be registered, even if they engage in small-scale and currently still informal activities such as collection.

Comment on the figure below: the different tiers should conform with the activities listed. Also, there is no collection volume limitation with respect to tier 1 and we are yet to set same for tier 2.

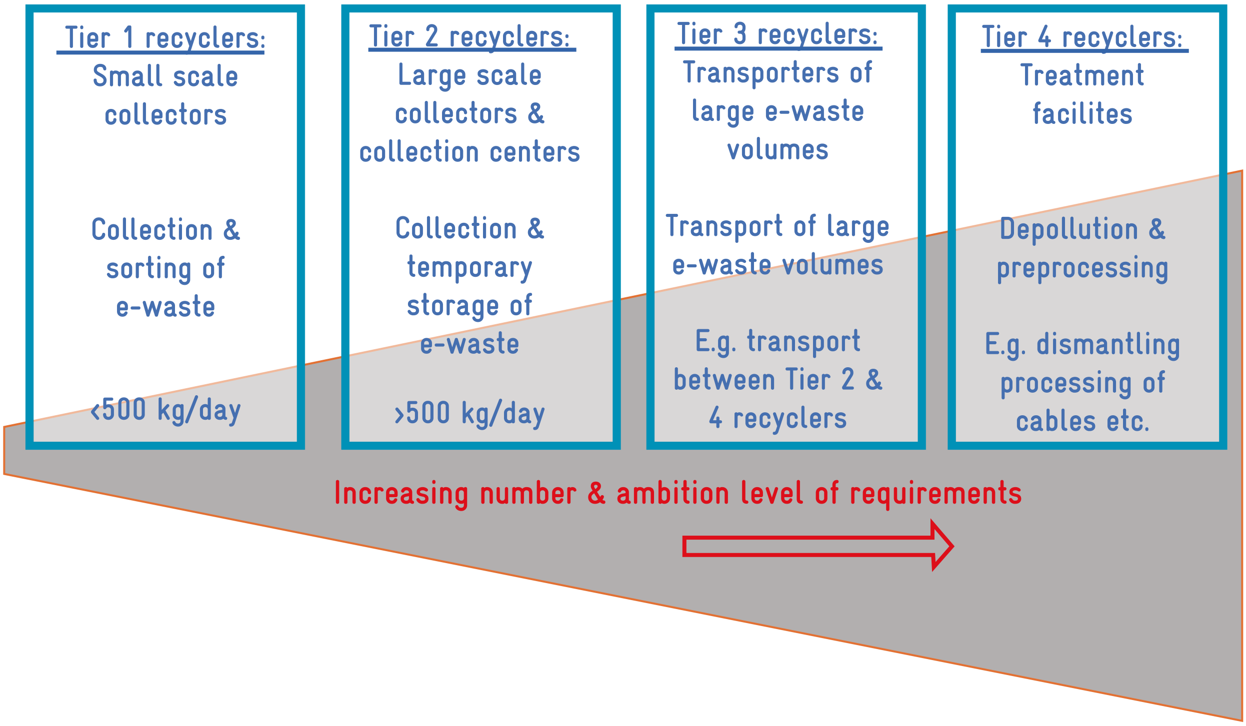


Illustration of the tier-approach taken by the Technical Guidelines

The Technical Guidelines by the Environmental Protection Agency serve as a quick reference material for proponents or persons interested in the management of e-waste in Ghana. They also provide regulatory requirements for registering and monitoring an activity within the value chain.

The Technical Guidelines address specific requirements for activities within the tiered system of the e-waste value chain. They refer to five specific e-waste activities (tier) namely:

a) Collectors (Tier 1)

b) Collection centers (Tier 2)

c) Transporters (Tier 3)

d) Treatment facilities (Tier 4) and

e) Final disposal (Tier 5)

Collectors (Tier 1)

A person registered by the Agency and the relevant MMDAs within the locality in which they operate is required to adhere to strict permit conditions including the following;

a) The collection and storage location should be adequately protected against unauthorized entry and theft.

b) Provide appropriate training to all staff including standards on health and safety and the use of appropriate personal protective equipment (PPE)

c) Materials management in order to prevent release of pollution to the external environment.

The regulatory approach for this activity (Tier 1) is for persons registered as collectors to have all their collectors/staff registered and easily identified by the public, generators of e-waste such as households and commercial entities. They are also allowed to operate small collection or aggregation points for onward transport to registered and permitted collection centers (Tier 2).

Collection Centers (Tier 2)

The collection centers are to serve as the receiving points or buy-back centers for the small collectors (Tier 1). The Agency will permit collection centers to operate satellite centers in order to be closer to and reduce the transport distance from collectors (Tier 1). The collection center is also required to adhere to facility management standards as prescribed in the permit conditions. These conditions include security of the facility, training of staff, materials management and data management or record keeping. In an effort to streamline the e-waste activity landscape the guidelines have proposed a prototype collection center to ensure equal regulatory requirements and enforcement.

Transporters (Tier 3)

The transport of e-waste is permitted for an entity to transport e-waste from a collection point to a recycler, between collection centers (from a collector to collector), or from a recycler to a recycler (between treatment facilities). This service can be permitted to an independent entity who is not permitted to collect, dismantle, recycle/treat or dispose of e-waste.

Dismantling/Treatment Facilities (Tier 4)

The treatment of e-waste is considered to include activities such as dismantling, recycling, and recovering of electrical and electronic waste (e-waste). The national e-waste recycling plant will play a critical role in the management of e-waste in Ghana. The recycling of hazardous fractions is planned to be undertaken mainly by the national e-waste recycling plant. Other activities including dismantling are to feed most of their e-waste materials to the national plant.

The setup for the dismantling facility is expected to conform to the requirements of the collection center where the prototype facility could be adopted. It is the plan of the Agency to formalize the informal collection and dismantling activities in Ghana through collaboration with our development partners. It is important that the activity of the dismantler should ensure that the process follows health, safety, as well as record or data management standards. Also, non-recyclable and non-recoverable e-waste materials are sent to an authorized or permitted treatment, storage and disposal facility.

Final Disposal (Tier 5)

This tier refers to the management of landfill and incineration sites and is therefore not of relevance to manual dismantlers.

1.9. Current Practices at Old Fadama Scrap Yard

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Agbogbloshie (Old Fadama) is a district of Accra. Within the last twenty years, the area of Agbogbloshie has changed into a large scrap yard where mainly electronic waste and scrap metals are processed and dismantled by informal workers.

An estimated 1,500 dismantlers and 4,000-5,000 collectors operate in the Old Fadama scrap yard. At the Old Fadama scrap yard 27% of the workers are women all of whom provide auxiliary services in the e-waste management value chain. More than half of the workers at the Old Fadama scrap yard are younger than 25 years.

Over 90 percent of workers at the scrapyard belong to the ethnic groups that are typically located in northern Ghana, with the Dagomba ethnic group forming about 60 percent of the population.

With little or no formal education, over 95% of the workers learned their trade through apprenticeships (informal vocational training) or natural talent.

Moreover, a little over a tenth of the workers at Old Fadama perceive themselves to have high/expert level of knowledge (more than 10 years' experience) in informal e-waste processing while half (53%) of the workers ranked themselves as novices (or least skillful) in e-waste processing. This can be partly attributed to the lack of skill improvement centers in the scrap yards, long distance to known training centers and other opportunity costs. This suggests that the perceived need for skill improvement training is high in the scrap yard. Despite the apparent need for skill improvement training, a few (2%) of the workers ever participated in any skill improvement training.

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The average monthly income of workers at the Old Fadama scrap yard is GHS 820 or US$ 182. The largest part (43%) of their income comes from e-waste dealing (buying and selling).

Most of the workers in Old Fadama live in rented buildings made of wood. Among TV owners, 71-80% of them owned CRT TVs, which suggests they are either among low-income earners or that they prefer those TVs.

In addition, less than 1-in-100 workers in Old Fadama have adequate knowledge of the effects of their e-waste management activities on the environment. However, more than half (65%) of the workers have knowledge of the negative impact of e-waste on their health. They often cite body pains, tiredness, headaches and fever as the symptoms e-waste activities effect on their health.

It is important to mention that there are other interest groups such as women and truck drivers who work in the scrap yard but are not members of Greater Accra Scrap Dealers Association (GASDA).

A Material Flow Analysis shows that the work at Agbogbloshie consists only about to one quarter of e-waste processing. The main mass flows represent scrap metals rom cars, construction sites, households etc. Workers mainly extract iron, aluminium, copper and brass. Also, printed circuit boards (PCBs) of the e-waste are important collected fractions.

Recycling efficiency is low due to a lack of knowledge in valuable materials and improper methods of separation. From the 76,016 tons of all waste brought to Agbogbloshie every year only about 17,100 tons account for e-waste. Most of the e-waste consists of devices brought from households in the Greater Accra Region.

© GIZ

Also, used oil from cars, transformers and engines is exported to local industry for example for production of tar or for usage as a fuel in the metal industry.

The scrapyard of Agbogbloshie processes approximately 17,100 tons of e-waste every year. Ghana's annual e-waste generation is 39,000 tons per year (Baldé, C.P., 2017). According to research, around 44% of Ghana's e-waste is processed at the scrapyard of Agbogbloshie.

Almost all devices are bought and dismantled by the scrap dealers and dismantlers in Agbogbloshie. Dismantling takes place in so called shops. Each shop owner employs about 3 to 10 dismantling workers. For the dismantling process usually hammer and chisel are used. Screw drivers are used rarely.

There are about 50 different processes taking place at the scrapyard. Around 70 % of them are dismantling processes, 15 % are repair and production processes and 15 % consist of burning, collection, import and export processes. There is a vibrant repair where materials come in to the scrap yard and leave the scrap yard transformed. Agbogbloshie is an innovation development ban for the north. Innovative ideas are developed at the scrap yard and transferred to the north. It is also a resource center for further resource development and resource mining. The production of aluminum pots and coal pots are some examples of the production processes happening at the scrap yard.

Processes in Agbogbloshie are primarily dismantling processes to recover FE-metals, aluminium, copper, brass and PCBs. E-waste is a source of copper, brass and PCBs. The burning of copper cables and car parts, which also contain copper, is a main process. Another main process is the collection of used oil from cars, transformers and other devices. The oil is partly mixed with water and detergent for selling to local manufacturing companies as a fuel. However, oil from dismantled devices like fridge compressors is usually poured away instead of collecting properly and selling to the oil collectors on the yard.

Dismantling of electronic devices containing PCBs has shown that the workers separate valuable boards from invaluable boards. However, removing of higher valuable fractions, such as processors from boards, does not take place.

Machines for shredding of cables have been provided at Agbogbloshie by other institutions but workers are not using them due to maintenance reasons and time efficiency.

Sources:
1 Aladago, D. et. al. Informal sector baseline report – environmentally sound disposal & recycling of e-waste in Ghana. GIZ, (2018).
2 Owusu-Sekyere, K., Batteiger, A. Improving the e-waste management conditions in Agbogbloshie through a material flow analysis, ISWA, (2017).

1.10. The Maker Movement

Creating Communal Knowledge and Skill Sharing Platforms

The maker movement is a global culture promoting openness and sharing of both resources and knowledge.

What is a Makerspace/station?

A Makerspace/station is a fixed collaborative work space typically inside a school, library or separate public/private facility for making, learning, exploring and sharing that uses high-tech to no tech tools.

These spaces are open to kids, adults, and entrepreneurs and have a variety of maker equipment including 3D printers, laser cutters, CnC machines, soldering irons and even sewing machines [1]. However, they do not need to include all of these machines or even any of them to be considered a Makerspace/station.

Most importantly, Makerspaces/stations are fostering entrepreneurship and are being utilized as incubators and accelerators for business start-ups. With all the existing artisanal skills and experience that can be found in the informal sector it is no surprise that there is also a very active movement in Ghana with two establishments standing out namely the

- Kumasi Hive (www.kumasihive.com) as well as
- AMP Spacecraft (https://qamp.net/)

The Kumasi Hive is set up as a typical Makerspace and offers dedicated academic oriented software and hardware based training programmes next to more specialised training themes including introduction to robotics and the use of special equipment (3D printers) as well as alternative virtual currencies (cryptocurrencies) and financial flow models (blockchain) [2].

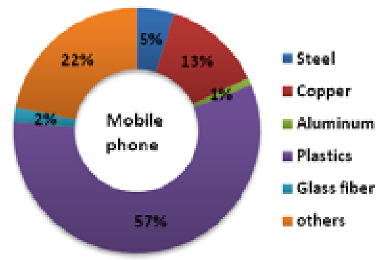
The AMP Spacecraft initiative is based at Agbogbloshie and promotes the idea of "crafting the space" required for a desired activity (e.g. for doing repairs or product design) rather than expecting that one is readily available for people needing it. The website notes that "whereas makerspaces are community labs or workshops fixed in place the AMP activity areas are not". Therefore, the modular designed Spacecrafts rather grow and replicate "organically", based on need and/or expertise found in certain places. The AMP Spacecraft movement is therefore very grassroot oriented and this is also reflected in the shared "Makers and Development" knowledge library which offers detailed, locally relevant information on proper WEEE handling for informal workers with the help of simple A4 fold-up education sheets as shown on the next page [3].

Interestingly the term "EEE" or "3E" is preferred by AMP instead of "WEEE" (Waste Electrical or Electronic Equipment) or e-waste, to point out that "scrap" is not "waste" (as much as Agbogbloshie is a scrap yard and not a dump site), but rather equipment that does currently not work (yet) but may still be repairable, have salvageable parts or components and/or include recyclable and marketable materials - next to valueless and/or hazardous ones, that need obviously to be handled and disposed of properly.

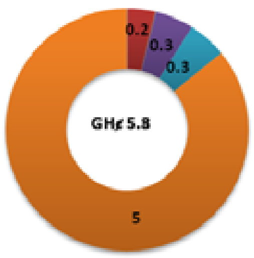
1 https://www.makerspaces.com/what-is-a-makerspace/
2 http://kumasihive.com/academy/
3 https://qamp.net/library/

Education sheet by AMP Spacecraft describing the dismantling of mobile phones

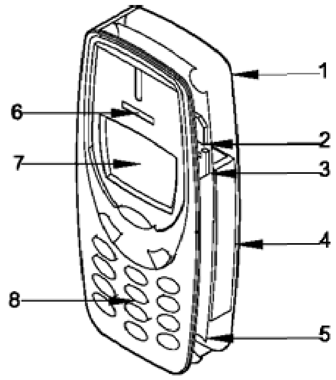
Material Composition



Scrap Value In Agbogbloshie



Mobile Phones



1.Back Cover	5. Micro Processor
2. Power IC	6. Earpiece
3. Battery	7. LCD Display(screen)
4. Circuit board	8. Keypad

Mobile Phone Overview

Common Brands:
Apple, Blackberry, HTC, LG, Nokia, Motorola, Samsung, Sony Ericsson

Hazardous Material:
Beryllium (Be), brominated flame retardants (BFRs), cadmium (Cd), chlorine (Cl), lead (Pb), lithium (Li), mercury (Hg)

Key components/Parts:
Battery, circuit board, and display screen.

Primary Materials:
Aluminium (Al), copper (Cu), glass, Iron (Fe), plastics

Types:
Cell phone, iPhone, Smartphone

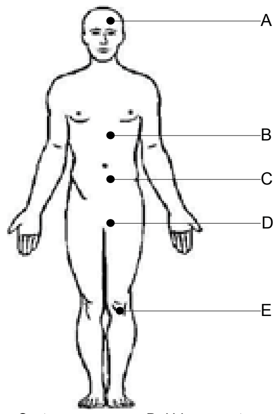
Weight Composition:
1% Al, 13% Cu, 2% glass, 57% plastic, 5% steel [1]

⚠ **Mobile phones have several tiny components that should be handled with care during disassembly, to avoid swalloing and other related risks.**

Urban Mining

Urban mining presents an opportunity to reclaim and recycle precious metals and REEs that are used in prolific consumer and communication goods. One ton of gold ore yields about 5 grams of gold, but one ton of phone circuitry yields about 150 grams, 30 times as much..[REFEE] A phone circuit board (CB) contains precious metals: Gold (Au) and silver (Ag) which can be recovered. Copper (Cu), brass and other valuable metals can also be recovered. All the precious metals can be sold for good value. The circuit board (CB) can be reused and the recovered of gold (Au) can be sold.

Health Hazards



A. Nervous System	D. Urinary system
B. Respiratory system	E. Reproductive system
C. Immune system	F. Bone

Health

Beryllium (Be) - Pneumonia, lung damage, increased cancer risk and DNA damage. **Cadmium (Cd)** - Psychological disorder, cancer, liver & kidney damage. sperm damage, birth defects and headaches.Mercury (Hg) - Brain and DNA damage, disruption of nervous system, sperm damage, birth defects, skin rashes and headaches.

Safety Gear

The disassembly process exposes the worker to various levels of potential harm. There is a need for protective gear to reduce impact of these practises. Safety gear include gas masks to protect e-waste workers from dust and toxic gases, safety boots, hand gloves and mostly HazMat suits, which are full garments with footwear and masks, worn to protect workers from dangerous chemicals.

Tools For Disassembly

The main tool needed in disassembling a mobile phone is a screwdriver. The steps involved in taking the parts include:

Screw driver

Tools are essential to the process of disassembly and are the primary means by which industrial activities are carried out. Tools have always represented societal advancement. The lack of proper tooling is a major hindrance to the industrialisation drive. In this case, knowlegde of how to use them and make them represents a major cultural breakthrough.

⚠ **Tools are a potential source of injury. The risk can drastically be minimised by using the right tool for the right job. In addition, all requirements of the tool as provided in various manuals should be adhered to strictkly**

Step by Step Disassembly

1. Open the back cover and take out the battery. Note that, the battery must be treated with care and specially disposed.

2. Carefully peel off the screen.

3. Loosen all the screws at the back of the phone to get access to the circuit board (CB).

4. The CB consists of different metal like Ag, Au, Cu and brass. These metals should be carefully removed by hand, separating the precious metals from the other parts for sale or reuse.

