UNIT-II CLASSIFICATION OF E-WASTE

Composition of E-Waste →

Composition of e-waste is very diverse and differs in products across different categories. It contains more than 1000 different substances, which fall under "hazardous" and "non-hazardous" categories. Broadly, it consists of ferrous and non-ferrous metals, plastics, glass, wood & plywood, printed circuit boards, concrete and ceramics, rubber and other items. Iron and steel constitutes about 50% of the e-waste followed by plastics (21%), non ferrous metals (13%) and other constituents. Non-ferrous metals consist of metals like copper, aluminium and precious metals ex. silver, gold, platinum, palladium etc. The presence of elements like lead, mercury, arsenic, cadmium, selenium, and hexavalent chromium and flame retardants beyond threshold quantities in e-waste classifies them as hazardous waste.

Components of E-Waste →

E-waste has been categorized into three main categories, Viz. Large Household Appliances, IT and Telecom and Consumer Equipment. Refrigerator and Washing Machine represent large household appliances, Personal Computer, Monitor and Laptop represent IT and Telecom, while Television represents Consumer Equipment. Each of these E-waste items has been classified with respect to twenty six common components, which could be found in them. These components form the "Building Blocks" of each item and therefore they are readily "identifiable" and "removable". These components are metal, motor/ compressor, cooling, plastic, insulation, glass, LCD, rubber, wiring/ electrical, concrete, transformer, magnetron, textile, circuit board, fluorescent lamp, incandescent lamp, heating element, thermostat, BFR-containing plastic, batteries, CFC/HCFC/HFC/HC, external electric cables, refractory ceramic fibers, radio active substances and electrolyte capacitors (over L/D 25 mm). The kinds of components, which are found in Refrigerator, Washing Machine, Personal Computers (PC) and TVs, are described in table 1. The observations from the analysis of table 1 are given below:

1. Radioactive substances, refractory ceramic fibers, electrolyte capacitors (over L/D 25 mm), textile and magnetron are not present in any item.

2. Plastic, circuit board and external electric cables are present in majority of items. BFR containing plastic is present in refrigerator, laptop and television.

3. Refrigerators are unique items because of presence of CFC/HCFC/HFC/HC, cooling, insulation, incandescent lamp and compressor.

4. Heating element is found in washing machine, while thermostat is found in both refrigerator and washing machine.

5. Fluorescent lamp is found only in laptop

6. Metal and motor are found in majority of items except refrigerator

7. Transformer is not found in washing machine and refrigerator

8. CRT is found in personal computer and TV, while LCD is found in PC and TV

9. Batteries are found in PC and laptop

10. Concrete is found in washing machine

11. Rubber is found in refrigerator and washing machine

12. Wiring/ Electrical is found in all the items

Large household appliance (refrigerator) may consist of electric motor, a circuit board, a transformer, capacitor, thermal insulation, switches, wiring, plastic casing that contain flame retardants etc. A typical washing machine may consist of the metal casing, concrete ballast, inner and outer drums, a motor, a pump, washing cycle controller unit, switches and other components. The latest trends in these appliances is the phase out of the use of ODS and improvement of energy efficiency. Old washing machines are likely to contain large capacitors, while in relatively new machines, variable speed motors are controlled from the circuit board. IT and Telecom equipments sector is observing a trend of "micro miniaturization", while CRTs are being replaced by LCD screens. Table 5.1 indicates that the range of different items found in E-waste is diverse classifying it a waste of complex nature. However, it shows that E-waste from these items can be dismantled into relatively small number of common components for further treatments. The composition and hazard content of each of these components is being described in following section to establish the overall hazardousness of each item of E-waste.

Components in WEEE (by Category)

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

Table 1

Possible hazardous substances present in e-waste

The possible substance of concern, which may be found in selected E-waste item is given in table 2.

