Guide to Disassembly

Waste Electrical and Electronic Equipment

REMINARE
CETEM CENTRO DE TECNOLOGIA MINERAL
UNIDADE DE PESQUISA VINCULADA AO MINISTÉRIO DA CIÊNCIA, TECNOLOGIA, INOVAÇÕES E COMUNICAÇÕES
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Presentation

The management of Waste Electrical and Electronic Equipment (e-waste) represents a challenge for managers and decision-makers, since e-waste are residues that can be characterized as hazardous, due to their composition with substances harmful to human health and the environment. On the other hand, such residues contain elements with high market value and difficult prospecting, such as gold, silver, platinum, among others, which justifies, therefore, special management of e-waste through strategic practices of environmentally appropriate destination with the recovery of value through urban mining.

Non-destructive manual disassembly techniques for e-waste are considered more thorough and effective options for recovering the value of waste, since they are based on visual segregation and the worker's experience. To guarantee the maximum possible recovery of e-waste value, non-destructive disassembly techniques are configured as the most appropriate, to avoid the mixing of materials, enhancing the recovery of materials and contributing to social inclusion recommended by the Brazilian Policy on Solid Waste (BPSW). On the other hand, the destruction of these residues using destructive techniques would generate a mixture of components and increase the degree of difficulty in separating those valuable from the other elements with low market value in the industry.

Thus, this document aims to guide companies, cooperatives and associations of waste pickers, environmental education professionals, among others, regarding the basic and appropriate procedures for the manual disassembly of e-waste, addressing, in particular, information technology equipment (IT) and telecommunications. To this end, this manual has been divided into six parts:

i) Presentation of the guide, with its justifications and objectives;

ii) Theoretical approach with basic concepts regarding e-waste and its regulation in Brazil;

iii) General e-waste disassembly procedures, pointing to the particular cases of IT and telecommunications waste, and the presentation of techniques for recovering secondary raw material;

iv) Final considerations, bringing the challenges of the e-waste segment in Brazil, in addition to the contributions of this guide and the next steps;

v) Presentation of the technical team responsible for preparing this guide, and

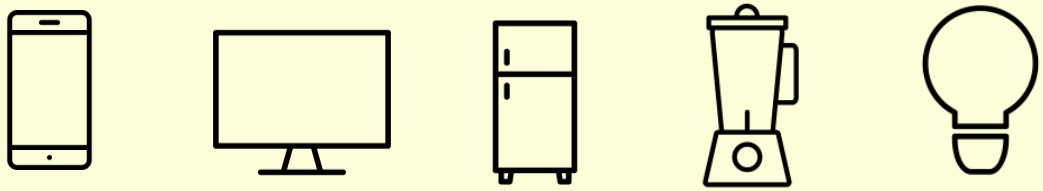
vi) References.

2

E-waste and Reverse Logistics Systems

Waste Electrical and Electronic Equipment (E-waste)

Waste electrical and electronic equipment (e-waste) is that resulting from the consumption of products that require energy (electric current or accumulators - batteries) for their operation.



Due to its particularities, such as its multimaterial composition and substances that are both harmful and valuable to the market, this type of waste is considered special, requiring differentiated management.

Despite the variety of components, e-waste, in general, consists mainly of ferrous metals, aluminium, copper and plastics, and, in smaller quantities, but not less impacting, toxic metals (ARDI, 2016), substances that are highly harmful to the human health and the environment, when disposed of inappropriately.

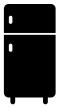
Electrical and electronic equipment also have elements of high added value, such as gold, silver, palladium, the so-called precious metals. In addition to these, e-waste has in its composition metals of lower added value, such as copper, aluminium, etc. In addition to metals, such as chromium, cadmium, mercury and lead, with potential for environmental risks.

Waste Electrical and Electronic Equipment (E-waste)

Thus, it is understood that the management of e-waste is not only necessary to avoid contamination and environmental impacts, but also as a strategy to recover these valuable elements again in the production chain. Precious metals correspond to 80% of the intrinsic value of the equipment, however they do not reach 1% of the total weight (ABRACI, 2010 apud DE MORAES et al, 2014). The idea of using e-waste as new sources for the extraction of strategic minerals, such as gold and silver, has gained strength in the productive market in recent years, and has come to be called Urban Mining, a more sustainable way of extracting raw materials. Conceptually, urban mining is the recirculation or recycling of post-consumer products and materials in the form of secondary raw material, as a way of minimizing environmental impacts, valuing waste, and creating and optimizing economic benefits in favor of a sustainable environment (XAVIER & LINS, 2018).