⚠ The special attention given to the battery is because it contains toxic substances like cadmium (Cd), nickel (Ni) and lithium (Li). These are highly toxic. Incineration of phone batteries should be avoided at all cost, as this is also unsafe.

Circuit Borad

Screen

Camera

Switch

Front Cover

The "Right to Repair"

A key objective of the maker movement is to fight for local government legislation that grants any consumer the right to repair or modify or upgrade his/her own electronic devices without any limitation or producer imposed "penalties" (e.g. in form of warranty loss). Global organisations such as Ifixit [4] go to great length to provide the public with so called "teardown" instruction manuals and even videos that can assist anyone to conduct repairs using step-by-step instructions on how to dismantle and replace required components as part of the repair process. The internationally applicable "Repair Manifesto" summarizes the conditions needed and demanded to ensure the "right to repair" is enabled.

Source: www.ifixit.com

4 www.ifixit.com

2.

Manual Dismantling

2.1. Introduction to Manual Dismantling

Safe and environmental sound e-waste recycling requires certain pre-treatment steps, where components containing hazardous substances are removed and recyclable materials are separated into fractions, from which secondary raw materials can be re co-vered.

Manual dismantling is the pre-treatment technique that ensures best proper depollution of equipment and leads to the highest recovery rates in the subsequent recycling and recovery steps. Dismantling of WEEE usually comprises the following main dismantling steps:

1. Opening of the appliance (separation of the housing from the rest of the appliance)
2. Localization, identification and removal of hazardous components
3. Dismantling and separation of the remaining components into marketable fractions

In the following sub-chapters 2.2. – 2.9. detailed step-by-step guides provide instructions for proper manual dismantling of selected items.

Tools

For the process of manual dismantling only hand-tools are required. This includes a set of screw drivers, a hammer and pliers. A detailed list of the specifications for the tools can be found in the Annex.

Tools for manual dismantling

Personal protective equipment

It is required to wear personal protectiven equipment during manual dismantling.

Robust gloves

protect the labourer from cutting his hands by sharp objects or splints. Optimal gloves are tight so that the labourer is not handicapped in executing his work.

Protective goggles

should be worn whenever the hammer is applied or while removing cartridges and toners from printers.

Dust masks

should be worn while equalising the pressure in the CRT monitor, while cutting the CRT tube and while handling with the printer.

Protective shoes

contain steel bars and protect the worker in case of heavy components drop.

Aprons

are robust and easy to clean.

Dismantling levels

For manual dismantling, different dismantling levels can be applied, ranging from only depolluting the devices to in-depth dismantling of all components.

Generally, a more detailed and in-depth dismantling generates purer fractions with higher values. At the same time, a detailed dismantling is more labour intense and therefore generates higher personnel costs. Further, appropriate downstream partners have to be found for the separated fractions. Therefore, the optimal dismantling level should be chosen depending on the available subsequent recycling processes as well as on the expected labour costs.

Dismantling Level A

Dismantling Level B

+

Dismantling Level C

- dismantling HDD, CDD
- obtaining more pure metals (copper, etc.)
- removing impurities from plastic parts

2.2. PC

A Central Unit (CU) generally consists of a steel or plastic case, several subcomponents like hard drive, CD ROM, power supply, printed wiring boards (PWB) and cables. Dismantling of subcomponents does not always make sense as it is highly labor-intensive and can be processed by appropriate industries. However, the removal of hazardous substances (e.g. batteries on PWBs) is required.

Health & Safety

It should be ensured that the different components, particularly the monitor, are not broken or damaged. Personal protection equipment like gloves, apron and robust shoes should be worn.

TOOLS:

- Several screwdrivers
- Flathead Screwdriver
- Side cutter
- Pliers
- Industrial Scissors
- Cutter
- Power Screw Driver

WORLD RESOURCES FORUM
DRZ DEMONTAGE- UND RECYCLING-ZENTRUM
Empa

Dismantling Guide for IT Equipment, which was elaborated within the SRI project and financially supported by SECO and UNIDO, (2015)

Step 1

- Remove the CU casing to get access to the internal components by unscrewing all screws. Use an automatic screw driver where applicable to save time.
- Put the cover aside.

Step 2

- Now remove the screws holding the internal components to be able to remove them all.
- Unplug all the cables and wires by pulling them straight out or releasing them by applying pressure to the clip in case they have a locking clip.

Step 3

- Once all wires and cables have been disconnected the drives (floppy drive, CD drive and hard disk drive, etc.) can be removed. Also remove the power supply.

Step 4

- To remove the motherboard it is necessary to remove all other components first from the computer case. Along with the motherboard all other PWBs can be removed.
- The number of mounting screws attaching the motherboard to the case will vary from 3-10 depending upon design. Some will be held in place with plastic clips rather than screws. For removal of plastic clips, simply pry them off with a screwdriver.
- The motherboard contains some components that can be removed such as RAM, Cmos battery, NIC (network interface card) and the CPU (central processing unit).
- Put any batteries in a separate box for adequate disposal!

Step 5

- After removing the motherboard, the casing should be completely blank.

Step 6

- Separate the remaining materials according to their type (e.g. aluminium, ferrous metals, plastic, further PWBs, etc.).
- Make sure the plastic parts are completely free of metal pieces.
- For information about storage and handling refer to chapter 3 (Output Fractions).

2.3. Laptop

A large variety of different laptop models exist and disassembly steps can thus vary a lot according to brand and model. A laptop usually consists of the following subcomponents: LCD screen, hard disk drive, battery, PWBs, compact disk drive, cables, keyboard, etc. To separate the subcomponents of a laptop computer can be tricky and laborious.

Dismantling of subcomponents does not always make sense as it is highly labor-intensive and can be processed by appropriate industries. However, the removal of hazardous substances (e.g. capacitors on PWBs) is required.

Health & Safety

Workers should wear aprons, gloves and protective shoes.

The critical step when disassembling a laptop is the removal of the cold cathode fluorescent lamps (CCFL). Avoid the damage of the CCFL during the removal of the LCD screen from the laptop body. Once the CCFLs are separated, they must immediately be put into an adequate container. As these lamps contain mercury, wearing an appropriate mask is recommended.

Note: As the construction of laptops can differ a lot, the dismantling steps mentioned below can vary in their order. However, the described steps show what parts the removal should focus on.

TOOLS:

- Several screwdrivers
- Flathead Screwdriver
- Side cutter
- Pliers
- Industrial Scissors
- Cutter
- Power Screw Driver
- Robust gloves
- Protective shoes
- Apron

Step 1

- Remove the battery. Usually, no tools are needed to remove it.
- Remove all cards on the bottom (memory module, wireless card, modem card, etc.).

Step 2

- Remove all drives (HDD, CDD, etc.). If you cannot find the HDD, it is most likely hidden under the keyboard or under the top cover assembly. If you cannot find securing screws for the optical drive on the bottom, they are most likely under the keyboard.

Step 3

- Remove all screws on the bottom of the laptop.

Step 4

- Remove the keyboard securing strip and remove the keyboard.

Step 5

- Remove the mainboard battery.

Step 6

- Remove all screws under the keyboard and cut/ disconnect all cables.

Step 7

- Remove all screws securing the display assembly. Lift the LCD display off the base.
- If this is not possible, break the display off the main body (e.g. by hyper-extending the hinges). Go on along instructions for LCD screens.
- Take care the LCD backlights won't get damaged!

Step 8

- Lift the top cover assembly off the base and put it to the appropriate fraction.

Step 9

- Remove all screws securing the system board, the power board, the video board, etc. Disconnect all cables connecting the boards.

Step 10

- Remove all boards and remove the CPU (motherboard).

Step 11

- Separate the remaining materials according to their type (e.g. aluminium, ferrous metals, plastic, further PWBs, etc.).
- Make sure the plastic parts are completely free of metal pieces.
- For information about storage and handling refer to chapter 3 (Output Fractions).

2.4. Printed Wiring Board (PWB)

PWBs are omnipresent in WEEE – almost every appliance or even component contains one or several boards. A printed wiring board or also printed circuit board (PWB or PCB) is the board base for physically supporting and wiring the surface-mounted and socketed components in most electronics. Most PWBs are made from fiberglass or glass-reinforced plastics (possibly with flame retardants) with copper tracks in the place of wires. The copper tracks link the components together forming a circuit.

PWBs can be single- or multi-layered and components, such as capacitors in different shapes and sizes, connectors, plugs, heat sinks, and batteries are soldered to the board.

Simple electronic devices usually have single layered boards which are of less value and have less components soldered to them. Printed wiring boards for complex hardware, such as computer graphics cards and motherboards, may have up to twelve layers. PWBs are most often green but they can come in any colour. The following different grades of PWB exist. The source of a PWB often indicates to which grade it belongs to. The dismantling depth of the boards will depend on the grade of the boards, as high grade boards need very little pre-processing and can be sold as such, while low grade boards need to be „up-graded" by removing the heavy parts. For grading indications and more details about downstream options for PWBs refer to chapter 3.8.

Health & Safety

Handling PWBs doesn't present any particular direct danger due to the hazardous content of components. The main exposure of the worker to hazardous substances comes from the dust that can be contaminated by several substances present inside the computer. Therefore, it is recommended that workers:

- fix the dust by spraying a little bit of water on the boards before handling them
  use dust masks
- wash hands regularly
- heal injuries immediately (cuts)
- avoid breaking open batteries and capacitors.

TOOLS:
- Several screwdrivers
- Side cutter
- Pliers

For all grades of boards, the first step is the decontamination or depollution phase, i.e. removing and storing securely components containing hazardous substances.

Step 1

- Place the board on a table.
- Identify and remove the battery.
- Store the battery in a separate secure container a go on along instructions on batteries (see chapter 3.7.).

Step 2

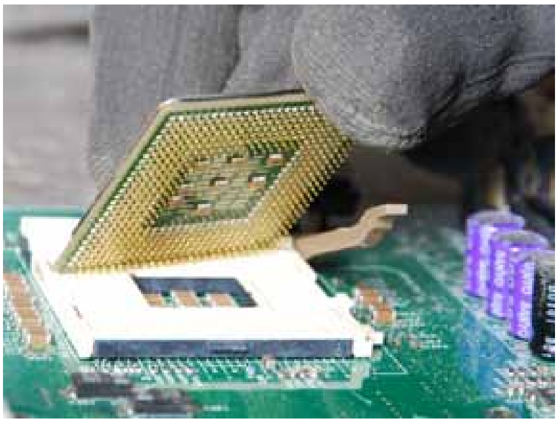
- Identify and remove large capacitors (diameter > 2 cm, or larger than a thumb) and store in a separate secure container. Continue with the instructions on capacitors (see chapter 3.6.).
- Also screen the PWB for mercury switches and remove existing switches. Store them in a separate secure container.

Step 3

- Unclip and remove the heat sinks (and the fan).

Step 4

- Remove the fan from the heat sink. Sometimes the fan is pasted and a screwdriver may be needed to separate it.
- Store the fan and refer to mixed fractions (see chapter 3.14.)
- Store the heat sink and continue according to chapter 3.11. (aluminium).



Step 5

- Depending on the receiving smelter, a separation of the central processing unit CPU (or processor) from the PWB might be economically advantageous. If the CPU can be sold separately, it is economically recommended to remove it. The CPU is usually found on the motherboard, but may also exist on some video cards and on server boards.
- Release the locking lever and remove the CPU. Store separately and follow instructions in chapter 3.8.

Step 6

- No additional processing is required for high-grade boards, which may be stored separately and sold to a refinery for end-processing (see chapter 3.8.)

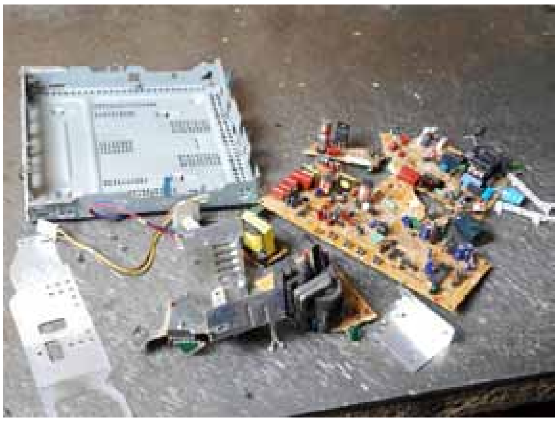
Medium & low-grade boards need further processing and finer dismantling before being sold. The low amount of precious metals contained in these boards may cause the shipment prices to exceed the sales value of the boards. Therefore, it is necessary to concentrate the value on the boards by removing heavy parts made of homogeneous materials.

Step 1

- Remove the aluminium, the ferrous, the plastic and copper containing parts. If possible, unscrew and simply remove the components.
- If they are pasted, a hammer, tweezers and a chisel may be needed.
- Gloves and goggles are needed if parts are being broken off, as splinters could cause eye injuries or cuts.
- Store the different removed fractions separately (see 3.10. for Ferrous Metals; 3.11. for Aluminium; 3.12. for Copper; 3.14. for Metal Plastic Mix; 3.6. for Capacitors).

Step 2

- Store the „stripped" PWB separately and go on along instructions in chapter 3.8. for end-processing.



2.5. Mobile Phone & Smartphone

The technology of mobile phones has evolved rapidly during recent years and consequently the models differ a lot in function and shape. Nevertheless, the disassembly of a mobile phone has generally remained quite simple: remove the battery and casing and supply the rest to an integrated metal smelter which treats PWBs. PWBs in mobile phones are commonly high-grade quality and can – if supplied to the adequate downstream processor – generate a high revenue.

Dismantling Process

Depending on the requirements of the downstream processor, it is sufficient to remove the battery from the mobile phone and omit the further dismantling steps described below.

TOOLS:

- Several screwdrivers
- Flathead Screwdriver
- Side cutter
- Pliers
- Industrial Scissors
- Power Screw Driver

Dismantling Guide for IT Equipment, which was elaborated within the SRI project and financially supported by SECO and UNIDO, (2015)

Mobile Phone

Step 1

- Remove the battery first. Generally, the battery is located under the back cover.
- In some cases, there is no quick access to the battery, thus the casing must be pried open.

Step 2

- Remove the casing and keypad from the inner parts (unscrew, pry open, etc.)

Step 3

- PWBs from mobile phones are usually high-grade board quality.
- If easily detachable, it might be wise to separate further materials like plastics, steel, aluminium, etc.

Smartphone

Step 1

- Pry open the casing and remove the back cover.
- Carefully remove the battery without bending or puncturing it.

Step 2

- Unscrew the casing.

Step 3

- Pry off the screen.
- Remove the PWB.

Step 4

- Separate the remaining materials according to their type (e.g. aluminium, ferrous metals, plastic, further PWBs, etc.).
- Make sure the plastic parts are completely free of metal pieces.
- For information about storage and handling refer to chapter 3 (Output Fractions).

2.6. CRT Monitor

A CRT monitor consists of a plastic case (ABS/PC), a cathode ray tube (CRT) with an attached magnetic deflector and electron gun, printed wiring boards (PWB) and cables. The CRT glass contains a large amount of lead which may be released when it breaks. Therefore it is crucial to only conduct dismantling operations on monitors in adequate facilities.

Health and Safety

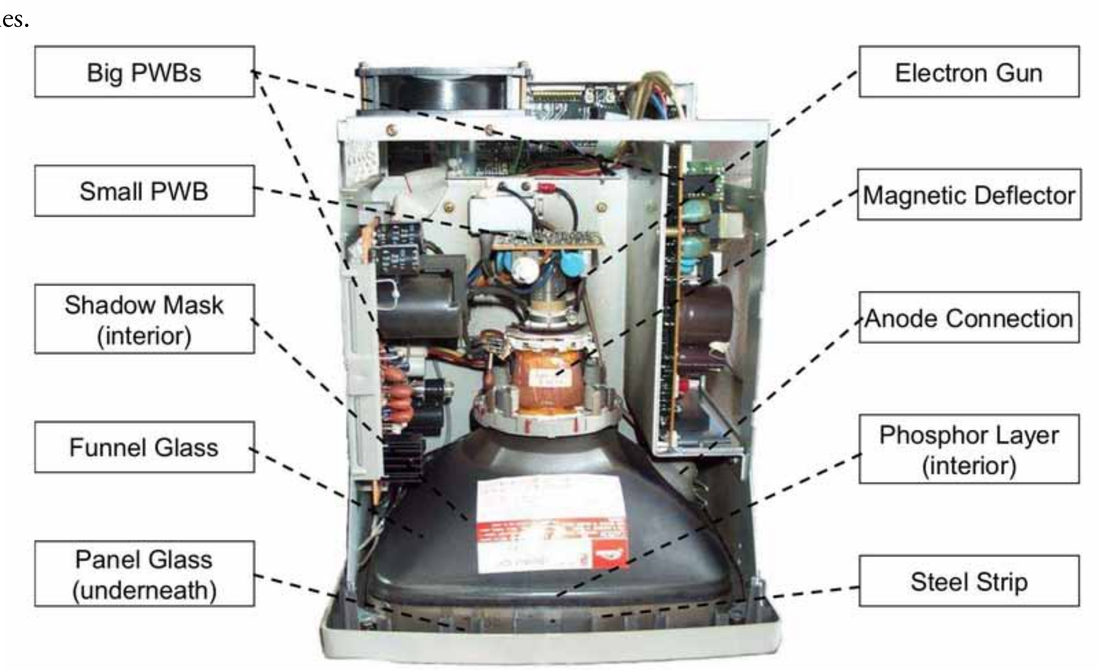
A vacuum is applied to the interior of all CRT monitors. The monitor may implode if the outer glass envelope is damaged. Due to the power of the implosion, fractions may bounce and explode outwards with splints travelling at potential fatal velocities. To avoid personal injury, it is therefore crucial to equalise the pressure before any further treatment.

Wear protective equipment to smash the magnetic deflector with a hammer as flying splints can injure personnel.

CRTs must be handled carefully also after pressure equalizing to ensure that no substances of concern are released. CRT glass bodies should be further processed only in industrial channels with adequate facilities.