Table 2: Possible Hazardous Substances in Components

Component	Possible Hazardous Content
Metal	
Motor \ Compressor	
Cooling	ODS
Plastic	Phthalate plasticize, BFR
Insulation	Insulation ODS in foam, asbestos, refractory ceramic fiber
Glass	
CRT	Lead, Antimony, Mercury, Phosphors
LCD	Mercury
Rubber	Phthalate plasticizer, BFR
Wiring / Electrical	Phthalate plasticizer, Lead, BFR
Concrete	
Transformer	
Circuit Board	Lead, Beryllium, Antimony, BFR
Fluorescent Lamp	Mercury, Phosphorus, Flame Retardants
Incandescent Lamp	
Heating Element	
Thermostat	Mercury
BFR – containing plastic	BFRs
Batteries	Lead, Lithium, Cadmium, Mercury
CFC, HCFC, HFC, HC	Ozone depleting substances
External electric cables	BFRs, plasticizers
Electrolyte Capacitors (over L/D 25mm)	Glycol, other unknown substances

The substances within the above mentioned components, which cause most concern are the heavy metals such as lead, mercury, cadmium and chromium (VI), halogenated substances (e.g. CFCs), polychlorinated biphenyls, plastics and circuit boards that contain brominated flame retardants (BFRs). BFR can give rise to dioxins and furans during incineration. Other materials and substances that can be present are arsenic, asbestos, nickel and copper. These substances may act as a catalyst to increase the formation of dioxins during incineration. The description about some of these substances where uncertainty exists regarding their "level of concern" based on literature review are given below.

(1) Plastics containing Brominated Flame Retardants (BFRs)
(2) Insulation
(3) Asbestos
(4) Refractory Ceramic Fibers (RCFs)
(5) Liquid Crystal Display (LCDs)

(6) Components containing Plasticisers/Stabilisers
(7) Circuit Boards
(8) Flame Retardants
(9) Lead
(10) Mercury
(11) Beryllium
(12) Capacitors
(13) Electrolyte Capacitors
(14) Capacitors containing Poly Chlorinated Biphenyls (PCBs)

Possible hazardous substances present in e-waste →

E-waste scenario →

Basis for Defining e-waste →

Proposed definition of E-Waste →

RoHS in the Electronic & electrical Equipments ,EPR →

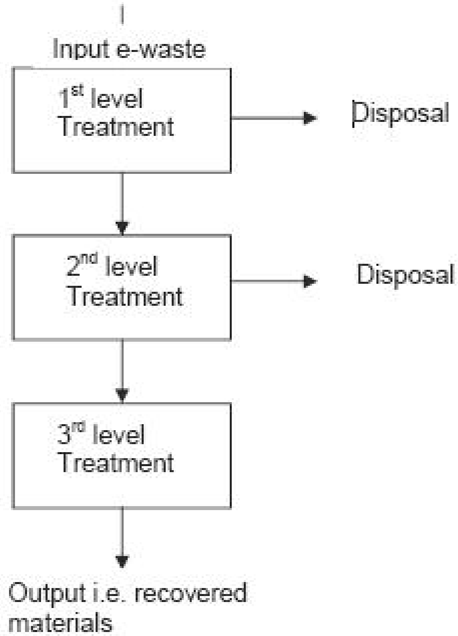
ENVIRONMENTALLY SOUND E-WASTE TREATMENT TECHNOLOGIES

Environmentally sound E-waste treatment technologies are used at three levels as described below:

1. 1st level treatment
2. 2nd level treatment
3. 3rd level treatment

ANALYSIS

All the three levels of e-waste treatment are based on material flow. The material flows from 1st level to 3rd level treatment. Each level treatment consists of unit operations, where e-waste is treated and out put of 1st level treatment serves as input to 2nd level treatment. After the third level treatment, the residues are disposed of either in TSDF or incinerated. The efficiency of operations at first and second level determines the quantity of residues going to TSDF or incineration. The simplified version of all the three treatments is shown in Figure 1, while a comprehensive version detailing each stage is given at Annexure – IX. EST at each level of treatment is described in terms of input, unit operations, output and emissions.



Simplified version of EST for e-waste

Figure 1

EST for 1st Level Treatment

Input: e-waste items like TV, refrigerator and Personal Computers (PC) Unit Operations: There are three units operations at first level of e-waste treatment

1. Decontamination : Removal of all liquids and Gases
2. Dismantling -manual/mechanized breaking
3. Segregation

All the three unit operations are dry processes, which do not require usage of water.