Waste Electrical and Electronic Equipment (E-waste)

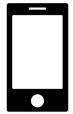
A proposal for the classification of e-waste, adapted from Xavier et al (2017), considers eight categories:



Large household appliances

Small household appliances

Monitors

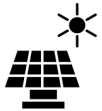


IT and Telecommunication

Cables

Batteries

Lighting equipment



Photovoltaic panels

This proposal for the classification of e-waste considers batteries, batteries and lamps, in addition to highlighting some interesting components for the reconditioning, remanufacturing, recovery and recycling markets, such as wires and cables, which are very valuable due to the significant presence of copper in its composition. Photovoltaic panels should also be included in this categorization soon, because of the increased disposal of these post-consumer products.

Brazilian Regulation

Environmental Crimes Law no. 9,605/1998

Brazilian Policy on Solid Waste no. 12,305/10

Decree no. 7,404/10 - Regulates the Brazilian Policy on Solid Waste

Decree no. 9,177/2017 - Regulates article no. 33 of Law no. 12,305/2010 and changes Decree no. 7,404/2010

Decree no. 9,373/2018 - Movable assets within the scope of the direct, autarchic and foundational Brazilian federal public administration

Sectoral Agreement for Reverse Logistics of E-waste

Decree no. 10,240/2020 - Regulates the implementation of a reverse logistics system for electronic products and their components for domestic use

Reverse Logistics Systems (RLS)

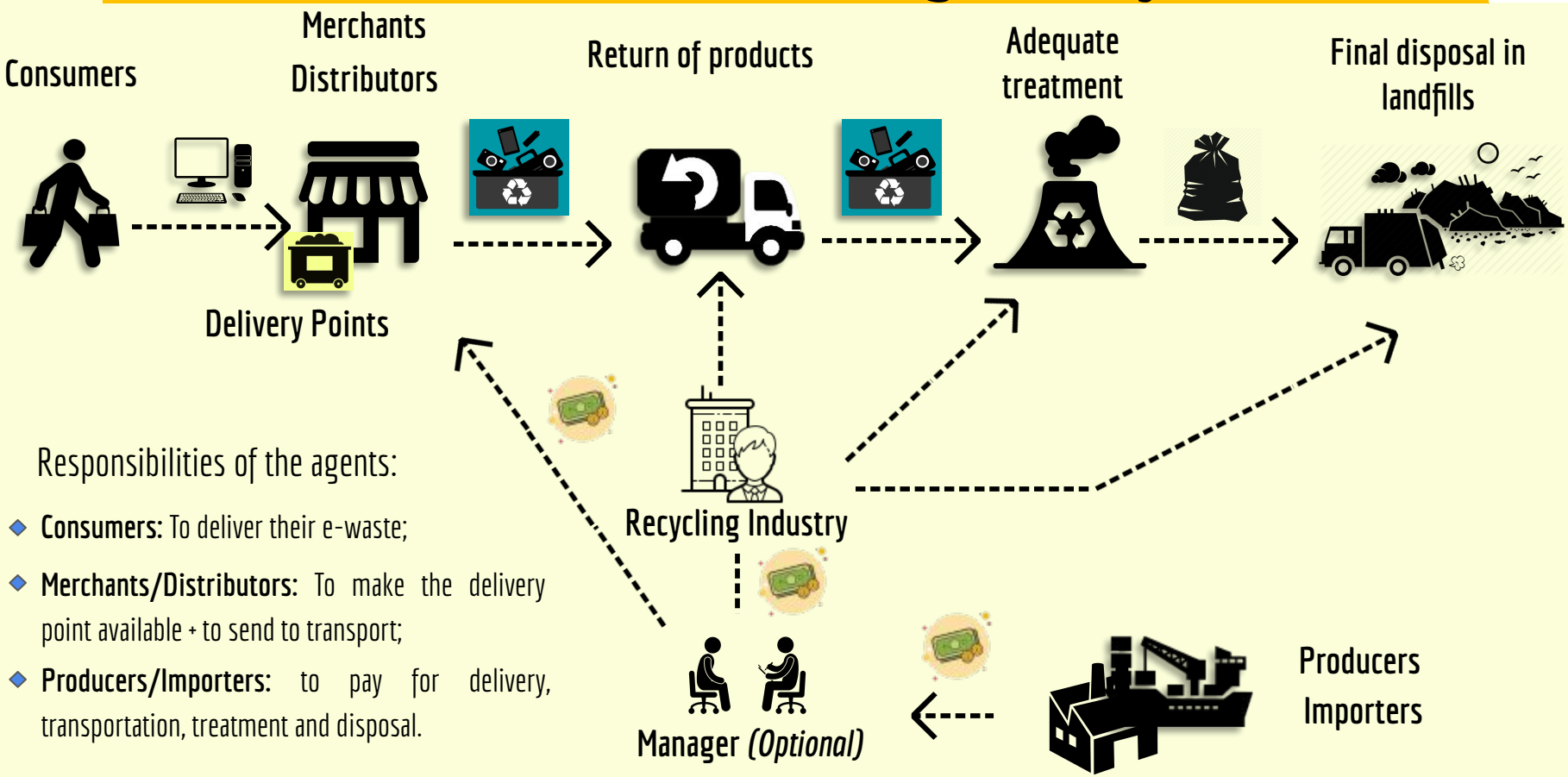
Based on the concept of shared responsibility for the life cycle established by the Brazilian Policy on Solid Waste, it is understood that, in reverse logistics, each agent has specific responsibilities. In general, consumers are responsible for disposing of waste properly, segregating the categories and disposing of them in an appropriate place or returning them to the merchant; while traders, distributors, producing industries and importers (direct chain) are effectively responsible for the implementation of reverse logistics systems (RLS)(Xavier et al., 2013).