TOOLS:

- Several screwdrivers
- Flathead Screwdriver
- Side cutter
- Hammer
- Pliers
- Industrial Scissors
- Power Screw Driver
- Putty Knife



Separation and Removal of All Components

Step 1

- Before doing anything the monitor has to be placed face down to protect the monitor screen from breaking.

Step 2

- Remove the plastic casing by unscrewing all the screws in the cover (generally around 4). Clean the casing properly by removing all the foreign materials in the plastic such as labels, rubber mountains etc.

Step 3

- Before removing other parts from the monitor it is crucial to equalize pressure in the CRT glass body. Therefore place the side of the monitor screen with the flap (anode connection) away from your face.
- Remove the flap in the monitor screen with a flat screw driver and punch carefully a hole into the CRT glass where the flap was fixed.

- Equalize the pressure carefully and wear protective equipment!

Step 4

- Remove the cable ties around the wires, so that you can freely remove the wires from the monitor.

Step 5

- There are generally two Printed Wiring Boards (PWB) in a monitor. A small PWB is attached at the base of the monitor screen by glue or a screw. A bigger PWB is attached at the back. Particularly the bigger PWBs might need further dismantling.

Step 6

- Cut off all the wires around the monitor to be able to remove the magnetic deflector (on top of the CRT glass) that is surrounded by copper windings.
- Remove the magnetic deflector carefully to avoid that the electron gun on top of the CRT gets destroyed.

Step 7

- Remove the copper from the Magnetic Deflector by crashing it with a hammer. Strip the big wire around the monitor screen with a knife or side cutter and remove the copper. Clean the copper, plastic and steel and place it aside separately.

- Wear protective equipment. Especially goggles and gloves are crucial as splints can injure arms, hands and eyes.

Step 8

- Unscrew the CRT glass from the front plastic casing and break off the electron gun from the tube with a hammer or a small axe just below the gun.
- Be careful so that only the glass just below the electron gun breaks (and not the complete funnel glass)!

Step 9

- Separate the remaining materials according to their type (e.g. aluminium, ferrous metals, plastic, further PWBs, etc.).
- Make sure the plastic parts are completely free of metal pieces.
- For information about storage and handling refer to chapter 3 (Output Fractions).

Step 10

- The CRT glass body can be separated into panel glass, funnel glass, shadow mask and phosphor coating (as shown in the picture on the right: CRT dismantling equipment at the WEEE Centre, Nairobi, Kenya).
- See the procedure in detail on the next page.

Separation of Funnel and Panel Glass

Step 1

- Before starting to separate funnel and panel glass, make sure the CRT is not under pressure anymore (see Step 3 of Separation and Removal of all Components).
- Place the CRT firmly in a clamp or a similar device.
- First, the metal tension ring must be removed from the tube.
- Remove sticker and other adhesive residues from the tube with a putty knife.

Step 2

- The glasses are then separated along the intersection between panel and funnel glass by means of a hot wire, or laser-cutter.
- If possible, avoid dust formation. Use a fume hood to minimize worker exposition.

Step 3

- Store the funnel glass in a segregated box.

Step 4

- Remove the shadow mask and place it aside separately together with the ferrous metals.

Step 5

- Carefully vacuum the phosphor layer on the inner face of the panel glass.
- Avoid dust formation!

Step 6

- Store the phosphor layer or the vacuum cleaner bag containing it, respectively, separately in a bin with a cover.

Step 7

- Store the cleaned panel glass in a gaylord box.

For information about further handling and processing of the output fractions refer to chapter 3.2.

2.7. Flat Screen Monitor

There are three basic types of flat panel display (FPD) TVs which have a different material composition and may require a different recycling strategy.

Plasma TVs

Plasma display panel (PDP) TVs, or simply Plasma TVs, use small cells containing electrically charged ionized gases to display the image. You can usually recognize plasma TVs without disassembling them.

- Plasma TVs are relatively heavy (around 20kg for a 40“ screen or 100 cm diagonal)
- Plasma TVs use more power than other types of flat screens, therefore they have a fairly large built-in power supply unit.
- Plasma TVs have a solid glass screen which also contributes to the weight. The glass feels cold to the touch and isn‘t flexible.
- Plasma TVs also have a sheet metal back cover instead of a plastic back.
- Plasma TVs are packed with electronic components containing valuable materials. They do not normally contain any hazardous substances.

OLED TVs

Organic light-emitting diode (OLED) display TVs use individual LEDs for each pixel of the image and therefore do not require any backlight.

LCD TVs

Thin-film-transistor liquid-crystal display (TFT LCD) TV‘s use small LCD shutters to selectively filter light emitted from cold cathode fluorescent lamps (CCFLs) or light-emitting diodes (LEDs), which can be mounted either to the side of the display or behind the LCD screen.

CCFLs contain mercury and should therefore be handled and treated with particular caution. A single lamp contains 1 to 5 mg Hg, meaning a 36“ LCD display can contain up to 80mg of Hg.

If a plat panel TV is not a plasma TV (see previous step), look for the mercury Inside or Mercury Free logo. These were introduced in 2014 by Digital Europe and Wrap to aid in segregating TVs containing mercury.

If no Mercury Inside or Mercury Free logo is visible, you will need to take off the back cover of the TV in order to look for CCFL mounting clips protruding through the display panel.

Health and Safety

The critical step in demanufacturing a flat screen monitor is to remove the crystal liquid containing glass and the CCFLs. Often the backlight lamps are already broken due to transportation. As these lamps contain mercury, wearing an appropriate mask is essential.

TOOLS:

- Several screwdrivers
- Flathead Screwdriver
- Side cutter
- Pliers
- Industrial Scissors
- Power Screw Driver

Step 1

- Before doing anything the monitor has to be placed face down to protect the monitor screen from breaking.
- Remove the monitor stand and dismantle it. It consists of some steel and plastic elements.

Step 2

- Remove the back casing and clean the casing properly by removing all the foreign materials in the plastic such as labels, rubber mountains etc.
- LCD casings do not contain flame retardants and are thus adequate for plastic recycling.

Step 3

- Remove the front frame, so that you can freely remove the wires and switches.
- Remove the inner back casing by unscrewing all fixing screws to get access to the Printed Wiring Boards (PWBs).
- Also cut off all wires.

Step 4

- Remove the steel cover protecting the layers by releasing it with a flat screwdriver (see picture).
- Check if the LCD is illuminated by CCFLs or by LEDs.
- If the LCD is illuminated by CCFLs go on with step 5.
- If the LCD is illuminated by LEDs go on with step 6.

Step 5

- The black connection at the bottom left and right indicate where the backlight lamps are attached. Carefully lift and remove the steel cover at this point to avoid the breakage of the lamps.
- Remove the backlights carefully and place them aside. Depending on the screen model, the backlights can be removed before or after taking apart the LCD module (see pictures).
- Avoid the breakage of the backlight as mercury vapour can be released. The lamps should be stored in a closed container which disposes of a mechanism preventing the release of air from the inside at the insertion of further lamps.
- If a lamp is broken it should be placed immediately into the container.

Step 6

- Remove the dark liquid crystal layer (foil) and other layers to get access to the backlights (see below).

Step 7

- Separate the remaining materials according to their type (e.g. aluminium, ferrous metals, plastic, further PWBs, etc.).
- Make sure the plastic parts are completely free of metal pieces.
- For information about storage and handling refer to chapter 3 (Output Fractions).

2.8. Printer

Due to the large variety of printers available on the market it is impossible to give a specific manual how to dismantle a printer. Therefore, the dismantling steps for inkjet printers indicated below have to be adapted from case to case.

TOOLS:

- Several screwdrivers
- Flathead Screwdriver
- Side cutter
- Pliers
- Industrial Scissors
- Power Screw Driver

Inkjet Printer

Step 1

- Remove the ink cartridges and put them aside. Cartridges can be refilled and reused!
- In case they are broken, they need to be disposed of as hazardous waste.

Dismantling Guide for IT Equipment, which was elaborated within the SRI project and financially supported by SECO and UNIDO, (2015)

Step 2

- Open the plastic casing by unscrewing all screws and removing clips. Clean the casing properly by removing all the foreign materials in the plastic such as labels, rubber mountains etc.
- Make sure the plastic parts are completely free of metal pieces.

Step 3

- Unscrew and remove the PWB.

Step 4

- Remove the printer motor. If possible, separate the copper coil or the magnets inside the motor.
- The magnets should be stored separately .

Step 5

- Separate the remaining materials according to their type (e.g. aluminium, ferrous metals, plastic, further PWBs, etc.).
- Make sure the plastic parts are completely free of metal pieces.
- For information about storage and handling refer to chapter 3 (Output Fractions).

Laser Printer

Step 1

- Remove the toner cartridge.
- Cartridges can be refilled and reused! In case they are broken, they need to be disposed of as hazardous waste.

Step 2

- The photoconductive drum is usually located within the cartridge.
- Drums from older copy and fax machines may be coated with the toxic substances cadmium-sulfid or selen and should therefore be segregated and supplied to an adequate treatment.
- To segregate the drum, remove the axis and store the photoconductive drum separately.
- Avoid exposure to the coatings of the Cd- and Se-drums! Selenium-coated drums should be stored without exposure to light (barrel with cover)!

Step 3

- Open the plastic casing by unscrewing all screws and removing clips. Clean the casing properly by removing all the foreign materials in the plastic such as labels, rubber mountains etc.
- Make sure the plastic parts are completely free of metal pieces.

Step 4

- Remove all screws and segregate the PWBs.

Step 5

- Remove the fan.

Step 6

- Cut off and remove the heating unit, including (brown) heated roller.

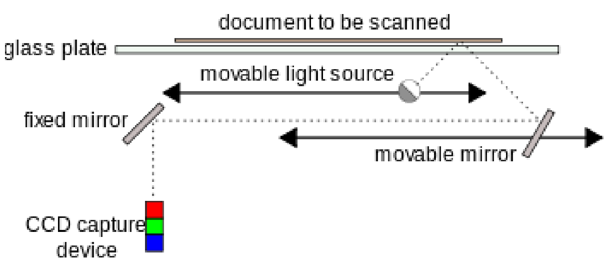
Step 7

- Separate the remaining materials according to their type (e.g. aluminium, ferrous metals, plastic, further PWBs, etc.).
- Make sure the plastic parts are completely free of metal pieces.
- For information about storage and handling refer to chapter 3 (Output Fractions).

2.9. Scanner

Flatbed or desktop scanners (as shown in the image) are the most commonly used with PCs. They optically scan an image (or object) laid on the glass and convert it into a digital image by shining white light onto the object to be scanned and reading the intensity and colour of light that is reflected from it, usually a line at a time. Then they direct the reflected light (usually through a series of mirrors and lenses) onto a photosensitive element. In most modern scanners, the sensing medium typically is an electronic, light-sensing integrated circuit known as charge-coupled device (CCD).

A flatbed scanner is usually composed of a glass pane under which there is a bright light (often LED or cold cathode fluorescent) which illuminates the pane, and a moving optical array. CCD-type scanners typically contain three rows (arrays) of sensors with red, green, and blue filters.



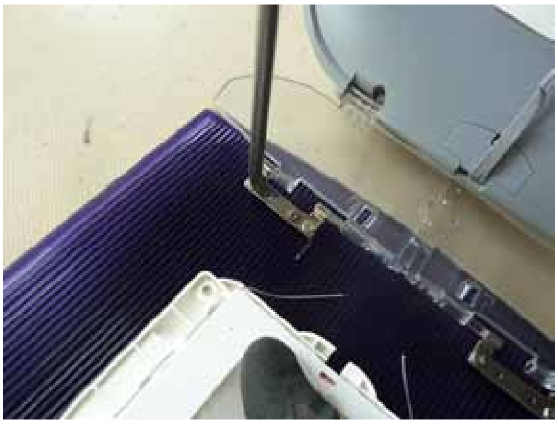
Health and Safety

Dismantling doesn‘t include any harmful steps. Nonetheless workers should wear personal protection equipment like gloves, goggles, apron and robust shoes.

Note: This is a general guide for most scanners. As the construction can differ, the dismantling steps mentioned below can vary in their order. However, the described steps show what parts the removal should focus on.

TOOLS:

- Several screwdrivers
- Flathead Screwdriver
- Side cutter
- Pipe Wrench
- Industrial Scissors
- Power Screw Driver



Step 1

- Remove the foam layer and unscrew the lid.

Step 2

- Unscrew the case.

Step 3

- Pry open the glass frame.
- Remove the glass frame.
- Remove the glass.

Step 4

- Carefully remove the lamp without breaking it.

Step 5

- Unscrew the PWB.

Step 6

- Remove the motor.

Step 7

- Unscrew and remove the PWB.

Step 8

- Separate the remaining materials according to their type (e.g. aluminium, ferrous metals, plastic, further PWBs, etc.).
- Make sure the plastic parts are completely free of metal pieces.
- For information about storage and handling refer to chapter 3 (Output Fractions).

2.10. Large Household Appliances

To dismantle Large Household Appliances (washing machines, dish washing machines, microwaves), follow the main steps of manual dismantling: (1) open the device, (2) remove hazardous components, and (3) separate the remaining materials. For this appliance group special focus should be put on the following parts:

- large capacitors (containing hazardous substances; see Chapter 3.5.),
- coils (containing windings of pure copper, which can be removed and set aside quite easily, see Chapter 3.11. for Copper) and
- motors (rather heavy due to their high content of iron and partly copper, and therefore of higher value; refer to Chapters 3.9. for Ferrous Metals and 3.11. for Copper)

The following pages show what capacitors, coils and motors look like in large household appliances, and explain where you can most probably find them during dismantling.

Health and Safety

Dismantling of large household appliances generally doesn't include any harmful steps. Nonetheless workers should watch their safety and wear personal protective equipment like gloves, goggles, apron and robust shoes. For heavy equipment, workers should work in pairs to avoid back injuries.

TOOLS:

- Several screwdrivers
- Flathead Screwdriver
- Hammer
- Side cutter
- Pliers
- Industrial Scissors
- Cutter
- Power Screw Driver
- Pipe Wrench
- Socket Wrench set
- Ring / open-end spanners

Capacitors (see also Chapter 3.5.)

Remove the capacitor and unclip all wires, being careful not to touch the contacts as this could lead to a potentially dangerous electrical discharge!

Washing Machine

- A washing machine can contain up to three capacitors.
- Their position is usually close to the motor, right at the bottom of the appliance. An additional one can be positioned close to the top. Their size varies, from 3,5 cm in diameter and about 6 cm to 11 cm length.

Dish Washing Machine

- Also the dish washing machine can contain from one to three capacitors.
- Here, the capacitor(s) will most likely be close to the motor and possibly additionally near the top.

Microwave

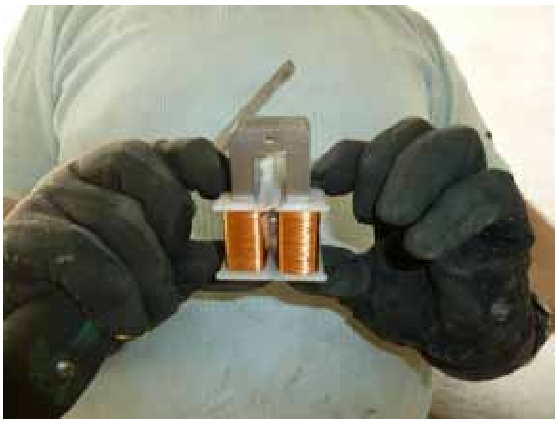
- The capacitor in a microwave is usually positioned close to the large transformer.

Coils (see Chapter 3.11. for Copper)

The coils in water pumps (washing machines, dish washing machines) or also in microwaves contain pure copper and are therefore most valuable.

Washing Machine

- In washing machines, the water pump, located at the very bottom, weighs between 300 g and 500 g.
- It contains a copper coil that can be removed and unwound.



Dish Washing Machine

- The same is the case in a dish washing machine: the water pump that contains a copper coil also sits at the bottom, weighing between 300 g and 500 g.

Microwave

- In the microwave, the coil of the fan, with visible pure copper windings, weighs from 30 g to 60 g.

Motors (see Chapter 3.9. for Ferrous Metals and 3.11. for Copper)

The motor is quite heavy, depending on when the machine was manufactured. It consists of a mix of materials: iron, copper, mixed fractions, and sometimes a plastic casing. Older ones are larger and heavier than more recent ones.

Washing Machine

- The motor of a washing machine can be found near the bottom of the appliance and weighs 2500 g to 5000 g.

Dish Washing Machine

- In a dish washer, the motor (or circulation pump) is also situated near the bottom and weighs 500 g to 2000 g.

Microwave

- In the microwave, there is a much smaller motor (around 50 g to 100 g) which only drives the turning glass plate. It is located at the very bottom of the appliance.

- There is higher value in the transformer, made of an iron casing and a copper coil core. It is most likely to be found on the side and weighs approximately 3400 g to 4100 g.

2.11. Temperature Exchange Equipment

Domestic refrigerators and air conditioners are especially important appliances because:

1. they are mass products, found in almost all households worldwide;
2. beyond the typical hazardous components in WEEE, these appliances also often contain
   - refrigerants and foam blowing agents (the latter only in refrigerators)
   - with a high global warming potential (GWP) and ozone depletion potential (ODP), thereby
   - damaging the ozone layer and contributing to global warming if released uncontrolled to the environment.

When refrigerators and air conditioners are subjected to proper waste management, there are various benefits:

- the protection of the ozone layer and climate system as well as the prevention of releases of toxic substances polluting the ecosystem,
- saving (depleting) raw materials,
- economic benefits from the resale of valuable materials.

Manual pre-treatment:
Cutting the power cable and removing loose parts are the only steps that should occur in manual dismantling. All further treatment should happen at a designated recycling plant, in order to extract oil, refrigerant and gas from foams adequately.

Step 1

Cut the power cable and dispose of the plug separately.

Step 2

Remove all loose parts of the fridge:

- glass,
- plastics,
- steel.

Plastics and steel are valuable materials.

