# WASTE OF ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE)

**RELEVANCE OF WASTE STREAM:**

- Waste of electrical and electronic equipment (WEEE) consists of devices and components that can cause severe environmental damages based on contained hazardous substances and materials. But it also provides a huge recoverable resource potential, which demands a separate collection and treatment.
- The EU implemented the directive 2012/19/EU on waste electrical and electronic equipment that stipulates legally binding requirements on the collection and treatment and obliges producers to carry out their producer's responsibility.

**COMPOSITION/ MAIN MATERIAL COMPONENTS**

The generic term "waste of electrical and electronic equipment" or "scrap electronics" comprises a large spectrum of different consumer products. The waste stream is classified into 10 different categories according to the European directive 2012/19/EU, whereby the material composition highly fluctuates per type of device.

1. Large household appliances (LHA)
2. Small household appliances (SHA)
3. IT and telecommunications equipment (ITT)
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 shows orientation values for compositions of large household appliances (e.g. washing machines, cookers) small household appliances (e.g. toaster, fryers) and IT and telecommunications equipment (e.g. telephone, printer).

Table 1: Composition of categories (according to EMPA 2009)

| Material | Large HH appliances | Small HH appliances | IT equipment |
|---|---|---|---|
| Iron | 43 | 29 | 36 |
| Aluminium | 14 | 9.3 | 5 |
| Copper | 12 | 17 | 4 |
| Plastics | 19 | 37 | 12 |
| Glass | 0.017 | 0.16 | 0.3 |
| Gold | $6.7E^{-07}$ | $6.1E^{-07}$ | $2.4E^{-04}$ |
| Silver | $7.7E^{-06}$ | $7.0E^{-06}$ | $1.2E^{-03}$ |
| Palladium | $3.0E^{-07}$ | $32.4E^{-07}$ | $6.0E^{-05}$ |
| Indium | 0 | 0 | $5.0E^{-04}$ |
| Lead | 1.6 | 0.57 | 0.29 |
| Cadmium | 0.014 | $8.3E^{-03}$ | 0.018 |
| Mercury | $3.8E^{-05}$ | $1.9E^{-05}$ | $7.0E^{-05}$ |
| Plastics „brominated" | 0.29 | 0.75 | 18 |
| Lead glass | 0 | 0 | 19 |
| Others | 10 | 6.9 | 5.7 |

## EUROPEAN LEGISLATION AND REFERENCE DOCUMENTS

Current legislation of the waste stream of WEEE is given by the amended Directive 2012/19/EU on waste electrical and electronic equipment and the amended Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment. Member states are obliged to report collected and treated amounts of WEEE on a biannual basis according to Commission decision 2005/369/EG.

## NEEDS AND PRINCIPAL REQUIREMENTS FOR HANDLING THE WASTE STREAM

The member states in the EU consider the waste from electrical and electronic equipment as a material fraction with a high potential value but also one carrying a considerable amount of environmentally harmful substances and posing a risk to the environment when disposed off without appropriate precaution and treatment. That is why the above mentioned directives govern the separate collection and treatment of WEEE and stipulate restrictions to the use of certain hazardous substances in electrical and electronic equipment. Accordingly, mechanisms for the take-back and treatment of WEEE should be established by producers (producer's responsibility). They are legally obliged to label their products put on the market with the symbol of figure 1. It shall inform users about the necessity to collect the equipment separately from other waste streams to provide an adequate treatment. Consumers must be given the possibility to return their used items free of charge.

If other states than EU member states do not have similar legislations, take-back systems for WEEE, however, should be established to ensure an efficient recovery of value materials and to prevent damages to the environment caused by an inadequate disposal.

Figure 1: Symbol / label for the separate collection of waste electrical and electronic equipment

In order to prevent the generation of hazardous waste, producers ensure the substitution of various heavy metals (lead, mercury, cadmium, and hexavalent chromium) and brominated flame retardants (polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE)) in electrical and electronic equipment put on the market from 1 July 2006 on. Exemptions from this regulation, concerning for example fluorescent lamps, are being specially defined in the annex of directive 2011/65/EU. Targets for collection, recovery and reuse of WEEE should be frequently controlled and adapted under consideration of technical and economic experiences and progresses. Currently recovery quotas of 55 to 80 per cent shall be achieved. Moreover, each Member state shall achieve a collection quota of WEEE of 45% calculated on the basis of the total weight of WEEE collected in a given year, expressed as a percentage of the average weight of EEE placed on the market in the three preceding years in that Member State. From 2019 the collection rate will account for 65 per cent.