1. Decontamination

The first treatment step is to decontaminate e-waste and render it nonhazardous. This involves removal of all types of liquids and gases (if any) under negative pressure, their recovery and storage.

2. Dismantling

The decontaminated e-waste or the e-waste requiring no decontamination are dismantled to remove the components from the used equipments. The dismantling process could be manual or mechanized requiring adequate safety measures to be followed in the operations.

3. Segregation

After dismantling the components are segregated into hazardous and nonhazardous components of e-waste fractions to be sent for 3rd level treatment.

Output:

1. Segregated hazardous wastes like CFC, Hg Switches, batteries and capacitors
2. Decontaminated e-waste consisting of segregated non-hazardous Ewaste like plastic, CRT, circuit board and cables

Emissions: The emissions coming out of 1st level treatment is given in table1.

Table 1: Emissions from 1st level E-waste treatment

Unit Operations/ Emissions	Dismantling	Segregation
Air	√ (fugitive)	X
Water	X	X
Noise	√	√
Land/ Soil Contamination due to spillage	√	√
Generation of hazardous waste	√	√

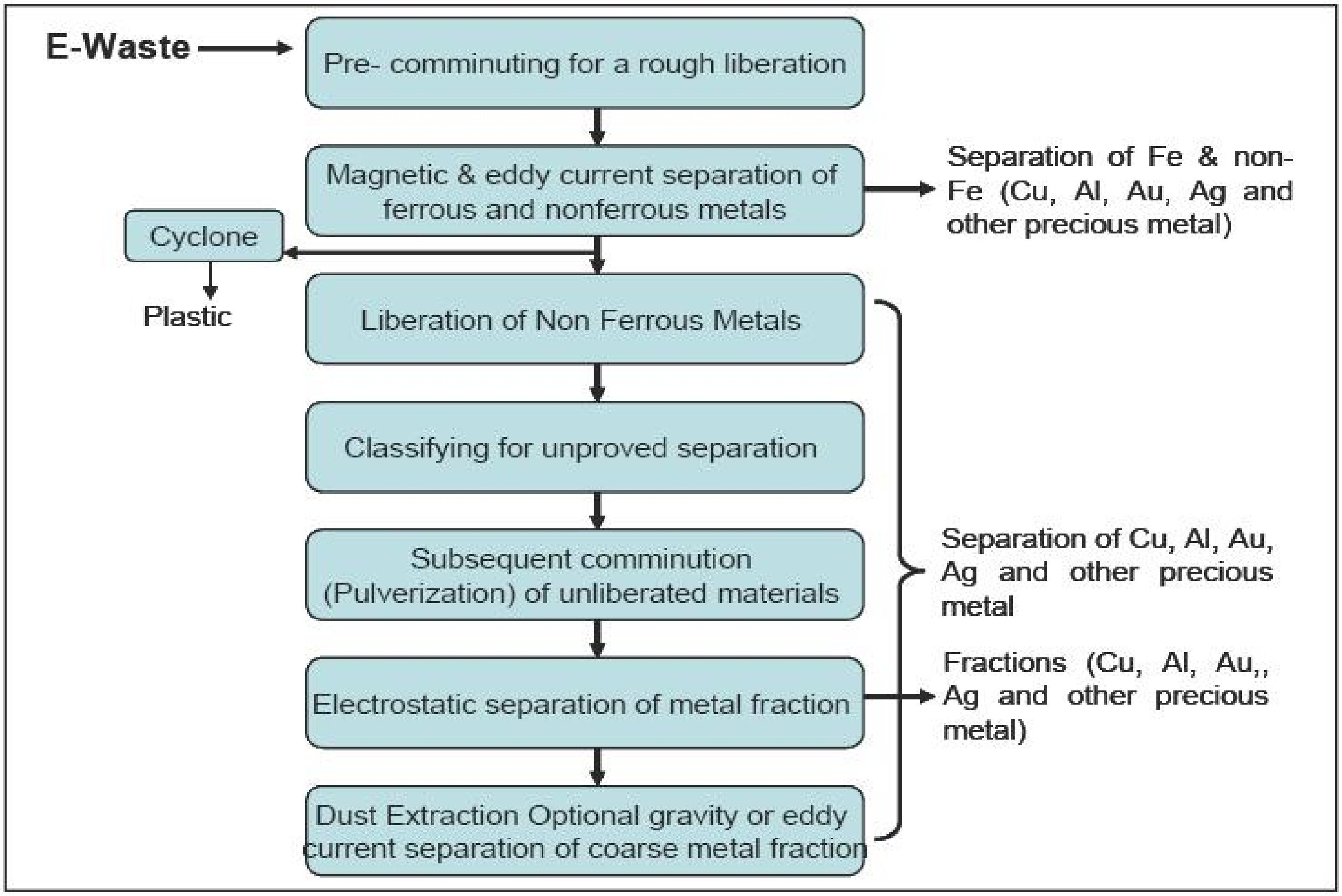
EST for 2nd Level Treatment
Input: Decontaminated E-waste consisting segregated non hazardous e-waste like plastic, CRT, circuit board and cables.