The RLS consist of structured models for each class of materials and post-consumer products, intending to enable the environmentally appropriate collection, packaging, transportation, processing and disposal, such as the options for reuse, repair, reconditioning, remanufacturing, reverse manufacturing and recycling (Xavier et al., 2017).

Extending the useful life of products is the first alternative to consider according to the concept of Circular Economy (URBINATI et al, 2017). The other alternatives, including recycling, consist of techniques that require a greater or lesser degree of disassembly of products to reuse parts, parts and components. Recycling, in turn, requires the disassembly or destruction of products to reuse materials through urban mining techniques - a concept that has been gaining strength since the last decade.

After the phase of discarding waste, in primary logistics, transport is done with the product intact. However, for subsequent steps, disassembly contributes to logistical efficiency and optimization of routes to the destination, in secondary logistics.

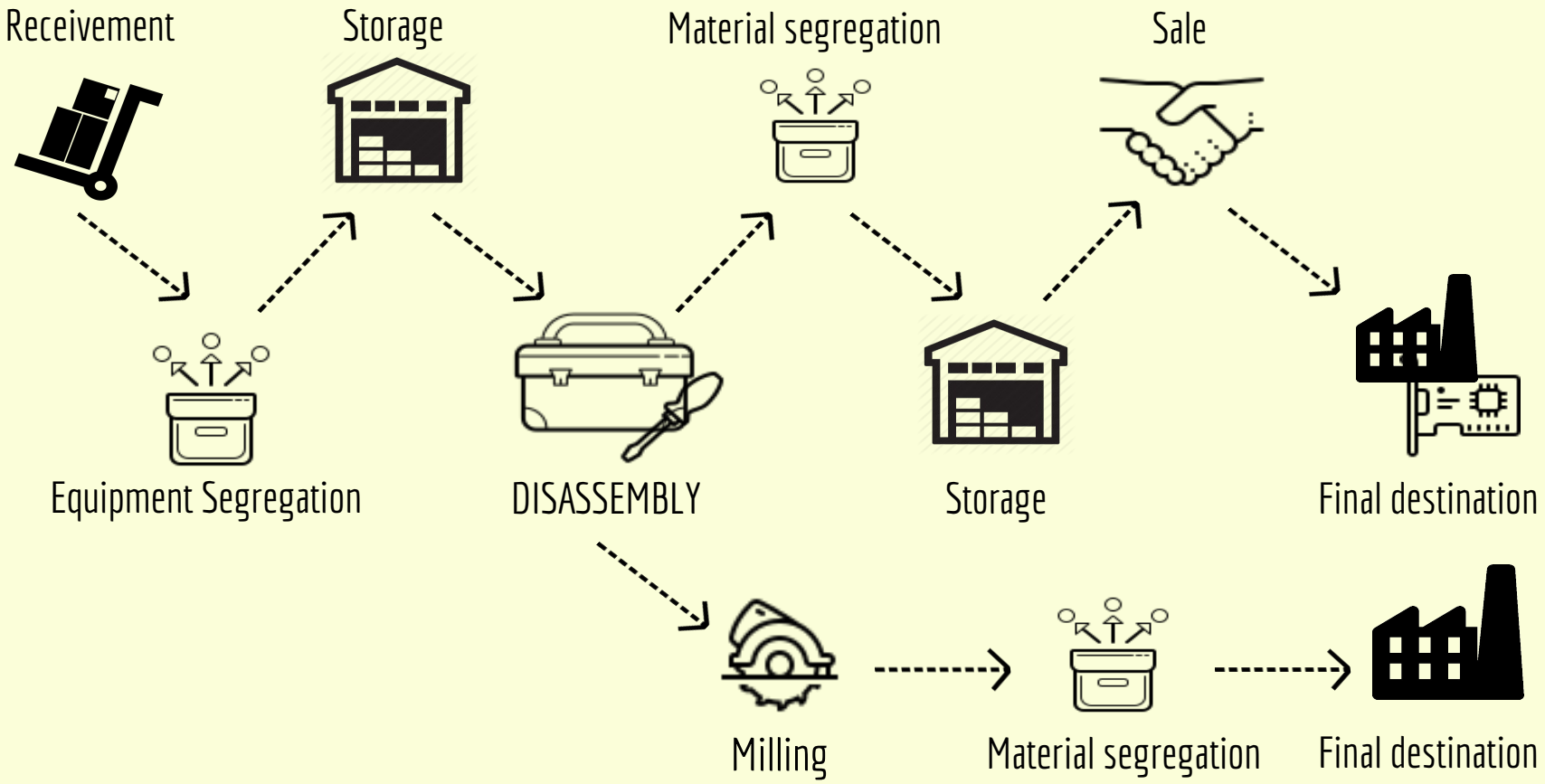
Reverse Logistics Systems (RLS)