## APPROPRIATE COLLECTION STRATEGIES AND SCHEMES

Effective ways for the separate collection of WEEE prove to be:

- Return option of WEEE at sales stores of electrical and electronic items through a legal obligation of them (only valid if sold items have a minimum size) or via a take-back agreements of distributors on a voluntary basis
- Utilisation of collection systems or structures that base on municipal collection points (e.g. recycling centres, figure 2) and selective collections (street collection) of public waste management authorities

Figure 2: Separate collection of WEEE at a collection point in roll-off containers (pictures: INTECUS GmbH)

- Public bodies may use special containers (for example roller container partitioned into several sections) to collect WEEE as various separate fractions (e.g. refrigerators, fluorescent tubes, TV-sets, household appliances, IT and communication equipment, multimedia/entertainment products). Alternatively, collection points should take care that appropriate fractions are separated in their place and as such forwarded to subsequent recycling processes.
- Special requirements shall be stipulated on the collection of old devices containing lithium-ion batteries, as the storage and transportation cause self-ignition and fire risks

To ensure compliance with the take-back obligation that has become a mandatory scheme for electric and electronic equipment in Germany, producers and retailer have to register themselves at the stiftung elektro-altgeräte register (EAR). Producers of consumer products (B2C) have to maintain a guarantee deposit as part of their registration. www.stiftung-ear.de

## APPROPRIATE TREATMENT AND RECOVERY SCHEMES

**Repair and refurbishment programmes**

The development of repair and refurbishment schemes should be the preferred option to deal with collected WEEE. This could consist of a multistage process adapted to the state in which the WEEE is upon collection or return. The different options could include
- the resale of tested, good looking equipment,
- a refurbishment and
- the recovery and utilisation of usable sub-assemblies and spare parts or total dismantling.

A high risk potential rests with processing and recovery techniques, which are performed without the necessary precaution and care for environmental damages and health risks. Their application can quite often be seen in the lesser developed regions of the world and entails practices such as the open burning of PVC cable insulations, dissolving of printed wiring boards in an open acid bath!

**Dismantling**

The dismantling of WEEE is executed with the objective to separate potentially hazardous components (e.g. polychlorinated biphenyl, condensers, mercury containing measurement and control technology) from the rest of the material and to recover valuable materials, especially reusable components and metals. Dismantling is manually done. During dismantling the following fractions are usually generated:

- Ferrous and non-ferrous metals
- Cable material
- Plastics
- Rubber
- Wood
- Monitor glass
- Metal-plastic-compounds
- Printed wiring boards
- Batteries
- Hazardous substances

Figure 3: Work station for manual dismantling for monitors (left) and separated monitor glass (right) (pictures left & right: INTECUS GmbH)

The intensity of separation depends from the available recycling options. For each fraction the respective recycling/disposal channels explained in this document can be used.

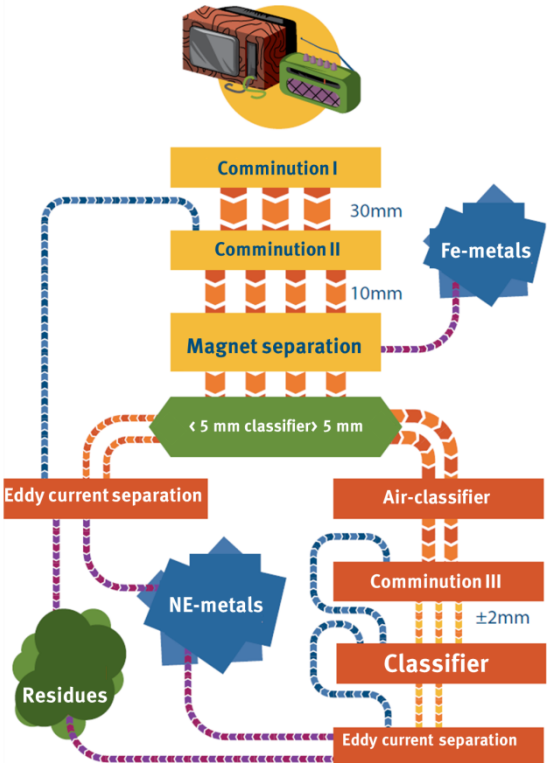
**Processing of WEEE**

The processing of WEEE comprises all mechanical and chemical processes that permit the further recovery of recyclable material.