THE IMPORTANCE OF THE PROPER WASTE MANAGEMENT OF REFRIGERATORS AND AIR CONDITIONERS TO THE ENVIRONMENT

Lots of discarded appliances ...

Refrigerators are found in almost every household, while air conditioners play a dominant role in hot climates. Particularly in developing countries, air conditioners are increasingly becoming popular products: the world's production of domestic refrigerators and air conditioners numbers around 100 million units per year. Globally, the number of domestic refrigerators in use is estimated to be between 2 and 2.3 billion units (UNEP RTOC, 2015), the stock of residential split air conditioners is estimated to be around 700 million units (GIZ, 2014). Considering the average lifetime of the equipment, between 75 and 90 million domestic refrigerators and about 45 million split air conditioners enter the waste stream each year – a massive environmental threat if these appliances are not properly dismantled at their end-of-life.

Lots of hazardous components ...

- The most important critical refrigerants commonly found in these appliances: CFC-12, HCFC-22, HFC-410A, HFC-32, ammonia solution containing chromium-VI
- The most important critical blowing agents: CFC-11, HCFC-141b
- Mercury
- Printed circuit board components
  - Lead
  - Cadmium
  - Hexavalent chromium
- Polychlorinated biphenyl (PCB) in capacitors
- Polybrominated biphenyl (PBB) and polybrominated diphenyl ether (PBDE) in plastics as flame retardants

The impact on the global climate and ozone layer ...

• If not properly dismantled, a chlorofluorocarbon (CFC) containing domestic refrigerator will release 0.56 ODP kg and 3.6 tons CO_2eq. The latter corresponds to a flight from Germany to Ghana.

• If not properly dismantled, a spilt residential air conditioner containing R-22 will release 0.08 ODP kg and 2.6 tons CO_2eq.

OIL AND REFRIGERANTS ARE HARMFUL SUBSTANCES! DO NOT RELEASE THEM INTO THE ATMOSPHERE!

Source:
Guideline on the Manual Dismantling of Refrigerators and Air Conditioners (GIZ 2017)

2.12. Record Template

Find a template for group work in the Annex.

GROUP WORK - DISMANTLING

Equipment: ______________________________

Group: ______________________________

Total Weight: ______________ Time: ______________

Fraction	Weight	% of Total

3.

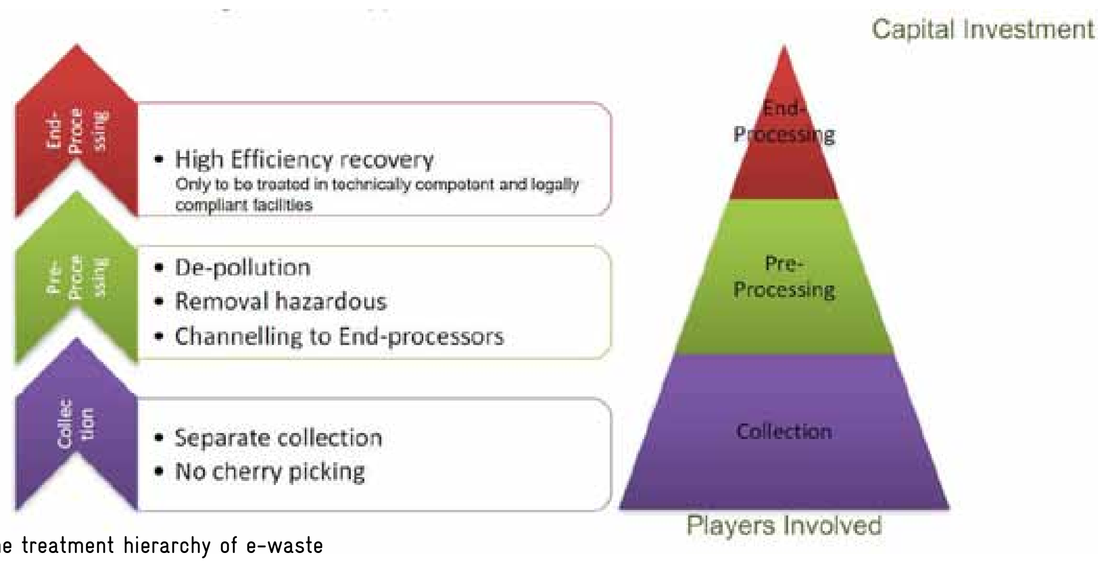
Output Fractions

3.1. Downstream Options after Manual Dismantling

As presented in chapter 1.3. the typical recycling chain consists of collection, pre-processing and end-processing steps. The pre-processing step receives entire appliances from collection and transport activities and may include manual and mechanical processing. With the manual processing step (see Chapter 2. Manual Dismantling) appliances are broken down into fractions, and later further into materials through mechanical processes and refining. Manual processing is crucial for the purpose of depollution of appliances and fractions, separating hazardous from valuable materials respectively. For the purpose of this training manual, further steps in the recycling chain are seen as downstream options after manual dismantling. This includes mechanical processing, that can serve as pre-processing or end-processing step, as well as refining, which is always an end-processing step. Refining usually entails technologies with high investment requirements, such as for large integrated smelters and is subject to an international market.
Depending on various factors, such as the size and economic development status of the country, volumes of e-waste, access to technologies and investments, etc. downstream options can be found on local, regional or international level.

Once the waste has gone through the various steps to ensure it is suitable for final and specific or selective treatment, it must be ensured that this waste adheres to the following steps:

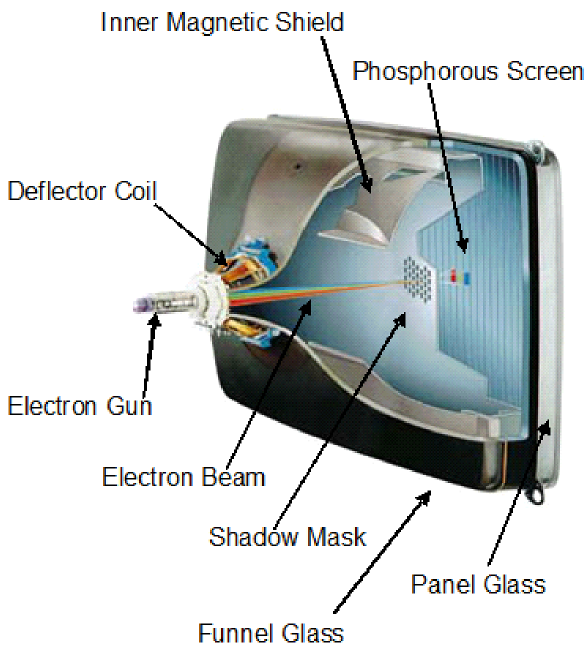
- The output fraction must be free of contaminants such as plastic, paper etc.
- The output fraction must only be sent to technically competent and legally compliant treatment facilities specialised to treat the output fraction
- All country specific containerisation and transportation regulations of the fractions must be adhered to, especially if the fractions are hazardous
- Fractions must be weighed upon leaving the pre-processor and weighed upon acceptance at the treatment facility
- Some treatment facilities may require an assay report before accepting the fraction
- Some fractions, depending on the hazardous nature and value, may attract a treatment fee, valuable fractions can possibly attract a rebate from the treatment facility. This is sometimes negated by the transportation cost to the treatment facility.
- As the capital investment only becomes viable upon sufficient volumes being generated (cost/benefit analysis), these treatment facilities or hubs may be located in neighbouring countries or abroad. In these cases, all Basel cross-boundary movement procedures must be complied to where required. If the fraction can be listed as a raw material, then the country specific export requirements must be adhered to.
- Tracking of all material treated including any residues emanating from the treatment process is important to ensure proper mass balance records are kept
- Records must be kept safely and for a minimum of 3 years



The treatment hierarchy of e-waste

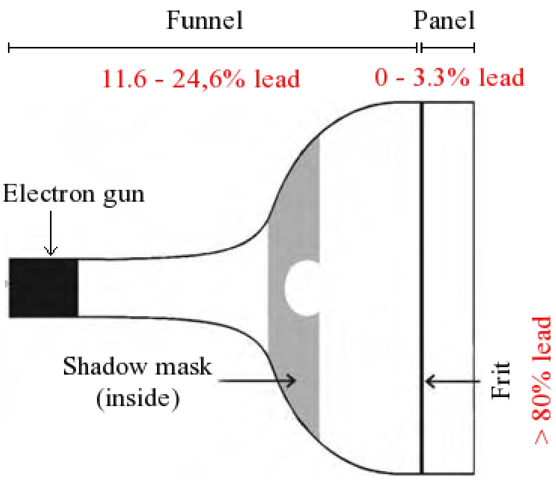
3.2. CRT Components

The Cathode Ray Tube (CRT), main component in CRT monitors and CRT TV sets, is a vacuum tube containing an electron gun (a source of electrons) and a fluorescent screen used to create images in the form of light emitted from the fluorescent screen. CRTs consist of different parts containing a large amount of hazardous substances such as lead and barium oxide and therefore must be treated carefully in an adequate plant to avoid personal injury.
The cleaned CRTs can be stored in open containers. To prevent leakage, the container should not be exposed to the weather. If CRTs or parts of it are exposed to rain, the above mentioned hazardous substances can elude and drain into the ground.



Funnel Glass & Panel Glass

The chemical composition of the panel and funnel glass is different because of the different technical requirements. Whereas in funnel glass lead oxide is used as an additive (in average 15%) for absorption of the high energetic radiation, the panel glass contains barium oxide or strontium oxide (in average 13%) (Gabriel 2001).



Lead contents in a CRT
Source: MacGibbon, J., and L. Zwimpfer. 2006. e-Waste in New Zealand - Taking Responsibility for End-of-Life Computers and TVs. Wellington, New Zealand: Computer Access NZ Trust.

Lead and lead-containing compounds are classified as cancer-causing. Uptake of lead can lead to acute and chronic poisoning. In the environment lead accumulates in aquatic and biological chains. In CRTs lead is embedded in the glass matrix and does not cause direct danger. After dismantling the CRTs, the cleaned glass fractions should be recycled.
However, during grinding of the glass fractions, lead can be laid open, eluted and transported by air.
For transportation to end-processing, it is possibly more effective to crush the panel and funnel glass separately, as the two glasses have different properties and therefore should not be mixed. While crushing the CRT glass, inhalation of the generated dust should be avoided.
Further processing of CRT glass should only happen in industrial channels with adequate facilities.

Source:
Dismantling Guide for IT Equipment, which was elaborated within the SRI project and financially supported by SECO and UNIDO, (2015)

Downstream Options for CRT Glass

Treatment	Description
CRT glass to flux agent in sintering operations	If recycling to CRT glass is not viable, CRT panel glass can be applied as a slag former in sintering processes. Used in small amounts (up to 5% in weight), it can replace conventional flux agents improving the densification process and the mechanical properties (Andreola et al. 2008).
CRT glass to lead recycling	"CRT glass to lead recycling" is a recycling process, where metallic lead (Pb) is recovered and separated from the CRT glass through a smelting process, where CRT glass acts as a fluxing agent in the smelting process. This process is a more automated process compared to "CRT glass to CRT glass recycling" and might be more cost-effective. It also provides safer working conditions because workers are protected from lead dust because of the automated process and an emission control system. The CRT glass to lead recycling process has a high overall throughput. However, this process reduces the value of high-quality glass (Kang and Schoenung 2005).
CRT glass to new products	To add heavy metals from CRTs to building materials or to give it to processes in the ceramic industry is critical because hazardous substances are diffusively distributed in the environment. This can lead to elution of these compounds by acid water. Nonetheless there are attempts to use CRT screen glass in the bricks and tiles production, as flux in brick and ceramic manufacture, in ceramic glaze, and in foam glass.

Phosphor Powder

During CRT manufacturing a phosphor layer is spread on the inner surface of the panel glass in form of a white powder (see chapter 2.6. Separation of Funnel and Panel Glass). Phosphors are substances that exhibit luminescence: when electrons (from the electron gun) strike the phosphor, it emits light. Depending on its composition, the light appears in different colours. Phosphors (not to be mistaken for the chemical element Phosphorus P) are often transitional metal compounds or rare earth compounds of various types. They are used in CRTs, fluorescent lamps (FL), compact fluorescent lamps (CFL), cold cathode fluorescent lamps (CCFL), light emitting diodes (LED) and other devices.

In black and white CRTs, a significant fraction of toxic cadmium (Cd) sulphide is found in the phosphor layer. To generate the colours red, blue and green, the panel glass is coated with three different phosphors, that contain e.g. zinc sulphide, cadmium sulphide, compounds of yttrium and europium. These monitor layers are applied in very thin coating (few nanometres) and weigh 5 to 7 g per monitor.

Interior view of the panel glass with phosphor layer

The powder consists of a large variety of elements, among them also hazardous ones, such as Yttrium (Y), Cadmium (CD), Barium (BA) and Lead (PB) (see Table).

Chemical composition of the powder from a CRT in weight-%

Y	In	Ce	Nd	Sm	Eu	Al	Si	S	K
17%	0.49%	0.02%	0.01%	0.02%	0.76%	4.55%	10.44%	17.36%	2.36%
Ca	Mn	Fe	Zn	Sr	Zr	Ir	Pd	Ba	Pb
0.80%	0.39%	0.54%	31.4%	0.82%	0.15%	0.42%	0.07%	2.15%	7.53%

Resende and Morais, 2010

The phosphor layer has to be stored in a closed container (cover!) which prevents its release.
Phosphors contain both valuable and hazardous elements. There are two alternatives for their treatment:

- Storage: If possible, the elements contained in the phophors should be recovered. Due to the lack of adequate technologies, this is not viable for many elements contained in phosphors at present. But given the content of valuable elements and the rising prices for rare metals, it might be not only environmentally, but also economically advantageous to store the phosphors until appropriate technologies are available.
- Disposal in a HW landfill: It should be ensured that the phosphors are disposed in a safe landfill which prevents the release of the hazardous substances (e.g. leachate) into the environment. By landfilling phosphors, a potential recovery of the contained valuable elements is impeded.

Electron Gun & Getter Platelet

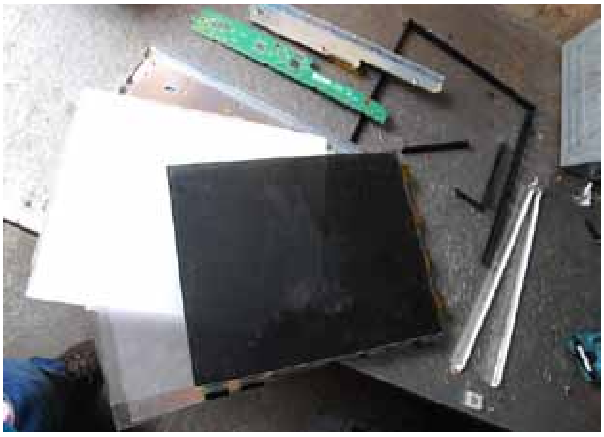
Each CRT contains an electron gun and at least one so called getter platelet. If the electron gun is still attached to the CRT, it should be removed. In some cases, the getter platelet is attached at the top of the CRT itself. It is a small, circular troughs attached by a metallic stripe to the electron gun and filled with an earth metal, Barium (Ba) being the most common. Barium is used to remove last traces of oxygen in the CRT. It is very reactive with air and water where it forms barium oxide. Barium is poisonous when dissolved in water. Therefore, the getter platelet should not be touched during dismantling of CRTs.

According to Pramreiter et al (2007) the getter platelet has to be separated from the electron gun. The getter platelet has to be stored in drums protected against ingress and disposed of as hazardous waste.

The electron gun consists of a high-alloyed nickel steel and can be commercialised as a recycling fraction.

3.3. Flat Panel Display Components

After dismantling a Flat Screen Monitor (see chapter 2.7.), the following parts and components have to be dealt with specially (apart from the frame and printed wiring boards): valuable transparent plastic layers, the liquid crystal layer, and the backlights.

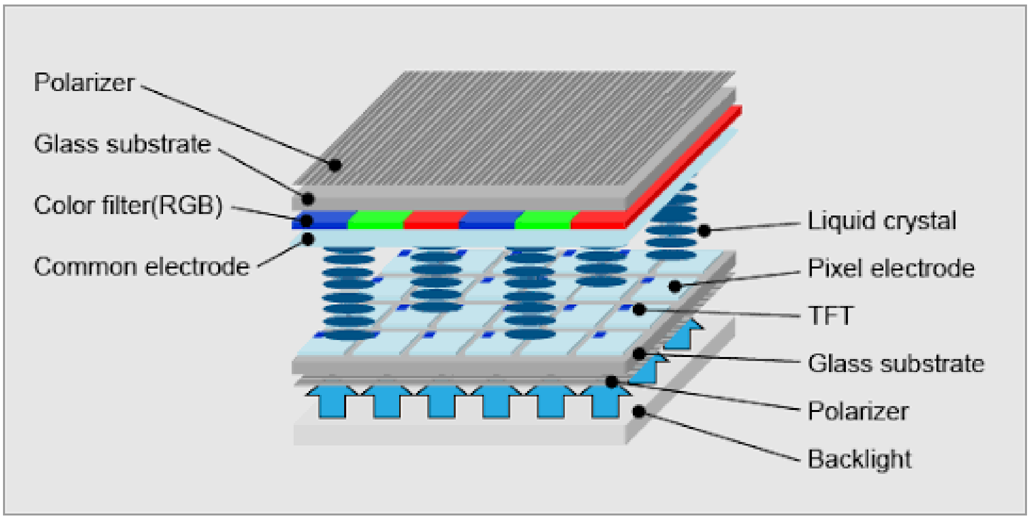


Large liquid crystal layers are mainly used in computer and TV monitors, smaller ones are found in printers, fixed line telephones, photo cameras etc. Despite their size, their properties are the same.

Plastic Layers

The light-conducting and -diffusion layer in an LCD or LED monitor is made of high-quality plastic which can possibly be commercialized separately from common plastics. If relevant amounts of this valuable material can be gathered, a potential way to sell it are online recycling markets.

As shown in the image, the layer is a thick layer which is highly transparent. It is directly connected to the light source (backlight of the LCD).