Responsibilities of the agents:

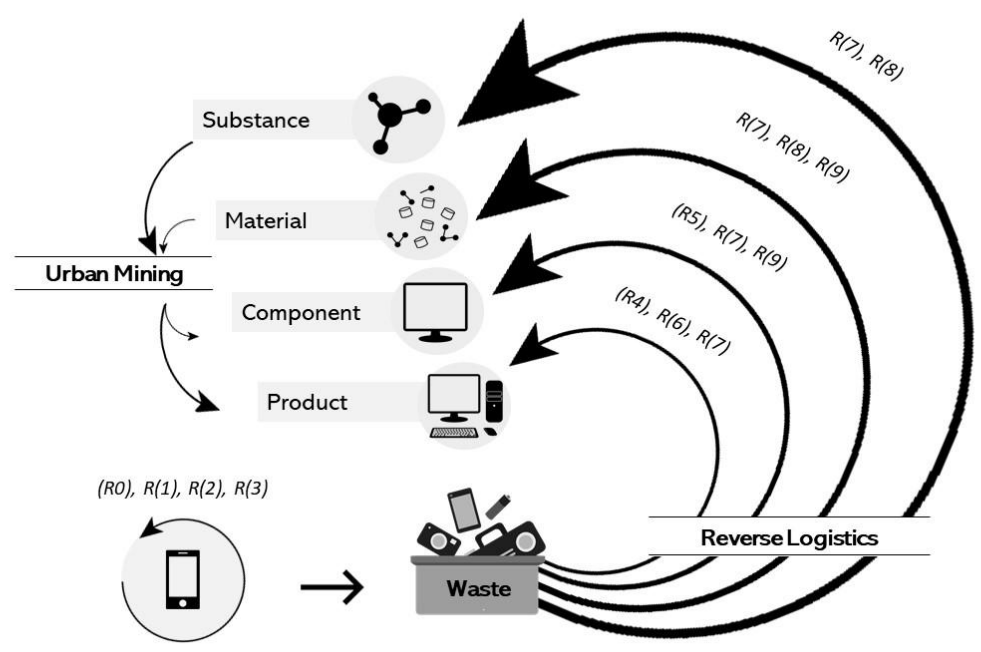
- **Consumers:** To deliver their e-waste;
- **Merchants/Distributors:** To make the delivery point available + to send to transport;
- **Producers/Importers:** to pay for delivery, transportation, treatment and disposal.

Logistic Procedures



Waste Electrical and Electronic Equipment (E-waste)

Relation between Urban Mining and Reverse Logistics for e-waste management, and the 10 Retention Options for e-waste value recovery (R0-R9):



Source: Based on Ottoni et al., 2020

R0: Refuse

R1: Reduce

R2: Reuse

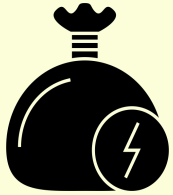
R3: Repair

R4: Refurbish

R5: Remanufacture

R6: Repurpose

R7: Recycle



R8: Recover (Energy)

R9: Remine

3

The Disassembly of E-waste

About the E-waste Disassembly

Why to disassembly e-waste?

Due to the heterogeneous (multimaterial) composition of each e-waste, the potential for adding value by separating the different parts of this waste is understood. The disassembly is designed to separate the parts that can be used, with the purpose of commercialization, in addition to facilitating the correct destination of each type of material for future reuse/recycling.

Disassembly Types

Disassembly for cargo compaction and environmentally appropriate disposal can be:

(a) Destructive: without considering the preservation of parts and components, or the need for segregation of materials;

(b) Non-destructive: considers the reverse procedure of the assembly to preserve materials and components.