- *Mechanical processes:*

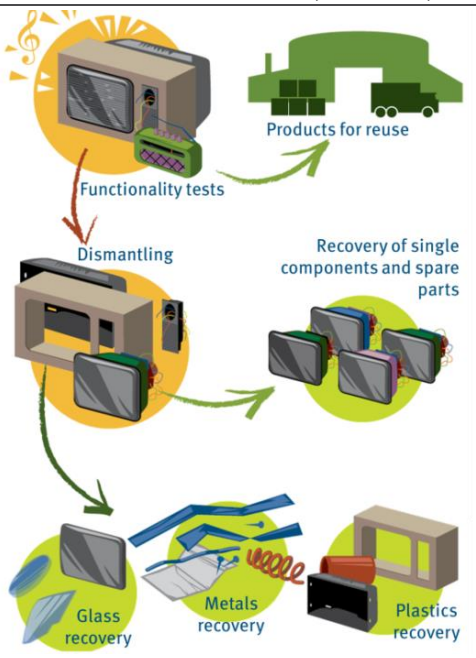
Mechanical processes for the purpose of recycling and material recovery from WEEE in the majority of cases are being applied for the separation of metal-plastic compounds. The possible flow scheme of a mechanical process is shown in the picture below.

Figure 4: Possible flow scheme for the mechanical processing of WEEE




Different recycling and reutilisation options become possible by combining various methods and treatment techniques. Integrated into a larger processing chain and one facility (e.g. a specialized recycling centre) a modern and very efficient WEEE treatment can be instituted. The example of such a combination is depicted by the following process arrangement within a dedicated disassembly and recovery facility.

Figure 5: Possible process combination in a dedicated WEEE recycling facility



Such arrangement uses various work stations for disassembly and recovery, each one specialized for a certain fraction such as monitors, personal computers (PC), large equipment or process steps such as oxy-gas cutting or plasma torch cutting.

Processing complex scrap starts with removing and sorting components or items for a subsequent processing. Shredder technologies specifically designed to process electronic complex scrap helps in material liberation and volume reduction. With a series of magnetic and other separators (e.g. eddy current separator) it is then possible to segregate the metals from non-metals and ferrous metals from non-ferrous metals.

The qualities of the material fractions obtained from such treatment can be described as follows:

Table 2: Qualities of produced material streams from mechanic processes of WEEE

| Produced material streams | Fe-metals [mass-%] | non-ferrous metals [mass-%] | non-metal components [mass-%] |
|---|---|---|---|
| Ferrous metals | 95–99 | 0.1–5 | 0.5–5 |
| Non-ferrous metals | | >95 | 0.5 |
| Mixed plastics and dusts | 0–2 | 1–5 | >95 |

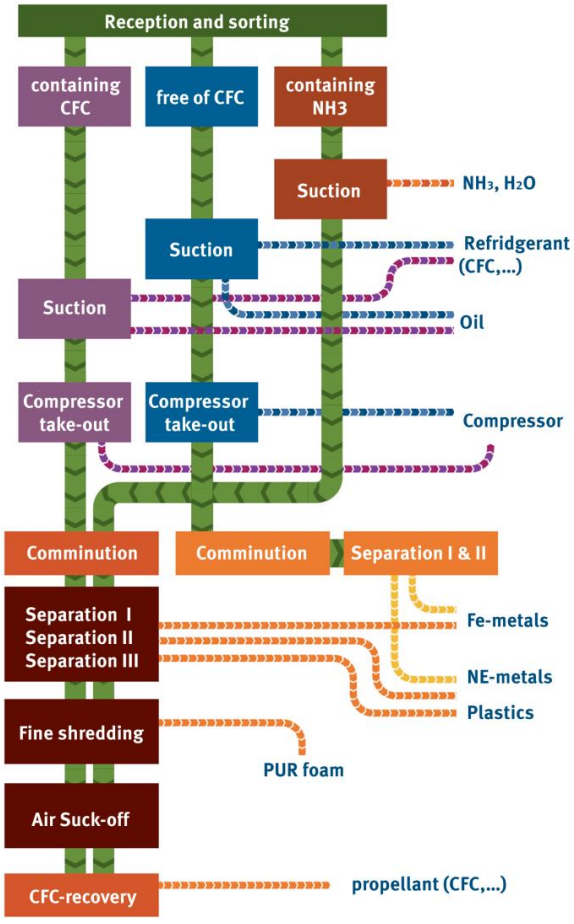
## APPROPRIATE RECYCLING TECHNOLOGIES

The recycling possibilities and techniques for selected WEEE fractions will be described hereunder.