Steemit

Liquid Crystal Layer

Liquid crystal displays rely on the light modulating properties of certain liquid crystalline substances. This liquid crystal layer is located between two (dark) polarizers, which is enclosed by several other, usually white or transparent plastic layers (see above. Liquid crystal is not just a liquid, it is actually a state in-between liquid and solid.

The optical properties of the liquid crystal layer are modified by applying an electric field to it. Liquid crystals do not emit light directly and are therefore dependent on a light source (in general cold cathode fluorescent lamps or LEDs). The CCFLs are hazardous and must therefore be treated cautiously (see below and Chapter 3.5. Lamps).

Store the LCD layers in a container. If possible, avoid breakage of the layers.

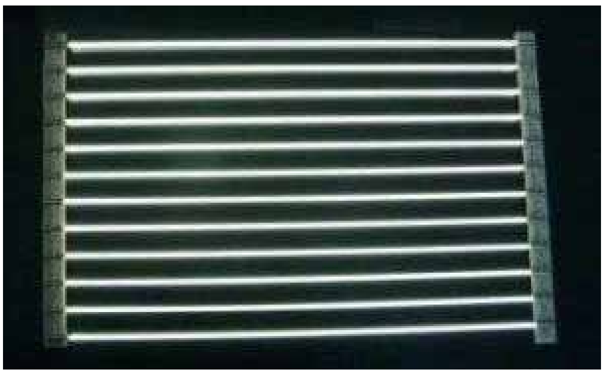
Liquid crystal layers contain indium, which is a valuable rare metal, increasingly in short supply: In the ITO (indium tin oxide) electrodes of the liquid crystal module, small amounts of indium (In) can be found. Due to the small volume of the liquid crystal layer and the potentially rising price of indium, it is recommended to store them for future indium recovery.

Another option is the disposal of the liquid crystal module (without CCFL) in a landfill or its controlled incineration

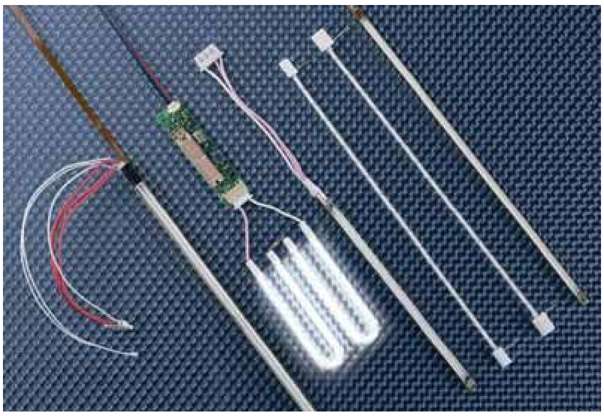
Cold Cathode Fluorescent Lamp (CCFL)

The most common way to illuminate the liquid crystal layer is to use a cold cathode fluorescent lamp (CCFL). They increase the luminosity of the screen. They are found in laptops, TVs, and other devices with LCDs (photocopy machine display, mobile phones, etc.). CCFLs are classified hazardous due to their mercury (Hg) content and the phosphor layer. The mercury is applied to the fluorescent tubes in a gaseous form. If it is ionised by electricity, it emits UV light, which in turn is transformed by the phosphor layer into visible light.

Two CCFLs are to be found inside the display frame, usually on the upper and bottom parts.



CCFL of a TV monitor



Selection of LCD backlights

Depollution should be done in a fume hood with an air pollution control system to avoid mercury vapour exposure to the workers when a backlight accidentally breaks.

The fluorescent tubes are very thin and fragile, and should not break during dismantling. Access to them is possible only through careful manual dismantling of the frame. Once it is located, the fluorescent tube can be disconnected easily by cutting the alimentation wires. Be careful, as some fluorescent tubes are, in addition, stuck to the support.

Usually, backlights from TV monitors are more difficult to remove than those in computer monitors, as they are larger. If possible the breaking of the fluorescent tubes should be avoided. In case of breaking, fluorescent tubes should be stored very carefully in a closed box or barrel that prevents the release of Hg-vapour.


Barrel with a special cover to store broken fluorescent tubes in a safe way


Safe storage in a box (with cover) for undamaged fluorescent tubes in a safe way

For further treatment, please refer to chapter 3.4. (Lamps, on the right)

3.4. Lamps

Many different types and shapes of lighting products can be found in households and even in IT appliances. The most common are as found in households and all these lamps contain hazardous components or substances. The pictures below illustrate the most common lamps which contain hazardous fractions.

Composition / main substances of content (Courtesy of Reclite SA (Pty) Ltd)

Most lamps contain heavy metals such as mercury and metalloids such as arsenic. The most dangerous heavy metal is mercury. Mercury is highly toxic to humans, fauna and flora. Mercury has the capability to accumulate in organisms (Bioaccumulation). When the lamp breaks, the mercury either in vapour form or elemental form can escape and be a threat to the handler or the surrounding environment.

Metallic mercury (Hg) is an odourless and silver coloured fluid. It is the only metal which is liquid at room temperature. It is important to know and remember that mercury vaporises at room temperature. This also applies for mercury which is blended with fluorescent powder or amalgamated to glass and/or metals. Mercury is insoluble in water, it easily forms amalgams with other metals and it cannot be broken down to less toxic substances in the environment. Mercury can pollute both the air (in vapour form) and water if allowed to come into contact with surface or ground water

Nevertheless, mercury can be used and handled safely and provided that the exposure of your handler is kept within the threshold limit values (50nmol/l blood), then there is unlikely to be any negative health effects. In severe cases of contamination or exposure special caution must be taken and correct clean-up and health measures must be taken.

Mercury is a neurotoxin and is odourless and can be inhaled without being aware of it, and health and safety precautions must be taken to avoid exposure to the handler and the environment.

Lamp localisation in appliances and IT Equipment

Lamps can be found in various appliances and IT equipment, for example lighting in ovens, fridges, laptops, printers etc.

This equipment must be de-polluted when dismantling and the lamps must be safely stored and sent to a certified and competent lamp treatment facility.

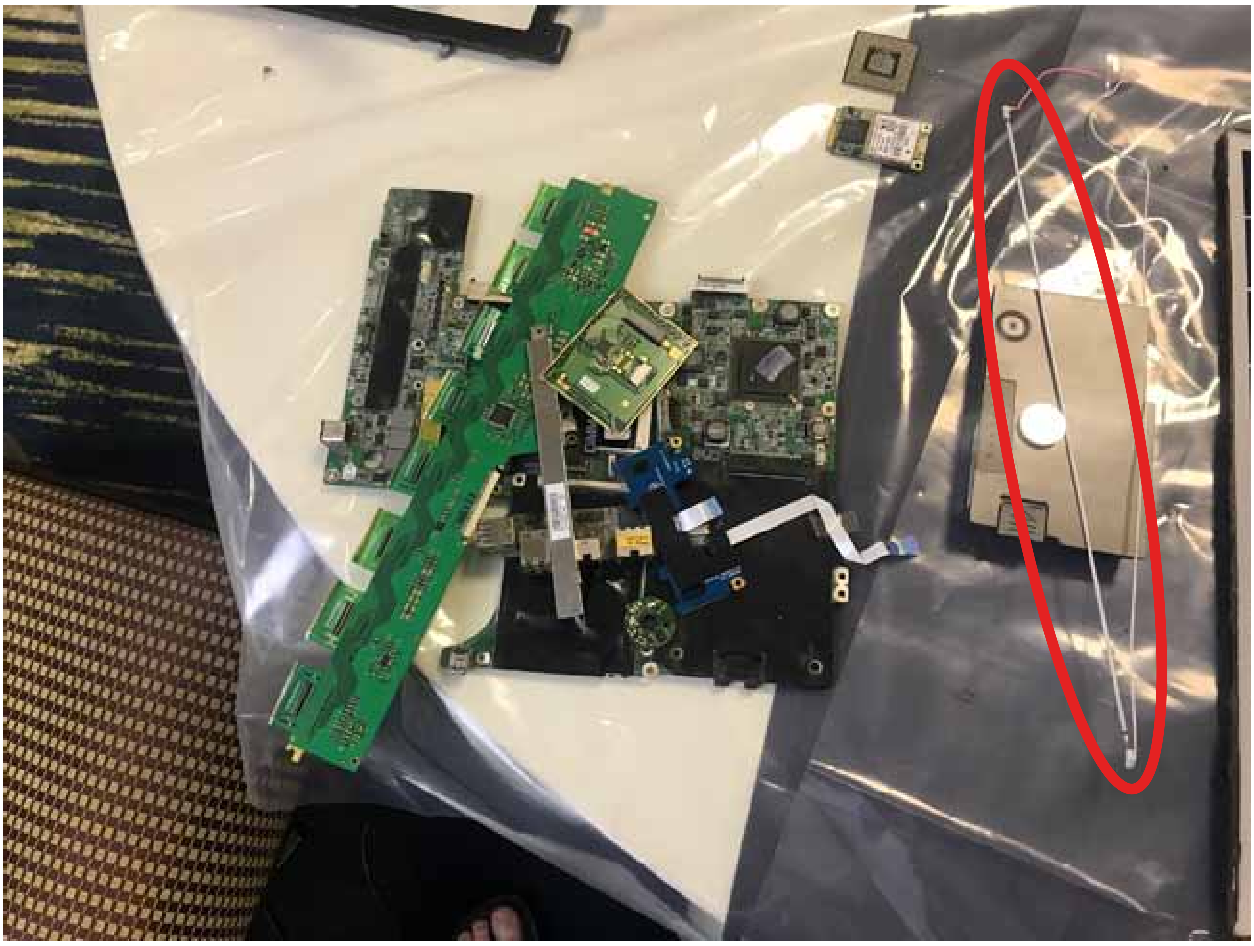


Figure 2: Fluorescent Lamp found in laptop screen which has high concentrations of mercury (Courtesy of Reclite SA (Pty) Ltd)

Storage and Transportation

All lamps that are stored until enough volume is obtained for transportation must be stored in safe and strong containers or boxes on site. The storage area must be inside or under cover with protection from the elements and preferably lockable. Long term storage of lamps must not exceed 90 days. Containers must be labelled showing that they contain hazardous lighting waste together with the UN code. When transporting the lamps to the specialized facility transport requirements need to be taken into account including the proper labelling of the waste as well as notification procedures.

Processing Lighting Waste

All lighting waste can be recycled. Lighting waste must NOT be manually dismantled prior to the treatment process as it is dangerous.

Lighting waste can only be processed in specialised lamp treatment facilities. These facilities are technically competent and legally compliant. The treatment equipment has strict technical operating standards and removes all the hazardous components through crushing and separation. The mercury is removed and separated safely, with no exposure to operators.

Figure 3: Container types for fluorescent tube and other lamps for secure and safe containment during storage and transportation (Courtesy Reclite SA (Pty) Ltd)

Figure 4: Lamp processing plant (Courtesy MRT, Sweden)

Fractions separated in the processing plant

The following fractions are recovered from lamps:

- Plastic
- Electronics (Ballasts, starters, circuit boards, wiring, LED Diodes)
- Ferrous metals
- Non-ferrous metals
- Glass
- Phosphor powder
- Mercury (elemental through separate distillation process or captured in activated carbon from vapour form)

These recovered fractions can be further processed at downstream treatment facilities and recyclers.

Figure 5: Recovered fractions from the lamp processing plant (Courtesy Reclite SA (Pty) Ltd)

Economic Value

The commercial value recovered from the recycled fractions is low and does not cover the total operational and administrative costs of the specialized lamp recycling facility. Therefore, a recycling cost will always apply. Lamps are termed as a negative waste stream. However, the environmental value recovered is high.

3.5. Capacitors

Also called condensers (old fashioned term), capacitors have many uses in electronic and electrical systems: energy storage, rectification of power energy supply and electrical signals, filter for electrical "noise", motor starting energy capacitor, signal processing of selection of information in frequency bands (tune for radio stations).

Capacitors are present in any electrical and electronic appliances and their appearance is very diverse. Some are similar to alkaline batteries, but wear a ruff on the upper part.

Inscription: nF, µF, mF (for nano-, micro- and millifarads).

Capacitors may retain a charge long after power is removed from circuit; this charge can cause dangerous electrical shocks. Those used in camera flash can be extremely harmful and dangerous.

Hazardous substances

Critical capacitors (with PCBs) are large (same size or larger than a thumb) and produced before 1987. Therefore, old appliances (HiFis, refrigerators, TV, electrical ovens, vacuum cleaners, etc.) should be depolluted with caution.

Polychlorinated biphenyls (PCBs)

Old large capacitors are very likely to contain polychlorinated biphenyls (PCBs) as dielectric fluids. New electrical components are no longer produced with PCBs. As a rule all capacitor with a diameter larger than 2 cm (same size or larger than a thumb) and found in appliances made before 1986-87 should be handled with extreme caution.

PCBs are a family of more than 200 different chlorinated organic molecules. They are either liquids or solids, colourless or light yellow. Besides capacitors, products made before 1987 with PCBs are fluorescent lighting fixtures, hydraulic oils, etc. They have been used as coolants and lubricants in electrical equipment because they don't burn easily and are good insulators. Exposure to PCBs may lead to skin diseases (chloracne, rashes), liver damage, alteration of estrogens formation (reproduction problems). PCBs are very probably carcinogens.

PCBs belong to the so-called Persistent Organic Pollutants (POPs) and are extremely stable compounds remaining in the environment for a very long period. They can travel easily into air or into water with organic particles and bind strongly in the soil. PCBs accumulate easily in animals, and can reach significant concentrations in fish and marine mammals. Therefore their elimination is regulated within the Stockholm Convention.

Capacitors may also contain harmful organic acids such as electrolytic solution.

Beryllium

There exists a certain concern about large capacitors from microwaves (magnetron) as they may contain beryllium in the ceramic material around the filament. Beryllium (Be) and its salts are toxic substances and potentially carcinogenic. It may cause acute beryllium disease, a form of pneumonia. Beryllium dust production and inhalation should be avoided, as they may provoke lung cancer. People working with beryllium may become sensitive to it and develop an inflammatory reaction called chronic beryllium disease (CBD) that occurs within a few months or many years after exposure. The symptoms are fatigue, weakness, night sweat, difficulty in breathing, persistent dry cough. It can result in anorexia, heart disease, and lung inflammation. CBD is treatable but not curable.

Handling Aspects

Caution during dismantling

Capacitors, especially large ones, may give an electrical shock that can be harmful and dangerous. The best way to avoid it is to leave the appliances disconnected from any energy sources during a few days. Therefore, WEEE should not be connected to the electrical network before dismantling.

Never test an appliance before opening it!

Concerning depollution of PCBs containing capacitors, the following criteria allow to identify the critical capacitors:

- diameter larger than 2 cm (same size or larger than a thumb),
- Product produced before 1986-87.

If such capacitors are found, any contact with the content should be absolutely avoided. Therefore, such capacitors should be handled with tools to avoid hand contact:

1. Separate the capacitor through a gentle ¼-rotation with a pair of pliers (see chapter 2.4. step 2)
2. Store hazardous capacitors in an adequate storage box
3. Use gloves and wash hands afterwards.
4. Throw the gloves away if they get contaminated by liquid from capacitors, as the gloves can be a source of contamination.

Do not crush or open capacitors!

Capacitors that do not match these characteristics can be processed with metal scraps.

Storage

Capacitors containing PCBs should be disposed of as soon as possible.

In case they have to be stored for any length of time, it is important to take the following points into consideration:

Store capacitors

- away from food preparation areas to prevent ingestion or cross-contamination!
- away from any source of heat or flammable liquids.
- in sealed containers and avoid any possibility of leakage to water.
- in a dry and sheltered place.

Transportation

The transport of PCB containing capacitors needs to follow the international regulations of transport of hazardous waste and dangerous goods. In Europe the ADR (European Agreement concerning the International Carriage of Dangerous Goods by Road -http://www.unece.org/trans/danger/publi/...) guidelines for transportation on road and IMDG codes (International Maritime Dangerous Goods Codes) for sea transport need to be followed. Special transport boxes and labelling is required for the transport of PCB containing capacitors.

When shipping PCB containing capacitors abroad the requirements under the Basel Convention need to be fulfilled. Therefore please be in contact with your corresponding authority to receive information regarding the required documentation and preparatory and administrative work.

Downstream Options

General indications concerning existing downstream partners

Removal and disposal of PCBs can only be undertaken by authorized hazardous waste service providers. Capacitors containing PCBs must not be sent to a metal recycler for recycling. PCBs is known as dioxin precursor when it is burnt at too low temperature and with lack of oxygen.

Related links
http://www.ct.gov/deep/cwp/view.asp?a=27...
http://www.basel.int/Portals/4/Basel%20C...
http://www.unep.org/chemicalsandwaste/PO...

3.6. Batteries

Many different types and shapes of batteries can occur in IT appliances. Small batteries (i.e. button cells) are used to cover the permanent low energy supply for alarm and computer system (clock, memory backup, etc.). In contrast, bigger batteries (e.g. laptop batteries) allow to run the whole device. Most modern devices do not need the small batteries anymore because the permanent energy demand for the system is reduced on the one hand. On the other hand the remaining energy demand can be covered by the capacitors.

Composition / main substances of content

Heavy metals such as cadmium (Cd), nickel, (Ni), and to some extent zinc (Zn). Organic solvents, etc.

Cadmium (Cd) is extremely toxic even at low concentration. Breathing large levels of Cd severely damages the lungs and can cause death. Water contaminated with Cd severely irritates the stomach, leading to vomiting, and diarrhoea. Cd stays in the body for a long time and can build up in kidney, or lead to lung damage and fragile bones. It is a probable carcinogen. Cd is also used in silver solders or as stabilizer for plastics as well as in phosphorescent coatings in some CRT.

The most common harmful effect of nickel (Ni) is an allergic reaction (skin rash, asthma) for people sensitive to it (10-20 % of the population). People working in nickel-processing plants have experienced chronic bronchitis and reduced lung function. Long use of drinking water contaminated with high concentration of nickel may lead to stomach ache and adverse effects to blood and kidneys. Ni compounds are known as carcinogens for human.