About the E-waste Disassembly

Disassembly Costs

It is difficult to estimate the cost of an electronic equipment disassembly due to its different materials. Also, for calculating the costs, transport of the post-consumer product, labour and storage must be considered.

Disassembly Regulation

There is no specific regulation on the e-waste disassembly. However, work safety standards must be observed, as well as the penalties resulting from inadequate logistics throughout the destination (Brazilian Environmental Crimes Law - Article no. 56).

How to properly discard e-waste?

According to the Sectoral Agreement, post-consumer electronic equipment must be discarded by the consumer, always turned off and without personal data. In the case of batteries and lamps, dispose of separately.
In the case of contracting the destination service, there may be a joint data destruction service or agreement to restrict the use of e-waste.

4.1. Criteria for non-destructive disassembly

The method of non-destructive disassembly of e-waste adopted by CETEM used some criteria:

- **E-waste Category**
- **Disassembly environment**
- **Tools**
- **Conditions for the workers**

4.1.1. E-waste Category

Post-consumer products must be segregated by categories to optimize the disassembly process, since each category, due to its particularities, requires different methods and tools.

Thus, due to the higher added value and greater availability in the market, the categories considered in this guide refer to the typologies of:

- **CRT and LCD Monitors**
- **Computing and Telecommunications (offices and printers)**
- **Wires and cables**

4.1.2. Disassembly Environment

Certain criteria must be considered during the preparation of the dismantling site, in order to provide security to the workers and to improve their performance The disassembly environment must be closed due to bad weather conditions and must have the following parameters evaluated:

- **Adequate lighting**
- **Proper ventilation**
- **Elongated table for disassembly (covered with Ethylene Vinyl Acetate sheets or other insulators)**

Thus, it is necessary to have an airy environment, since some parts of the equipment, when disassembled and/or damaged/broken, may release toxic gases or bad odours. Also, there is a need for good lighting, as some parts have very small sizes, as well as darkened colours, which in the absence of adequate clarity are capable of compromising the final product of disassembly.

The storage of pre-disassembly materials must be done with certain care, in order to avoid the mixture of materials with toxic potential, contact with water, delicate equipment breakage and risk of falling. If the equipment comes with batteries, their prior removal is necessary.

4.1.3. Tools

Each type of equipment requires certain tools for its disassembly. Thus, the suggested tools for the e-waste disassembly procedure are as follows:

- **Screwdrivers of varying sizes (screws)**
- **Universal pliers (wire and cable cutting)**
- **Philips screwdrivers**
- **Stylus cutter**
- **Balance**

4.1.4. Worker safety

For the work to be carried out under safety conditions, the operator must use the necessary personal protective equipment (PPE).

In this case, the presence of goggles and a pair of gloves are recommended.

- **Use of PPE (non-slip gloves, goggles, disposable mask)**
- **Long pants**
- **Closed shoes**

Disassembly Steps

For the disassembly of e-waste, the provision of space for the reception and packaging of post-consumer products, accommodation of workstations and tools, in addition to a space for the localization of different materials obtained during disassembly.

Post-consumer products must be accommodated by categories to optimize the disassembly process. Similar equipment requires the same tools and procedures.

To assemble the workstation, the tools must be made available according to the product categories to be disassembled.

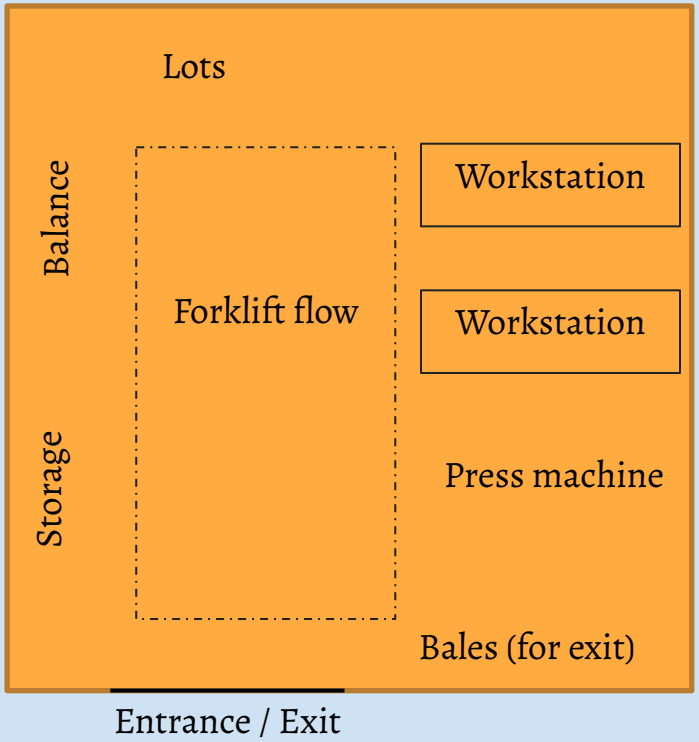
It is important to note that the areas must always be covered, with waterproofed floors and ventilation.