**Refrigerators and freezing devices**

Of utmost importance in the treatment of refrigerators and freezing devices is the isolation and recovery of the Chlorofluorocarbon (CFC) or of other volatile organic compounds (VOC) in the cooling agents contained in the newer items of this product group. The resulting process scheme can be one of the following kind:

Figure 6: Process scheme for a VOC facility *(modified according to R-plus Recycling GmbH)*

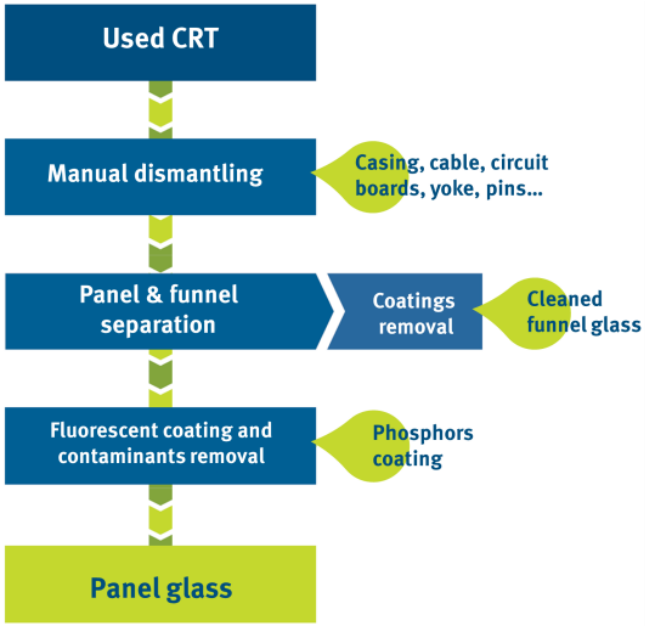


**Recycling of screens and monitors**

Computer monitors and televisions containing cathode ray tubes (CRT) are made of glass that includes lead oxide to protect user from stray radiation. Other heavy metal oxides, such as cadmium, are sometimes used in the phosphor coatings inside the CRTs. Because the lead may dissolve out of the glass and pollute the soil and groundwater, it is not environmentally desirable to dispose of CRTs in landfills.

The best alternative for disposing of CRT glass is by separating the different types of glass (panel from funnel), removing coatings, crushing and removing metal contaminants and then closing the loop by sending it back to glass manufacturers to make new CRTs. In order to produce cullet (clean, separated, crushed CRT glass) that can be used for closed-loop recycling, the panels and the funnels must be sorted into classifications consistent with the glass manufacturers' requirements. One challenge encountered when recycling CRTs stems from dealing with the hazardous materials. Coatings inside the panel usually contain zinc sulphides or lead and cadmium. A wet/dry vacuum with high-efficiency particulate air or special filter has to be used to remove the potentially hazardous coatings. CRT glass manufacturers require that the ferrous and nonferrous metals be removed from the glass prior to accepting it for reuse. This may be achieved with a magnetic head-pulley to remove the ferrous metals, and a vertical drop metal separator to remove the nonferrous metals from the crushed glass. The resulting product is cleaned, furnace-ready cullet that can be used for closed-loop recycling.

Figure 7: Simplified process scheme for the recycling of screens and monitors




Monitors that currently dominate the market (flat screens) work on the basis of a liquid crystal display (LCD) and of many small gas discharge lamps or light emitting diodes (LED). The recycling process of these flat screens starts with a manual dismantling of the LEDs (see factsheet "Lamps") to prevent mercury emissions caused by damaging the LEDs. Alternatively, facilities already exists that shredder flat screens while vacuuming mercury emissions. Shredded materials is then automatically sorted and separated into different fractions.