Zinc (Zn) is an essential element in human diet. Zn deficiency results from inadequate intake of Zn and can cause problem (hair loss, diarrhoea, brain development retardation of foetus and young children). However, large doses are harmful which can cause stomach cramps, nausea, vomiting. Intake over a longer period can cause anaemia. Free Zn ion (Zn^{2+}) in solution is highly toxic to plants, invertebrate and some fish.

Localisation in appliance

Batteries are very diverse in terms of characteristics, composition, form, size, colour, etc. Almost every IT-equipment contain at least one battery. Rechargeable accumulators can be found in mobile phones, laptops, toothbrush or electrical razors. Appliances like torches, portable CD players, etc. can be operated using rechargeable and non-rechargeable batteries. Small (button) cell batteries are often used as a backup battery to the main battery; it provides an independent energy supply for processors, timers, security backup, etc. in computers. It is commonly located on the PWB.

The following inscriptions can help to identify batteries and to distinguish from others components (capacitors, resistances). Inscription: + / -, Li-ion, NiCd, NiMH (nickel metal hybrid battery), alkaline (Zn/MnO2), „RAM“, „Dallas“, „Symphony“, „Danger do not open“, „Do not dispose in fire“, „Timekeeper“. Rectangle batteries are often disposed near the bios system of the motherboard, with the sign of a clock, or a dog.

Handling Aspects

Caution during dismantling

!!!NEVER CRUSH OR OPEN A BATTERY!!!

There is usually no difficulty or risk to separate the batteries from their support if they are in good condition. Use gloves, and wash hands and throw the gloves away after contact with substances from defective and leaking batteries.

Source:
Dismantling Guide for IT Equipment, which was elaborated within the SRI project and financially supported by SECO and UNIDO, (2015)

Requirements for storage and transport

Avoid long time storing. Batteries are subject to corrosion and cell rupture, which could release reactive hazardous substances (heavy metal oxide, organic solvents, sulphuric acid).

Lithium-ion batteries can easily rupture, ignite, or explode when exposed to high temperatures, or direct sunlight.

Avoid fire risk and contact with heat sources. All batteries must be stored in acid-resistant barrels. They should be stored in a dry and sheltered place.

Downstream Options

Batteries should be treated in an adequate plant for recovery or disposal. In any case, they should not be incinerated in an open fire or with municipal waste.

Lead-Acid Accumulators

Lead-acid batteries are one of the most commonly used independent and rechargeable energy supplies for automotives (cars, motorcycles starter, truck, etc.), for big appliances (e.g. off-grid household electric power system, portable TV)) as well as for torches, laptops, telephones, etc. They are also contained in UPS appliances (uninterruptable power supply).

Usually, a UPS is an easily identifiable separate unit, that is connected to the appliance by two wires. The following inscriptions can help to identify lead-acid batteries and to distinguish them from others batteries:

+ / - (for all batteries in general), lead, Pb, dry, SLA (Sealed Lead Acid battery), VRLA (Valve Regulated Lead Acid battery).

UPSs are usually easy to reach and disconnect from the appliance.

Hazardous substances: Lead (Pb), Lead oxide and Sulphuric acid

Lead is a global environmental contaminant. It is a threat for human beings, animals and plants. It can be spread through air or water and can be accumulated in the ground. It is a poisonous metal that can damage the nervous system, especially in young children, causing mental retardation, memory and learning difficulties as well as behavioural problems.

Pregnant woman should avoid contact with Pb. Basically, lead can affect almost every organ and system in the body. According to the EPA (US Environmental Protection Agency), lead is a probable human carcinogen.

Sulphuric acid can be extremely corrosive.

Handling Aspects

Caution during dismantling

!!!NEVER OPEN A LEAD-ACID BATTERY!!!

Usually they are not dangerous to handle when in undamaged condition, but be careful in handling when leakage due to mechanical damage can be observed.

Discharging them by short-circuiting (direct electrical connection between + and -) may rapidly increase heat and might lead to explosion. Especially large batteries can cause an electrical shock.

Caution during storage

Avoid long time storing. Batteries are subject to corrosion and cell rupture, which could release reactive hazardous substances (lead, sulphuric acid).

Avoid fire risk and contact with heat sources. All batteries should be stored in acid-resistant barrels.

They should be stored in a dry and sheltered place.

Downstream Options

Same as for general batteries, lead-acid accumulators should be treated in an adequate plant. In any case, they should not be burned in an open fire or with municipal waste.

Li-Ion Batteries

Li-ion batteries are rechargeable batteries and are very often used within modern electronic appliances as they are much lighter than other types of rechargeable batteries. Further they can hold their charges and do not have the so called memory effect, so they can handle hundreds of charge/discharge cycles. However, their lifetime is limited to 3-5 years. Therefore it is expected that the amount of Li-ion-Batteries occurring in the waste stream is steadily increasing.

% mass	Component	Material(s)
15– 24	Anode	Copper foil (collector) 1-12%; Graphite/carbon 8-13%; polymer 1%; solvent 1-6%
29 – 39	Cathode	Aluminium 4-9%; Lithium compounds 22-31%; Polymer 1-3%; Solvent 1-11%
2-3	Separator	Polymer
3-20	Cell casing	Steel or aluminium
8-12	Electrolyte	Carbonate solvent 7-13%; Lithium hexafluorophosphate 1-2%
2	Battery Management System	Copper wiring 1%; Steel 1%; Printed wire board <1%
17-23	Battery Pack Casing	Polypropylene or other type of plastics
17-23	Passive Cooling System	Steel or aluminium

Composition of an average 10-12kg Li-ion battery (source: http://energyskeptic.com/2015/epa-lithiu...)

The active material of the negative electrode of common Li-ion batteries mainly consists of graphite. The positive electrode contains usually lithium metal oxide, e.g. $LiCoO_2$, $LiNixMnyCozO_2$, $LiFePO_4$, or $LiMn_2O_4$.

Due to the contained energy, it is possible that Li-ion batteries get on fire which is usually caused by an internal short in the battery. This happens in case the separator of the battery is broken or got punctured. Since li-ion batteries are so energetic, they get very hot. The heat causes the battery to vent the organic solvent used as an electrolyte, and the heat (or a nearby spark) can light it. Once that happens inside one of the cells, the heat of the fire cascades to the other cells and the whole pack goes up in flames.

Handling Aspects

Caution during dismantling

Discarded Li-ion batteries often hold major residual charges leading to high probability of strong short circuits if not treated with caution. Therefore:

- NEVER short-circuit, open, dismantle, pierce, drop or squeeze Li-ion batteries
- DO NOT use electrically conducting tools

Carefully remove Li-ion batteries from the device. There is usually no difficulty or risk to separate the batteries from their support if they are in good condition. Use gloves and wash hands. Throw the gloves away after contact with substances from defective and leaking batteries.

In order to prevent short circuits all batteries should be masked with common adhesive tape – at least 2-3 layers. Obviously broken Li-Ion batteries (e.g. inflated ones) should be handled with additional care and stored separately.

Storage

Lithium-ion batteries can easily rupture, ignite, or explode when exposed to high temperatures, or direct sunlight, therefore Li-ion batteries should be stored at temperatures ranging from -20°C to 25°C. For safe storage use a designated storage box. The box should be filled with inherent flame resistant material. The box should not be air-proof. Although a lid is required it should be compensative to pressure due to heat development.

Transportation

The transport of Li-ion batteries needs to follow the international regulations of transport of hazardous waste and dangerous goods. In Europe the ADR (European Agreement concerning the International Carriage of Dangerous Goods by Road -http://www.unece.org/trans/danger/publi/...) guidelines for transportation on road and IMDG codes (International Maritime Dangerous Goods Codes) for sea transport need to be followed. Special transport boxes and labelling is required for the transport of Li-ion batteries. Further the preparation of a detailed packaging list (including number and type of packaging units, gross weight, net weight, type of material, lot reference, contract reference) is advisable and often required by the purchaser.

When shipping Li-ion batteries abroad the requirements under the Basel Convention need to be fulfilled. Therefore please be in contact with your corresponding authority to receive information regarding the required documentation and preparatory/administrative work.

Downstream Options

General indications concerning existing downstream partners

A variety of battery recyclers exist world-wide. Usually those recyclers also treat Li-ion batteries. During the last years some recycling facilities developed specialized treatment processes for rechargeable batteries including Li-ion batteries. Due to their lifetime and their increasing use in electrical equipment and electric vehicles, it is expected that the quantities of rechargeable batteries will increase within the next decade.

List of available state of the art recycling technologies

Recycling of batteries is not new, but historically has been limited to the most common chemistries such as alkaline batteries, lead-acid batteries and NiCd batteries. Therefore the recycling of Li-ion batteries is still in its infancy and standard recycling process is developed yet. The recycling of Li-ion batteries still needs further research and development. Some main recycling technologies are the following:

1. **Mechanical recycling process** – After mechanical size reduction through a hammer-mill and a shaker table mixed plastics and metals are separated. Metals are then sentfor recycling, but the process in only economical if cobalt and/ or nickel is contained in the input material.

2. **Pyrometallurgical processes (smelting)** - Valuable metals are reduced to an alloy of copper, cobalt, nickel, and iron. Through further hydrometallurgical processing those metals can be recovered from the alloy. Other materials that were present in the cathode like lithium, aluminium, silicon, calcium and iron end up in the slag. Further recovery of aluminium or lithium from the slag is neither economically nor environmentally viable. The following table lists the recycling efficiency of Li-Ion batteries.

Economic Aspects

As the treatment of Li-ion batteries is a costly operation and only small parts of valuable materials can be recovered, recycling facilities charge for their treatment.

Component	Input wt [%]	Output wt [%]	Output form	Recycling path	Recycling Efficiency [%]
Housing (steel)	18,8 %	18,8 %	steel crap	steel works	18,8 %
Copper foils	8,0 %	8,0 %	Cu scrap	Cu works	8,0 %
Aluminum foils	3,8 %	3,8 %	Al scrap	Al works	3,8 %
Plastic & Seperator	4,3 %	0 %	Pyrolysed gas	thermal use	-
Electrolyte solvent	13,6 %	0 %	Pyrolysed gas	thermal use	-
Iron	0,0 %	0,0 %	Powder / Pellets	nonferrous works	0,0 %
Manganese	0,1 %	0,1 %	Powder / Pellets	nonferrous works	0,1 %
Lithium	2,2 %	2,2 %	Powder / Pellets	nonferrous works	-
Nickel	0,1 %	0,1 %	Powder / Pellets	nonferrous works	0,1 %
Cobalt	13,5 %	13,5 %	Powder / Pellets	nonferrous works	13,5 %
Graphite / Carbon	17,4 %	17,4 %	Powder / Pellets	nonferrous works	17,4 %
Others (Oxygen, Phosphorus, etc)	18,2 %	18,2 %	Powder / Pellets	nonferrous works	-
Total	**100 %**	**82,1 %**			**61,7 %**

Recycling efficiency of Liion batteries.

Related links

Gaines, L. The future of automotive lithium-ion battery recycling: Charting a sustainable course; Sustainable Materials and Technologies, Volumes 1-2 (2014)

3.7. Printed Wiring Boards

Printed wiring boards (PWB) represent the most valuable fraction from WEEE. They contain several base, precious and special metals, that can be recovered by specialized metal refineries. On the other hand, PWBs also contain several toxic substances like heavy metals or flame retardants. Hazardous substances can be released by inappropriate treatment of the PWBs such as uncontrolled wet chemical processes or open burning (see worst and good practices under chapter 1). Not only do such processes present a high risk to human health and the environment, but also are inefficient, resulting in loss of recoverable materials.

Handling Aspects

Before any pre-processing is performed on the PWB, it is helpful to check the precise conditions of acceptance of the downstream partner. Often it is worthwhile to sort the PWBs according to the different grades or qualities – refer to the table on the right. Inaccurate crushing/shredding of the PWBs usually leads to a significant loss of precious metals and thus reduces the value of the fraction. Some downstream partners, such as integrated smelters, require essential depollution only as described in chapter 2 on manual disassembly of PWBs.

Some PWB-containing components can often also be supplied to integrated metal smelters (to be clarified with the respective smelter):

Optical reader of CD/DVD drives

Floppy disk drives

Hard disk platters of HDD (storage for future recovery or supply to integrated metal smelter)

Downstream Options

Due to the complex composition of PWBs, high recovery rates of the metals contained therein can only be met by an appropriate treatment in specialized plants. Different technologies like pyrometallurgy, hydrometallurgy, electrometallurgy and a combination of those can be applied to recover the metals. Schluep et al. (2009) describes the different existing technologies and reasons why integrated smelters often provide the most advantageous downstream option, combining high environmentally sound treatment standard with high material recovery rates. Such a downstream partner would be able to:

Recover multiple metals, in contrast to single metal recovery based on hydrometallurgical processes only, thereby offering higher revenue potential to the dismantler

Recover a higher percentage of metals due to higher process efficiency, thereby also resulting in a higher revenue potential for the dismantler

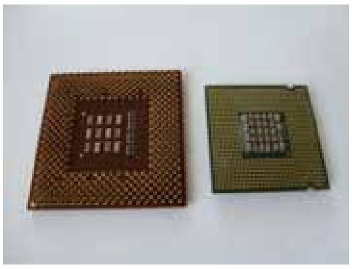
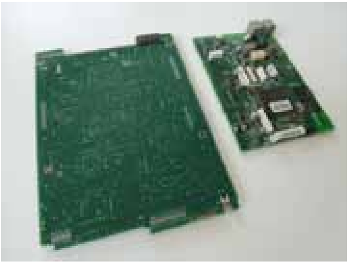
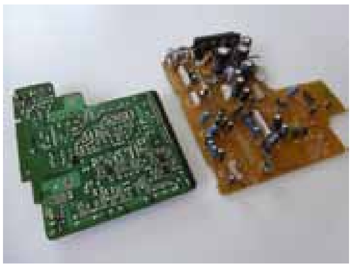
Offer controlled processes which allow for a treatment under environmentally sound conditions (off-gas cleaning system, waste water treatment, etc.) and for safe working conditions.

Often, these large integrated smelters that operate internationally demand certain prerequisites such as minimum lot shipment (quantities of at least one shipping container) or long credit terms (e.g. payment potentially with delays of 6 months after shipment) that are difficult for smaller dismantlers. In such cases, it is recommended to supply smaller lot sizes, with faster payment terms, to an intermediary that aggregates volumes from many smaller dismantlers.

Economic Aspects

Integrated metal smelters determine the price of the PWBs mainly by their concentration of gold (Au), palladium (Pd), silver (Ag) and copper (Cu). The below table gives an indication of the concentration of Ag, Au, Pd and platinum (Pt) for PWBs originating from different appliances.

Classification of Board Grades

	**Very High Grade** Processors
	**High Grade** IT/telecom boards (PC, laptop, server, mobile phones)
	**Medium Grade** IT boards (printers), mixed connectors, LCD monitors
	**Low Grade** Boards from CRT monitors (TV & PC), HiFi, power supplies, small domestic appliances, etc.

Equipment	Silver (g/t)	Gold (g/t)	Palladium (g/t)	Platinum (g/t)
Audio & Video Equipment	674	31		
Radio Set	520	68	8	
DVD Player	700	100	21	
Personal Computer	600-1000	81-600	90-100	up to 40
Keyboard & Mouse	700	70	30	
CRT Monitor	150	9	3	
LCD Monitor	1300	490	99	
Mobile Phone	5540	980	285	7
Small IT equipment	5700	1300	470	

Source:
Dismantling Guide for IT Equipment, which was elaborated within the SRI project and financially supported by SECO and UNIDO, (2015)

3.8. Printer Cartridges

An ink cartridge is a replaceable component of an ink jet printer. It contains liquid ink which consists of various pigments or colours for the coloration of a surface to create images and texts. Some ink cartridge manufacturers also add electronic contacts and a chip that communicates with the printer.

Toner cartridges contain fine dry ink (toner) particles, which adhere to the paper electrostatically and are fixed by heating.

Beside toner particles, toner material contains very small amounts of potentially toxic compounds. Among them are Volatile Organic Hydrocarbons ('Volatile Organic Compounds', VOC), such as Styrol, Toluol, Ethylbenzol, Xylols, Phenols, Aldehyds and Ketons as well as various carbonic acids. In exceptional cases also carcinogen Benzol has been found in toner material.

Fluid and pasty toners can contain solvents declared as hazardous waste. Moreover colouring toners can contain heavy metals.

Toner and ink cartridges of different sizes are found in photocopiers, fax machines or printers.

Handling Aspects

Caution during dismantling

Toner and ink cartridges must be manually separated from the rest of the printer by all means. Otherwise hazardous substances contained in the toner material would be released during possible further mechanical treatment and seriously pollute recycling material.

Requirements for storage and transport

Toner cartridges should be collected and stored in a way that prevents the release of any toner material.

Downstream Options

As far as possible toner cartridges should be refilled and reused.

All other toner cartridges should be disposed as hazardous waste.

Source:
Dismantling Guide for IT Equipment, which was elaborated within the SRI project and financially supported by SECO and UNIDO, (2015)

3.9. Ferrous Scrap

Ferrous metals comprise the different grades of steel parts, including chrome steel, chrome-nickel steel and stainless steel. It is often difficult to differentiate the different types of steel, so that they are usually stored together. Knowing which type of steel is found in which component makes the segregation easier. Chrome steel and chrome-nickel steel are usually not painted, shiny and without rust.

In a computer ferrous metals of different types are generally found in the protective tower, casings of the various drives, casings of the power supply and the loudspeakers. Some frame parts are also contained in other components.

Handling Aspects

Steel should be cleaned up to a degree where it is still viable. Steel with some plastic content is also accepted as plastic and can act as a burning facilitator. Stainless steel, an alloy of iron and chromium, should be stored separately and not be mixed with ferrous scrap.
No special caution needs to be taken into account when storing or transporting ferrous metals.