Disassembly Steps

For the e-waste disassembly, the following parameters must initially be considered:

- Space layout
- Number of post-consumer products
- Assembly of the workstation
- Movement of people, equipment and materials

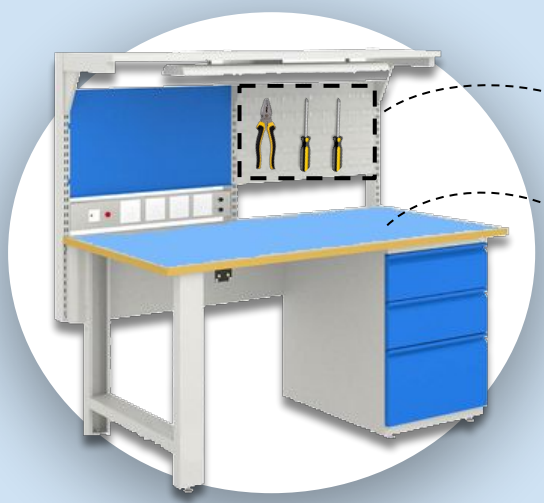
Suggested layout for e-waste disassembly environment.



Preparation of the Disassembly Workstation

The disassembly workstation must have a table of elongated length, covered by thin juxtaposed EVA (Ethylene-vinyl acetate) plates, glued on the table top using a double-sided tape and used to avoid the origin of surface damage and protection from possible electrostatic charges. The workstation must be of a suitable height for the worker to avoid long-term posture problems.

Disassembly Workstation Layout



E-waste

Tools

Countertop covered with EVA

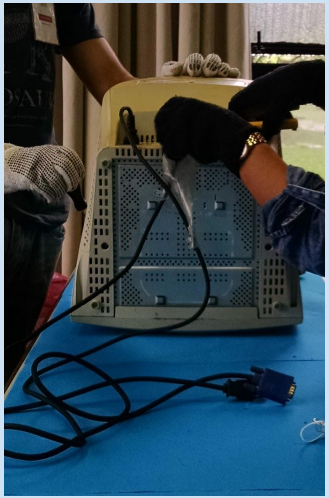
The disassembly process

The equipment must be arranged and separated into groups according to their classification (appliances, electronics, IT, monitors), aiming to facilitate the operator's work during disassembly and to guarantee a maximum degree of recovery.

The equipment must be segregated with the aid of tools, to obtain groups of materials (plastic, metal, glass, rubber) and components (wires and cables, printed circuit boards, source, copper yokes) that have market value. Thus, when dismantling equipment, materials and components are weighed separately.

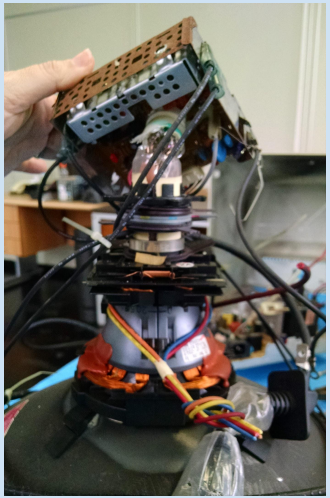
The degree of separation of materials/components requires knowledge of the buyer's needs. For example, some buyers of materials or components may require a greater or lesser degree of segregation depending on the intended destinations, thus avoiding wasted time.

Disassembly of CRT Monitors

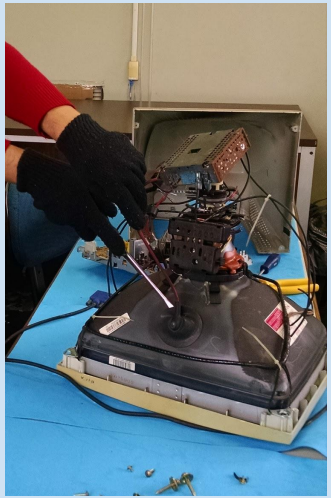


Start the procedure by removing the cables and the base.

Do not break the screen glass.



It is important to pay attention to the lamp breaking during the separation of the parts.