**Plastics components**

For an effective plastics recovery the system must include:

1. Volume Reduction (breaking large housings into small pieces) and Purification (removing contaminants).
2. Separation of plastics by type. This may include a 3-step density separation process (Redundant Hydrocyclone Process, 2nd Redundant Hydrocyclone Process, Sink-Float-System) and as the 4th step a Dual Electrostatic Separation.
3. Characterization and Identification of plastic compounds, determining the physical characteristics of the separated plastics.

After completion of all processes six output streams may be generated:

- Commingled Polyethylene & Polypropylene
- Acrylonitrile Butadiene Styrene (ABS)
- High Impact Polystyrene (HIPS)
- Polycarbonate
- Polycarbonate ABS alloys
- Other plastics, such as nylons and Polyvinyl Chloride (PVC)

The commingled Polyethylene & Polypropylene can be put into the market without further separation or processing. HIPS, ABS, polycarbonate and polycarbonate/ABS hold the highest value and can be used in place of raw material. The other plastics, such as nylons and PVC, as of now are generally not economical candidates for further separation and are disposed of as waste.

**Printed wiring boards (PWBs) and complex scrap**

Most of the metal-bearing stream in electronics demanufacturing consists of printed wiring boards (PWBs) and complex scrap. Complex scrap includes items such as hard drives, floppy drives, casings, chassis, printers, and keyboards. Different methods and equipment are required to process printed wiring boards versus complex scrap.
PWBs contain the highest value metals as well as some of the most toxic metals found in electronics scrap. There are 10 to 100 times more precious metals in PWBs than in an equal weight of ore taken from a mine.
Most practices for the recycling of complex scrap begin with demanufacturing works and continue with various steps leading to a comminution and subsequent segregation of components of different nature.

The majority of PWBs on the other hand are currently sent directly to copper smelters for recovery of precious metals and copper. Sending whole PWBs to copper smelters is, however, inefficient because a PWB is approximately 70% by weight non-metallic materials. A significant economic improvement in metals recovery can be achieved by separating the metals from the non-metals using various processing techniques, thereby improving the purity of the PWB material before it is sent to the smelter. For this beneficiation techniques introduced by the minerals processing industry can be used. Beneficiation includes the steps of grinding, screening, separating, and concentrating to improve the physical properties of an ore so that metal can be economically recovered.

Melting with differentiated treatment (refining process) can be used to recover metals of various types. One example for such process is applied at the Umicore plant in Belgium (www.preciousmetals.umicore.com). Precious metals get separated within the melting process by sending the other metals into the plumbiferous slag where they are concentrating. Copper and precious metals are then leached out while electrolysis is used to get them separated. Subsequent electro-refining achieves that precious metals of high purity are obtained. Other metals such as nickel or lead are recovered in parallel processes.

## IMPLICATIONS TO OTHER SECTORS

The treatment of WEEE for the purpose of recycling and reuse does constitute a very good chance to employ a larger number of persons, in particular for operations such as repair, refurbishment and disassembly. In conjunction with the provision of training, there is especially an opportunity for disabled, less qualified and socially deprived people to find work in this sector. Specialized workshops and charity organisations can make use of this business opportunity for income generating activities of their clientele.

## REFERENCES AND PROVIDER FIRMS

*(Important note: The list of firms does not constitute a complete compilation of companies active in the specified fields.)*

In Germany/Europe, it exist an established network of facilities for the demanufacturing and treatment of WEEE. These facilities were set up from waste disposal firms or operate as independent undertakings. Examples in Germany are the facilities of::

- Berliner Stadtreinigungsbetriebe, Berlin www.bsr-online.de
- REMONDIS Electrorecycling GmbH, Lünen www.remondis.de
- ALBA Elektronics Recycling GmbH, Eppingen www.alba.info/the-recycling-company.html

- GWAB Recycling-Zentrum, Wetzlar www.gwab-recycling.de
- Stena Recycling Sweden, Standort Wangerland www.stenatechnoworld.com/de/

Further information about recycling processes of WEEE and companies active in this area can be obtained from following organisations:

- ZVEI - Zentralverband Elektrotechnik- und Elektronikindustrie, e.V. www.zvei.org
- Bundesverband der Deutschen Entsorgungs-, Wasser- und Rohstoffwirtschaft e.V. www.bde.de
- Bundesverband Sekundärrohstoffe und Entsorgung e.V. www.bvse.de