Downstream Options

In general, metal recycling is a pyramid industry with many small companies at the bottom feeding scrap to large multinationals at the top. Steel recycling involves some, or, all of the following steps:

1. Sorting: Because magnets attract steel, this metal can be easily separated from other recyclables like paper in a recycling facility with magnetic belts. Different kinds of steel do not need to be separated.
2. Shredding: Shredders incorporate rotating magnetic drums to extract iron and steel from the mixture of metals and other materials.
3. Media separation: Further separation is achieved using electrical currents, high-pressure air flows and liquid floating systems. Other processes may be necessary in cases such as steel cans which have a protective layer of tin that must be removed and recycled separately.
4. Shearing: Hydraulic machinery capable of exerting enormous pressure is used to cut thick heavy steel recovered from railways and ships. Other cutting techniques, such as the use of gas and plasma arch, are sometimes employed.
5. Baling: Iron and steel products are compacted into large blocks to facilitate handling and transportation.
6. Steel is ideal for recycling because it does not lose any of its inherent physical properties during the process, which can be repeated ad infinitum. Steel is 100% recyclable and therefore, recycled steel can be used for the same applications as steel produced from virgin material.

Economic Aspects

Ferrous metals can be sold to scrap metal merchants. Like other commodity prices, ferrous metals prices are fluctuating considerably.

Related links
http://www.isri.org/home
http://www.bir.org/industry/ferrous-metals/

3.10. Aluminium

Nearly all electronic goods using electric power higher than a few watts contain aluminium plates. They generally act as heat sinks and therefore are found in the power supply pack in greater quantities. Also HDD and FDD housings as well as motherboards contain aluminium components. Aluminium can be found in various shapes within electronic appliances.

Handling Aspects

Aluminium can easily be distinguished from other metals as it is clearer and not magnetic. To clean recovered aluminium components, all foreign material, such as screws, rubber, plastic etc. should be removed.

Take care that aluminium is properly cleaned as aluminium recyclers refuse impure parts.

Downstream Options

General indications concerning existing downstream partners

Aluminium scrap can be sold to scrap metal merchants.

Aluminium's intrinsic material value means that it has always been worthwhile returning the material to the loop that comprises metal extraction, processing, use and recovery. There is no deterioration in quality when aluminium is recycled. New profiles or other high-value products can be made from scrap profiles and new rolled products can be made from used aluminium sheet and foil. The amount of recycled aluminium in circulation is growing continuously.

Recycling rates for aluminium from in Europe are above 80%.

Smelting of aluminium within metal furnace

Depending on the material composition aluminium waste is melted or refined. This process is taking place within a specialized recycling facility.

The melting process can be done within different furnaces. Scrap with high impurities or aluminium slags rotary drum melting furnaces are the most efficient solution. Coated scrap is usually processed within the so called chamber melting furnace.

Depending on the quality of the liquefied material it might be necessary to add another processing step – refining of the scrap in order to receive the desired quality.

Economic Aspects

Like other non-ferrous metals, aluminium prices are fluctuating considerably. Prices depend on the aluminium quality (grade).

Related links
http://www.aluinfo.de
http://www.hydro.com/en/About-aluminium/...

3.11. Copper

Copper is natural, fully recyclable, corrosion resistant, durable and antimicrobial. It is not persistent, bio-accumulative, or toxic to the environment under normal conditions of use.

Copper is used in all electronic devices. It's incorporated in cables and wires, in magnetic deflectors, coils and conductors. Electrical uses of copper, including power transmission and generation, wires for building purposes, telecommunication, and electrical and electronic products, account for about three quarters of total copper use - over 933,000 tons - a year. Because of its properties of high ductility, malleability, and electrical conductivity, it has become the benchmark for almost all types of wiring.

A considerably large amount of copper is found in CRT monitors respective in the magnetic deflector and the surrounding wire. It is comparably easy to access and can be recycled to a great value after cleaning. Other components like copper coils are harder to clean and therefore are of lower value.

Handling Aspects

Copper should be cleaned before further processing. Therefore all foreign materials like screws, rubber and plastic should be removed. Wires and cables can be granulated to remove copper (see Cables & Wires).
There are no special requirements regarding storage of copper. Dismantled copper scrap can be stored in simple boxes or drums.

Downstream Options

Copper shredding and smelting in a furnace is the common way of metal recycling. Recycled copper has the same attributes as virgin material and can be used the same way.
Copper smelting companies usually can be found in every country. When selecting a downstream partner to treat scrap copper, pay attention to their applied standards regarding environmental performance and health & safety standards.

Economic Aspects

Copper scrap can be sold to a scrap metal merchant. As other non-ferrous metals, copper prices are fluctuating considerably and depend on the copper quality (grade).

Related link
https://www.copper.org/environment/lifecycle/ukrecyc.html

3.12. Plastics

Nowadays plastics are found in almost every electronic appliance. They have replaced traditional materials over time, such as metal, wood or glass for many applications. They are usually found in casings, frames, covers and small parts of electronic appliances. Various types of plastic exist, of which ABS (acrylonitrile butadiene styrene), PS (polystyrene) and PP (polypropylene) are usually used in computer manufacturing. In addition, many other types are used depending on their characteristics, as well as plastic compounds.

When plastics are recycled the quality of the material often decreases (downcycling). If several plastic types are recycled mixed together, this degradation is even stronger. As a consequence, one of the main purposes of pre-processing plastics is their separation according to their plastic types and to clean the plastics from foreign material.

Symbol	Code	Description
01 PET	#1 PET(E)	Polyethylen terephthalat
02 PE-HD	#2 PEHD or HDPE	High-Density Polyethylen
03 PVC	#3 PVC	Polyvinyl chlorid
04 PE-LD	#4 PELD oder LDPE	Low-Density Polyethylen
05 PP	#5 PP	Polypropylen
06 PS	#6 PS	Polystyrene
07 O	#7 O(ther)	All other plastics
	#9 or #ABS	Acrylnitrile butadien styrene

Handling Aspects

Depending on the final treatment of plastics, different pre-processing steps can be performed:

1. In any case plastics should be cleaned from all foreign material. Especially steel parts are unwanted in the plastic mix as they can destroy recycling machines. Unclean plastic therefore has less value and some recyclers don't even take it.

2. To add a maximum value to the recycling process, plastics should be segregated by type and by content of BFRs. Depending on the requirements of the plastic processor, the segregation is realized at the dismantling facility or at the processor's plant. In most cases, plastic types apt for recycling can be classified by the plastic recycling code (see table on the left). A bigger challenge is the identification of BFRs within plastic (see below, Flame Retardants).
3. To transport plastics efficiently, it is reasonable to reduce the particle size of plastic by shredding it mechanically. This is sometimes required from the plastic processor, too.

When shredding, several aspects should be taken into account:

- Only pure plastic fractions should be shredded; avoid the presence of other materials in the plastic fraction.
- Ensure a good maintenance of the shredder.
- In the shredder high temperatures can occur. At temperatures above 300 °C, the generation of dioxins from BFRs is likely to happen. But if a proper maintenance of the shredder is ensured, those temperatures are not reached when shredding pure plastic fraction. At the absence of direct temperature gauging, blue colour changes of metal parts of the shredder are a clear warning signal that temperatures have reached a level where dioxins can be generated (> 300 – 350 °C). In that case the shredder should be stopped and (a) bearings and movable parts of the shredder should be cleaned (i.e. from stuck plastic), (b) the hammers and/or blades of the shredder should be grinded.

Flame Retardants

Some plastics contain brominated flame retardants (BFR), which are hazardous substances introduced to reduce the flammability of plastic parts. Theses plastics are found in many parts of electronic appliances and must be treated as hazardous materials.
A study by Waeger, Schluep, and Mueller (2010) on toxic substances in mixed WEEE plastic indicates that ICT equipment (excluding monitors) generally contains brominated flame retardants at concentrations close to or above the European Maximal Critical Value (MCV) .
However, the concentration of BFR in similar devices vary significantly. While i.e. CRT casings contain relatively high concentrations of BFR, no BFRs could be found in flat screen casings.
In practice, it is difficult to identify which plastic parts contain BFR and which do not if no special analytical equipment is available.
The heating of plastics containing brominated flame retardants (> 300°C) can cause the formation of brominated dioxins and furans, which are highly toxic. This has to be considered especially when shredding plastic fractions.

Downstream Options

At present, treatments exist which allow for the separation of different plastic types, including the separation of plastics with and without BFRs, respectively. The existing treatment alternatives for plastics are summarized in the below table.

Economic Aspects

Plastics are made of natural hydrocarbons such as oil, gas or carbon. Depending on the technique applied, homogeneous plastics can be valorised as plastics or fuel. This is more difficult for plastic compounds, which can be valorised thermally, i.e. by burning them appropriately in an incinerator.

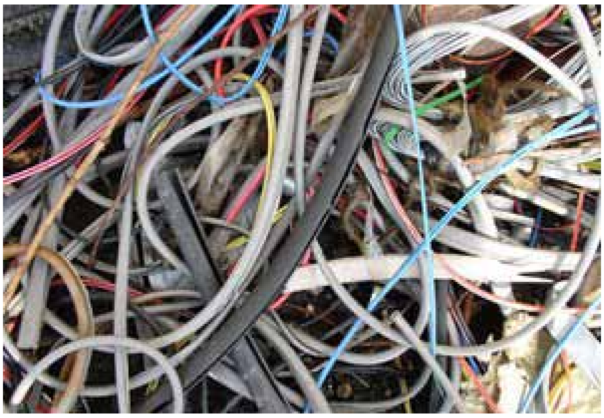
Related links
Restriction of Hazardous Substances in electrical and electronic equipment Directive or RoHS-Directive (2002/95/EC) by the European Union (https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:037:0019:0023:en:PDF)

Treatment	Description
Mechanical recycling (plastics in general)	Shredding of plastics and subsequent heating for pelletizing.
Chemical or tertiary recycling (plastics in general)	Waste plastics are treated by physicochemical processes in which the plastic molecules are broken in order to get monomers or other useful/valuable products for the petrochemical industry and convert into raw materials again. Chemical recycling can take place by different processes: pyrolysis, hydrogenation, gasification, degradative extrusion and methanolysis. A big advantage of some chemical recycling processes such as pyrolysis is that no previous separation by plastic resin type is required, which allows for the recycling of mixed plastic waste. Among the chemical processes used for the recycling of plastics is also the methanolysis (depolymerization process) which decomposes the plastic to its original components by applying heat and pressure in the presence of methanol. This combination not only causes the decomposition of the polymer chain (leaving only monomers which are purified and re-polymerized to a new resin), but enables the destruction of contaminants.
Incineration with energy recovery (plastics in general)	By a controlled combustion, this process takes advantage of the high energy content of plastic waste as alternative fuel. Although some plastics can be recycled with benefits to the environment, there may be remaining plastics from the recycling process that cannot be recycled. In case a mechanical or chemical recycling cannot be justified, energy recovery may be an effective way to recover the intrinsic value of plastic waste.
Incineration	In developed countries, plastics have to be incinerated. An incineration of plastics containing brominated flame retardants is reasonable if some specifications are considered. To avoid the generation of dioxins or furans, a controlled combustion in excess of 600 ° C must be ensured. Moreover, the incinerator must have appropriate filters and equipment in their furnaces to control pollution, emission of metals, VOCs and dioxins (off-gas control).

3.13. Cables & Wires

Cables and wires are found in all IT devices and there exist a lot of different types of them. Basically there are 3 types: thick black cables, flat cables and coloured wires. Cables are recycled to recover copper.

Cables' composition varies strongly according to their type. Most cables contain copper, others aluminium as conductor. Also the surrounding plastic type varies. Many cable insulations are made of PVC, which releases very hazardous substances if burnt.



In order to gain most economic value from cables, the insulation should be removed using a knife or side cutter. Alternatively, a cable stripping machine can be used to make the separation process more efficient.

The copper can then be sold to a copper smelter (see 3.11.) for further recycling. The insulation should be destined to an adequate plastic recycler (see 3.12.).

Handling Aspects

!!!Burning cables to recover metals is very hazardous and must be avoided!!!

3.14. Mixed Fraction

Depending on the applied dismantling depth, this fraction can be minimized to a very low amount. The more detailed the dismantling of equipment and sorting of fraction takes place, the less material will end up as “mixed fraction”. However, there will always be some components like cooling fans, loudspeakers, electrolytic capacitors, coils, transformers, connectors, transistors etc. which are considered as a mix of different materials, e.g. plastic and metal.

Downstream Options

In many countries there exist mechanical recycling plants which are able to separate mixed scrap containing Fe- and NE-metals and plastics by means of shredding, magnetic separation, sensor based separation and so on.

Economic Aspects

The value of mixed metal-plastic scrap depends on the composition. A higher content of copper in the material increases, high content of plastics decreases the value of the concerning fraction. Some scrap metal merchants take metal components even with a high fraction of plastic as plastic sometimes is used as a burning facilitator in the melting process.

4.

Management of a Small Scale Dismantling Facility

As described in detail in chapter 1.8. Technical Guidelines have been developed and adopted to provide management requirements for inter alia treatment facilities.

4.1. Procurement of Input

In order to ensure a continuous flow of material and utilize the existing capacity of the facility, a steady input should be ensured. This should be done through cooperation with registered collectors. The Technical Guidelines also define activities and management standards for collectors.

4.2. Handling and Storage of E-Waste

E-waste has to be handled and stored in a safe manner throughout the whole process. E-waste should be sorted according to categories and in appropriate storage boxes, e.g. lattice boxes. Further it is important to keep in mind that the stored quantities do not exceed the storage capacity of the treatment facility. The storage area shall have an effective and efficient impermeable surface to prevent ground water and soil contamination and further e-waste should not be stored at the vagaries of the weather.

During handling of e-waste, the afore described Health & Safety Measures have to be applied. This is of utmost importance to ensure workers‘ safety.

After the dismantling process, the fractions should be stored according to their characteristics. Especially for hazardous fractions specific storage requirements have to be applied. Detailed information regarding the storage requirements for each output fraction can be found in chapter 3.

4.3. Monitoring Input and Output

E-waste treatment facilities are required to continuously monitor their material flows. All incoming material shall be weighed and recorded at the receiving area and further classified according to the following categories which are further described in Annex C of the Technical Guidelines:

- Temperature exchange equipment
- Screens, monitors, and equipment containing screens having a surface greater than 100 cm^2
- Lamps
- Large equipment
- Small equipment
- Small IT and telecommunication equipment (no external dimension more than 50 cm)

Besides the type of the equipment and the weight also the origin should be recorded at the receiving area.

To monitor the whole process, the operator shall record the downstream treatment of all e-waste and the output fractions. Disposal certificates should be collected and filed at the facility in order to verify proper treatment of all fractions. This is especially crucial when handling hazardous fractions.

Where appropriate (as defined in Annex B of the Technical Guidelines) treatment operators shall carry out monitoring of depollution performance in accordance with the mass balance methodology that establishes a mass balance between incoming and outgoing streams.

4.4. Quality Assurance

Regular training of staff and compliance to the Technical Guidelines support operators to ensure high quality at their facility. All staff shall be trained by EPA or by an institution approved by EPA in order to be made familiar with the environmental, health and safety policy of the facility. Further, an emergency response plan shall be developed. The training of staff shall be conducted at a regular basis and be adapted to changing working conditions if necessary.

4.5. Process Optimisation

Treatment processes shall be evaluated on a regular basis in order to optimize process flows and adapt handling processes. When evaluating the process and developing an optimization plan, the requirement of downstream partners as well the mix of incoming equipment shall be taken into account.

4.6. Compliance

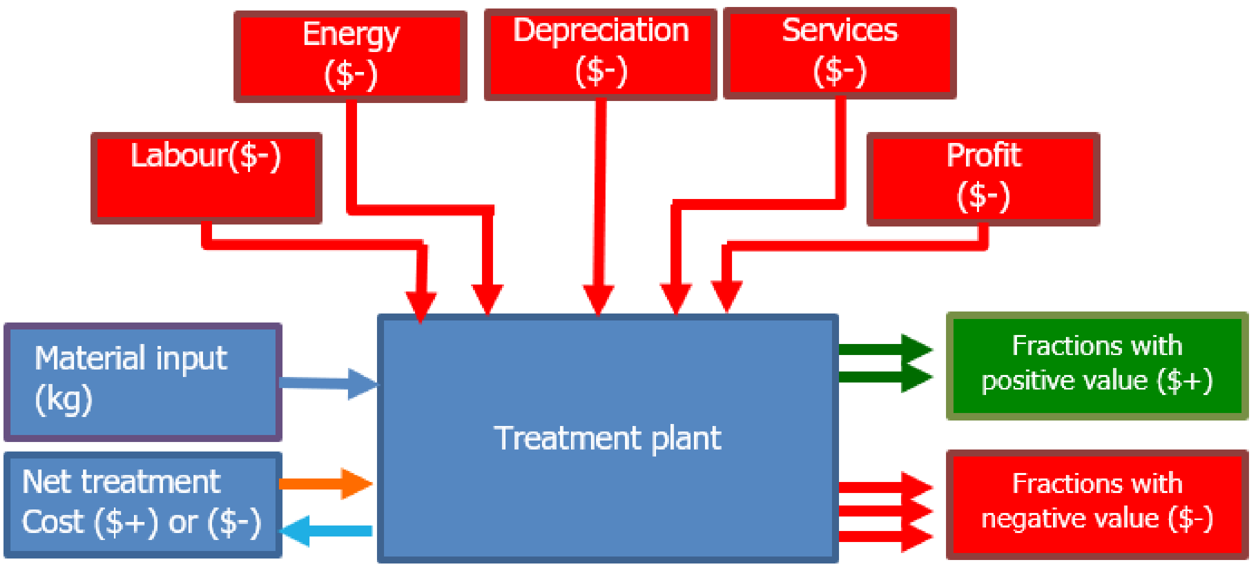
Complying with legal requirements as described in chapter 1.8. is necessary to keep a facility up and running.