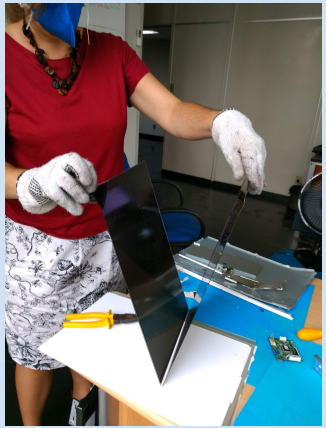
With the aid of a screwdriver, remove the rubber cover for loss of vacuum.

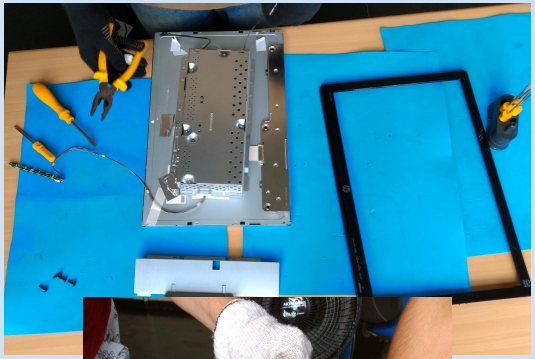
Be careful not to pierce the CRT tube behind the screen.

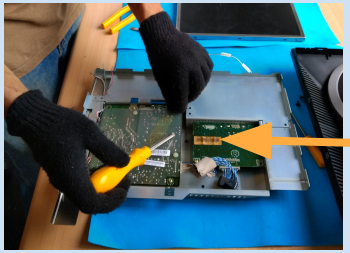
The main parts are the plates, wires, plastic housing, metals, yoke (copper) and the screen next to the CRT tube.

The screen with the tube must be used as a hazardous waste.

Disassembly of LCD Monitors





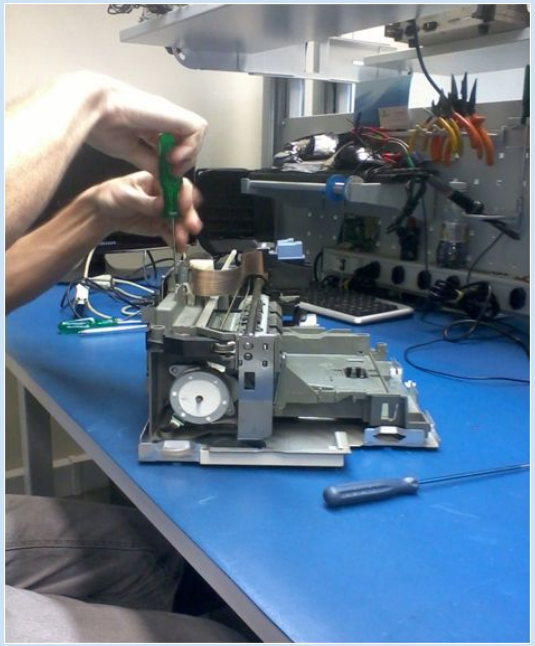


Printed circuit board and processor

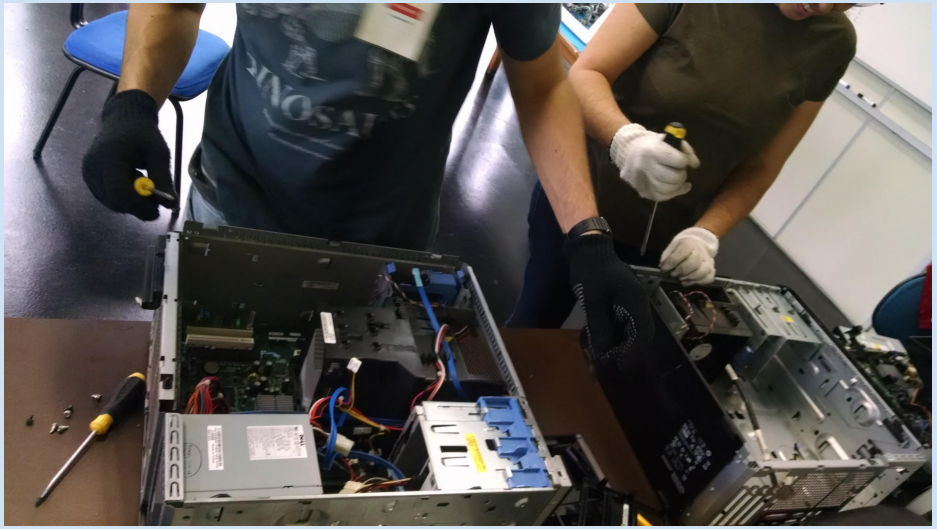
Lamps

Disassembly Steps

Printer Disassembly



Disassembly of Computer Cases



Data security

In equipments in which there is storage of personal data, such as desktop, cell phones, pen drives, external HD, credit card data processing terminals (“card machine”), notebooks, laptops, tablets, Ipods, Kindle, among others, the destruction of the parts responsible for data storage, such as HD, memory card and memories, is necessary.