The registration and permit of dismantling facilities as part of the environmental assessment procedures will be required to provide information on the monitoring, quality assurance and environmental management system established to minimize environmental impacts. Dismantling facilities are required to provide information on the source of material input, handling and storage in compliance with the requirements for handling and storage of e-waste.

4.7. Infrastructure and Costs

The infrastructure at treatment facilities have to be suitable to the activities performed on site in terms of size, technology installed and characteristics of the operations. A risk management helps to ensure suitability of the installed infrastructure for all performed tasks on site.

The costs of setting up and running a treatment plant are often underestimated. Below is a graphic representation of the cost versus value retrieved from the process. The red portions are the cost and the green portion is the value. It can be seen from this that the costs often outweigh the value. Some of the fractions need to be re-processed in other plants to create products of value. This is where the value increases and a cash positive business case can be developed. This should always be considered when establishing the treatment facility.



4.8. Business Plan Development

Dismantling of WEEE can be an opportunity for entrepreneurs to set up sustainable recycling businesses and creating green jobs. However, a lot of challenges have to be faced when implementing a new dismantling facility, e.g.:

- An efficient strategy for collection of e-waste from different input streams (households, B2B-collection ...) has to be identified and set up. Eventually purchase prices have to be paid for receiving the e-waste.
- Some of the collected appliances like desktop PCs or notebooks have an intrinsic value where revenues from trading fractions coming out of the dismantling of these appliances can cover the treatment costs. This is different for quite a few other appliances like CRT devices where dismantling expenses and disposal costs are usually higher than the achievable revenues.
- For each of the produced output fractions downstream partners have to be found. Some of the fractions, like copper, steel and aluminium can usually be treated locally. For other fractions like printed circuit boards a global market with quite volatile characteristics exists where prices offered for the same fraction can vary up to 40% within one year.
- Depending on the location of the facility transport costs for the output fractions to the different downstream partners (material recovery or disposal facilities) on national, regional and international level may significantly reduce the potential revenues.
- Depending on the local labour costs and existing mechanical recycling plants in the region, it might be necessary to dismantle appliances into as many pure fractions as possible or to apply a more superficial dismantling strategy focusing on depollution only and leaving material separation to mechanical recycling plants.

Therefore, when developing a business plan for a manual dismantling facility for e-waste, a series of different factors have to be taken into account, like legal framework conditions, potential input stream and mix, required personnel and infrastructure, downstream markets as well as the proper set-up of the facility. In order to strategically plan the development of a facility, the following steps should be conducted:

1. Analysis of the legal framework conditions
2. Get insights on the e-waste generation and mass-flows for the region
3. Stakeholder analysis (incl. potential competitors)
4. Estimation of the potential input (quantities and mix of appliances)
5. Definition of potential purchasing costs and / or collection fees
6. Planning of modes of collection and if applicable transportation of appliances
7. Development of the process chain and applied dismantling steps taking into account the expected input quantities and material mix
8. Planning of required personnel, equipment and infrastructure
9. Estimation of expected output fractions (material composition and quantities)
10. Identification of potential downstream options for hazardous as well as recyclable fractions
11. Design of a plant layout taking into account the required space for storage, work places, internal transportation and offices
12. Development of cooperation agreements with downstream partners (including transportation options)
13. Definition of costs (investment costs as well as running costs)
14. Calculation of revenues

In order to support entrepreneurs in the complex planning process of establishing a manual dismantling facility, the StEP Initiative [1] developed a Business-Plan-Calculation Tool. The main objective of the tool is to provide the user with a basis for further calculating a business plan. As the input data can easily be adapted, the tool can be used to develop different scenarios.

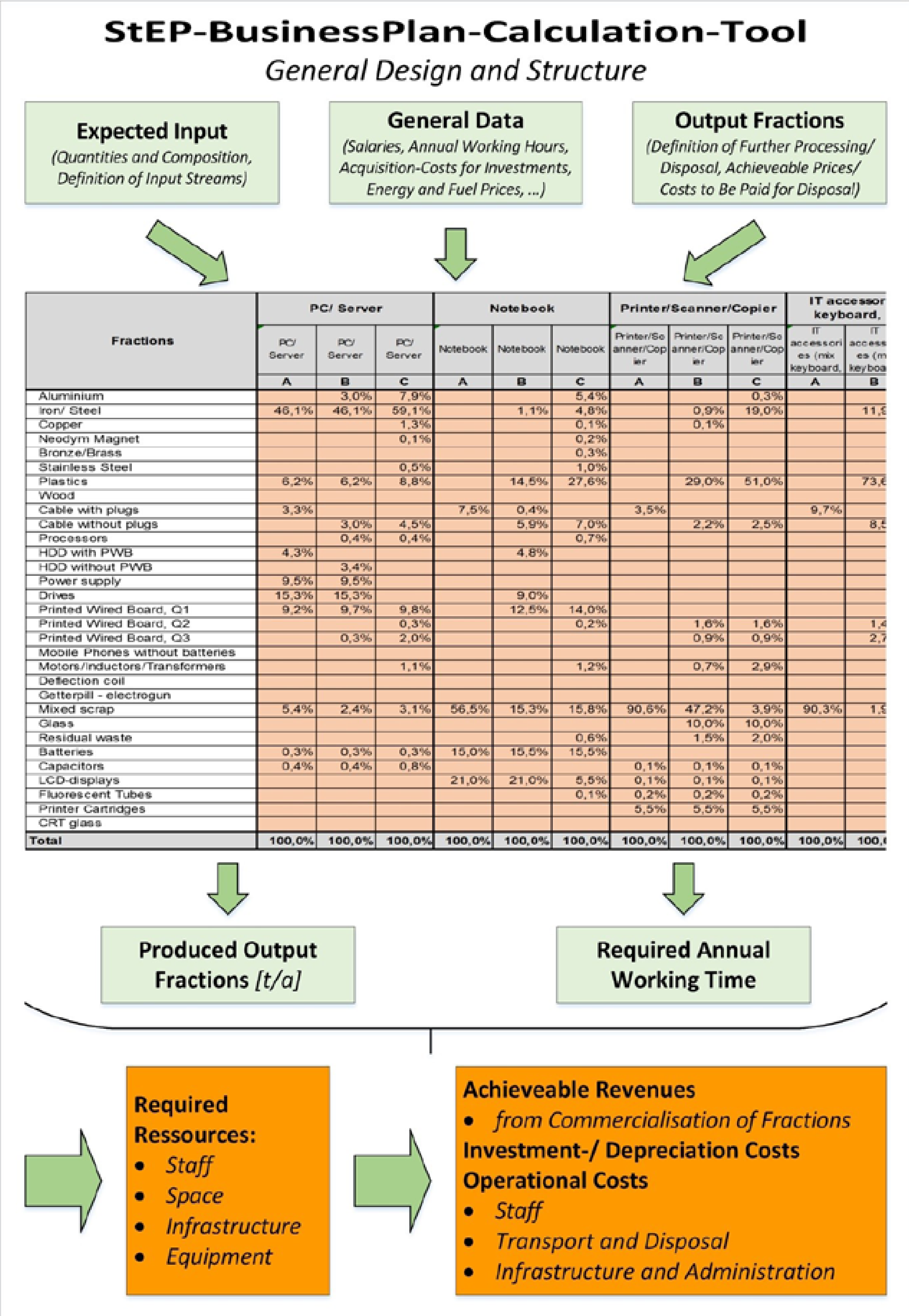
The following data have to be entered into the tool:

- Average salaries and annual working hours in the country
- Local price situation for energy and fuel
- Average rental and construction costs per sq. feet / sq. meter
- Purchase prices for investment of equipment and infrastructure
- Achievable revenues or disposal costs for each output fraction
- Average transport distances for each collection and downstream scenario
- Local interest rate for credit/loan
- Taxes to be paid

Based on the data input and the chosen dismantling levels as well as downstream options, the tool automatically calculates the following information on an annual basis:

- Quantities of produced output fractions
- Required staff, investments and equipment
- Required space for administration, dismantling, storage, etc.
- Expected revenues and operational costs
- Entire profit and loss forecast
- Computed break-even

1 Solving the E-Waste Problem Initiative, founded in 2004 as an international multi-stakeholder platform (www.step-initiative.org)



Fractions	PC/ Server			Notebook			Printer/Scanner/Copier			IT accessor keyboard,	
	PC/ Server	PC/ Server	PC/ Server	Notebook	Notebook	Notebook	Printer/Scanner/Copier	Printer/Scanner/Copier	Printer/Scanner/Copier	IT accessories (mix keyboard,	IT accessories (m keyboa
	A	B	C	A	B	C	A	B	C	A	B
Aluminium		3,0%	7,9%			5,4%			0,3%		
Iron/ Steel	46,1%	46,1%	59,1%		1,1%	4,8%		0,9%	19,0%		11,
Copper			1,3%			0,1%		0,1%			
Neodym Magnet			0,1%			0,2%					
Bronze/Brass						0,3%					
Stainless Steel			0,5%			1,0%					
Plastics	6,2%	6,2%	8,8%		14,5%	27,6%		29,0%	51,0%		73,
Wood											
Cable with plugs	3,3%			7,5%	0,4%		3,5%			9,7%	
Cable without plugs		3,0%	4,5%		5,9%	7,0%		2,2%	2,5%		8,
Processors		0,4%	0,4%			0,7%					
HDD with PWB	4,3%				4,8%						
HDD without PWB		3,4%									
Power supply	9,5%	9,5%									
Drives	15,3%	15,3%			9,0%						
Printed Wired Board, Q1	9,2%	9,7%	9,8%		12,5%	14,0%					
Printed Wired Board, Q2			0,3%			0,2%		1,6%	1,6%		1,
Printed Wired Board, Q3		0,3%	2,0%					0,9%	0,9%		2,
Mobile Phones without batteries											
Motors/Inductors/Transformers			1,1%			1,2%		0,7%	2,9%		
Deflection coil											
Getterpill - electrogun											
Mixed scrap	5,4%	2,4%	3,1%	56,5%	15,3%	15,8%	90,6%	47,2%	3,9%	90,3%	1,
Glass								10,0%	10,0%		
Residual waste						0,6%		1,5%	2,0%		
Batteries	0,3%	0,3%	0,3%	15,0%	15,5%	15,5%					
Capacitors	0,4%	0,4%	0,8%				0,1%	0,1%	0,1%		
LCD-displays				21,0%	21,0%	5,5%	0,1%	0,1%	0,1%		
Fluorescent Tubes						0,1%	0,2%	0,2%	0,2%		
Printer Cartridges							5,5%	5,5%	5,5%		
CRT glass											
Total	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,

Figure 1: Structure of the business plan calculation tool

5.

How to Organise Trainings

5.1 Target Audience

E-waste specific health and safety issues are of concern even to groups that are not directly involved in dismantling. Consequently, the target audience for trainings is anyone involved in now informal e-waste downstream activities, who is willing to learn about sound practices, and ready to change even longstanding habits, e.g.:

- Collectors
- Persons engaged in transportation
- Dismantlers
- Shop owners
- Repair shops
- People involved in production (such as aluminium melting, or making new cooking pots out of recycled aluminium)
- Women and girls selling water and food to the workers on site
- Cable burners

It is important to keep in mind the specific target audience and its particular needs when planning a training workshop and choosing content from the whole range offered in the Training Manual.

5.2. Training Aims

Central aim of any training is to transmit knowledge about e-waste and how to handle it in a safe and economically viable way. The topics are to be chosen according to the target group's extent of exposure to negative impact from e-waste and/or related income opportunities. Shop owners will be trained in management of a business, whereas other participants might need more focus on the hazardous components of certain types of e-waste, and their detrimental health impact.

5.3. Location or Venue

The GIZ training workshop has been set up for the very purpose of providing trainings to people working and living in and around the scrap yard of Old Fadama. It is the given location for theory lessons and ideal dismantling sessions, with appropriate tools.

At individual shops, the aim will be to improve the situation, in terms of layout, safety issues (such as fire, leakage into the soil…), or intermediate storage of fractions.

5.4. Selection of Participants

A pair of trainers should be able to train a class of maximum 20 people at once. Since the content of each training will vary according to the target group, it is important to gather people who are engaged in more or less the same activity for any planned workshop. The participants should be able to name their concerns, raise issues to be addressed, and commit to the entire duration of the workshop.

5.5. Designing the Set-Up

When it comes to actually planning training workshops, these typical questions need to be considered and carefully answered:

- **Who will be in the training programme?**
  Define the type of audience(s) according to their profession or occupation and the characteristics they have in common. Have a clear idea of how many people should be trained, in total, and which subgroups you want to distinguish.
- **What are the concrete training needs?**
  Find out what the biggest problems are for each target group and subsequently, what is most important to learn for each one of them.
- **Which contents have to be included to meet these needs?**
  The training agenda: elaborate the specific topics to be taught. There might be general content that is relevant to all, no matter which sub-group you are dealing with, and there will be specific content that is only targeted to a specific audience. Ideally, come up with modular "training building blocks" that can then be put together in sequence to form an individualised curriculum.
- **How are these contents going to be taught?**
  Adapt the learning resp. teaching methods and materials to the education level of your audience, its cultural and language background, the training site, and the infrastructure available. Choose from a variety of preferably participatory methods, in order to grant for maximum impact: photo or video show, storytelling, demonstration, hands-on training, group discussion, local industrial theatre, games…
- **Where are the trainings going to take place?**
  Decide which parts of the training are better set in a training facility environment and which might be better taught directly on the ground, at the participant's workplace.
- **When are the trainings going to take place?**
  Find out what are better and less appropriate times for your target group in terms of season of the year, days of the week, time of day. Design your training schedule respecting e.g. prayer times, customs and traditions, and working hours of your participants.
- **Who are the trainers?**
  Establish specific roles and responsibilities within a training team, taking advantage of each individual's background and capacities. Some might be better at presenting (and preparing presentation material), and others might excel in technical sessions.
- **What are the key performance indicators?**
  In order to build a legacy, create a system of quality management and measurement framework for future workshops: determine which indicators of change should be achieved.

It can be of advantage to stage a special 3-day "Training Design Workshop" in order to answer all these questions, involving the funding entity, the future trainers, and possibly the agency that will organise the training workshops in the future.

5.6. Preparing Training Materials

The training material should be put together depending on the target group, choosing the type and amount of content according to the specific needs.

1. Take into consideration the grade of literacy to be expected.
2. Prepare reusable training materials, with the help of Chance for Children.
3. Decide which material is only for the training, and which material is of most importance to the participants and can stay with them (and has then to be reproduced for the next training).
4. Be inventive and creative, exchange experiences with your colleagues, use what works, discard what doesn't.
5. If possible, laminated paper sheets to be handed out – they will last longer.
6. When preparing presentations, keep them as simple and short as possible; leave enough time for questions and discussion.

5.7. Applying different Training Methods

Keep frontal lecturing to a minimum: the more participative you develop your workshop, the better for the actual learning effect on the participants' side. Use games, group work and interactive sessions as far as possible. Again, exchange ideas and experiences with your co-trainers. More creative and engaged minds – more worthwhile tries and new approaches.

6.

Literature, References and Links

6.1. Summarized References

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6.2. Document Download Locations

SRI: Baseline Assessment on E-waste Management in Ghana
https://sustainable-recycling.org/sampson_2016_sri-ghana/

SRI: From Worst to Good Practices in Secondary Metals Recovery
https://www.sustainable-recycling.org/from-worst-to-good-practices-in-secondary-metals-recovery/

SRI: Life Cycle Assessments of Selected Worst Practices in Secondary Metals Recovery and Recommendations to Move Towards Good Practices
https://www.sustainable-recycling.org/wp-content/uploads/2018/09/LCI-Worst-Practices_180831_.pdf

UNEP: E-waste Inspection and Enforcement Manual http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-EWASTE-MAMUAL-INSPEnforcement.English.pdf

UNODC: Transnational Organized Crime in East Asia and the Pacific chapter 9: Illicit trade in electrical and electronic waste (e-waste) from the world to the region
https://www.unodc.org/documents/toc/Reports/TOCTA-EA-Pacific/TOCTA_EAP_c09.pdf

6.3. Website Links

www.acen.africa
www.makerspaces.com
www.kumasihive.com
www.qamp.net
www.ellenmacarthurfoundation.org
www.storyofstuff.org
www.step-initiative.org
www.sustainable-recycling.org
www.ifixit.com
www.werecycle.eu

7.

Annex

TOOLS LIST

Tools	Sizes (mm)	Remarks
Lockable Tool Box		
Set of slotted-head screwdrivers	2,5 / 3,5 / 4 / 5,5 / 6,5 / 8	
Set of cross-head screwdrivers	0 / 1 / 2 / 3	Phillips head
TORO Grip Bits - PH 1	150 mm	
TORO Grip Bits - PH 2	150 mm	
Pozidriv screwdriver set	1 + 2	4 pc set
Set of inner hex profile screwdrivers	5/ 5,5 / 6 / 7 / 8 / 10 / 13	7 pc set
Set of torx screwdrivers	7 / 8-9 / 10-15 / 20-25/ 27	10-pc with handle
Chisel screwdriver	8 x 150 mm	with all-metal body & end
Set of mini bit screwdrivers		for laptops & mobile phones
Side cutter	160 mm	for cables
Universal pliers	180 mm	
Hammer	500 g	
Shears or industrial scissors		to cut wires
Cutter with extra blades		
Pipe wrench	250 mm	
Set of 8 Ring / Open-End Spanners	6 to 19	dismantling of large household appliances
Socket wrench set	4 to 14 mm	dismantling of LHHA
Hammer	1,25 kg	dismantling of LHHA
Magnet		to detect ferrous metals
Workplace Equipment		
Work Bench		
Scale		
Small boxes or containers		for smaller fractions (batte-ries, capacitors,
Large boxes		for larger fractions (metals, plastic…)
Hand brush		for cleaning the workplace
PPE		
safety gloves		
safety shoes		
apron		
dust mask		
safety goggles		
arm protection cuffs		to protect from splinters when dismantling CRTs

GROUP WORK - DISMANTLING

Equipment: ______________________________

Group: ______________________________

Total Weight: ______________ Time: ______________

Fraction	Weight	% of Total