This procedure is extremely important for the protection of users' personal and professional data and can prevent access and misuse of information.

Disassembly Values and Time

Useful for negotiating material purchase values, profit obtained and time needed for disassembly, the use of control sheets to make budgets and calculate the time to be reserved for a batch of equipment is essential for the finances of an organization in the segment.

For this purpose, it is necessary to know the composition of each equipment (plastic, metal, glass, etc.), if there is a buyer for each material or it will cause a cost with the destination, sales value/cost of each material (always updated), in addition to a estimated time needed for disassembly based on real practices.

Spreadsheet Template

Value Recovery

The post-disassembly steps aim to recover the value contained in the waste.

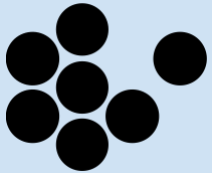
In the case of e-waste, such materials undergo disassembly, followed by processing, and, finally, refining.

The issue of storage of post-disassembly materials is crucial for ensuring the quality of such equipment, preventing these materials from being damaged before processing.

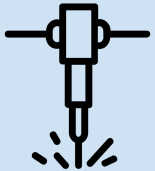
In the Beneficiation/processing stage, the materials are processed by crushing and separation, which can be magnetic, by density, by electric charges, etc. This step aims to segregate the final product of disassembly, concentrating the substances of interest. Thus, it is of great importance in the economic viability of the e-waste treatment process.

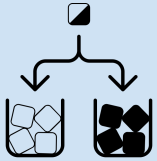
After beneficiation, the resulting materials pass through the refining stage, responsible for the actual extraction of the metals and polymers of interest.

Value Recovery



Sorting and Disassembly





Beneficiation

Crushing

Separation
(densimetry, vibration / spray, micronization, electrostatic separator)

Metallurgical Treatment and Refining

Extraction of Metals

4

Final considerations

Compared to destructive options, such as grinding, the manual dismantling of e-waste, despite requiring a longer processing time, adds considerably more value to the waste, as it avoids the mixing of different materials to facilitate its treatment.

However, all disassembly techniques require that a considerable and continuous volume of e-waste arrives for processing at the end of its useful life through reverse logistics systems.

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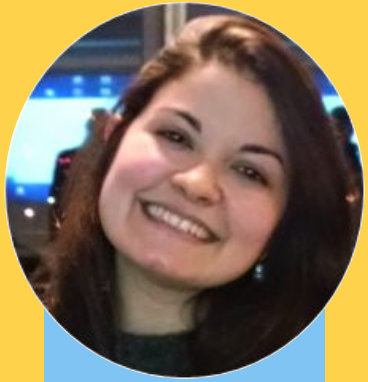

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6 Bibliographic references

ARDI, R., 2016. Waste Electrical And Electronic Equipment Waste Electrical And Electronic Equipment (Weee) Management Systems (Weee) Management Systems In The Developed And The Developing Countries: In The Developed And The Developing Countries: A Comparative Structural A Comparative Structural Structural Study. Tese de Doutorado, Faculty of Engineering, Department of Mechanical Engineering and Process Engineering, Universität Duisburg-Essen. Germany.

Xavier, L. H., Lins, F. A. F., 2018. Mineração Urbana de resíduos eletroeletrônicos: uma nova fronteira a explorar no Brasil. Brasil Mineral, v. 379, p. 22-26

Xavier, L.H., Corrêa, H.L., 2013. Sistemas de Logística Reversa: criando cadeias de suprimento sustentáveis. São Paulo: Atlas, 2013.

Xavier, L.H., Lins, F.A.F., Nascimento, H.F.F., Bellan, I. O., Ribeiro, F., Caldas, M.B., Silva, L.O.S., Zomer, B., Araujo, R.A., Filho, O.O.D., Reinol, P.C., Fagundes, R.L., Gusmão, A.C.F., 2017. Manual para a destinação de resíduos eletroeletrônicos: orientação ao cidadão sobre como dispor adequadamente os resíduos eletroeletrônicos na cidade do Rio de Janeiro. 1ªEdição. Rio de Janeiro: Cetem.

Urbinati A., Chiaroni D, & Chiesa V., 2017. Towards a new taxonomy of circular economy business models, Journal of Cleaner Production, 168, 487-498. https://doi.org/10.1016/j.jclepro.2017.09.047.

Ottoni, M.S.O., Xavier, L.H., Dias, P., 2020. A circular approach to the e-waste valorization through urban mining in Rio de Janeiro, Brazil. Approved to be published in Journal of Cleaner Production.

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