Unit Operations: There are three unit operations at second level of E-waste treatment

1. Hammering
2. Shredding
3. Special treatment Processes comprising of
   - (i) CRT treatment consisting of separation of funnels and screen glass.
   - (ii) Electromagnetic separation
   - (iii) Eddy current separation
   - (iv) Density separation using water

The two major unit operations are hammering and shredding. The major objective of these two unit operations is size reduction. The third unit operation consists of special treatment processes. Electromagnetic and eddy current separation utilizes properties of different elements like electrical conductivity, magnetic properties and density to separate ferrous, non ferrous metal and precious metal fractions. Plastic fractions consisting of sorted plastic after 1st level treatment, plastic mixture and plastic with flame retardants after second level treatment, glass and lead are separated during this treatment. The efficiency of this treatment determines the recovery rate of metal and segregated E-waste fractions for third level treatment. The simplified version of this treatment technology showing combination of all three unit operations is given in Figure2

Figure .2: Process flow of Non CRT based e-waste treatment



1. The proposed technology for sorting, treatment, including recycling and disposal of E-waste is fully based on dry process using mechanical operations.

2. The pre-comminuting stage includes separation of Plastic, CRT and remaining non CRT based E-waste. Equipments like hammer mill and shear shredder will be used at comminuting stage to cut and pulverize Ewaste and prepare it as a feedstock to magnetic and eddy current separation.

3. A heavy-duty hammer mill grinds the material to achieve separation of inert materials and metals.

4. After separation of metals from inert material, metal fraction consisting of Ferrous and Non-Ferrous metals are subjected to magnetic current separation. After separation of Ferrous containing fraction, Non-ferrous fraction is classified into different non-metal fractions, electrostatic separation and pulverization.

5. The ground material is then screened and de dusted subsequently followed by separation of valuable metal fraction using electrostatic, gravimetric separation and eddy current separation technologies to recover fractions of Copper (Cu), Aluminum (Al), residual fractions containing Gold (Au), Silver (Au) and other precious metals. This results in recovery of clean metallic concentrates, which are sold for further refining to smelters. Sometimes water may be used for separation at last stage.

6. Electric conductivity-based separation separates materials of different electric conductivity (or resistivity) mainly different fractions of non-ferrous metals from E-waste. Eddy current separation technique has been used

based on electrical conductivity for non ferrous metal separation from Ewaste. Its operability is based on the use of rare earth permanent magnets. When a conductive particle is exposed to an alternating magnetic field, eddy currents will be induced in that object, generating a magnetic field to oppose the magnetic field. The interactions between the magnetic field and the induced eddy currents lead to the appearance of electro dynamic actions upon conductive non-ferrous particles and are responsible for the separation process.

7. The efficacy of the recycling system is dependent on the expected yields/ output of the recycling system. The expected yields/ output from the recycling system are dependent on the optimization of separation parameters. These parameters are given below:

i. Particle size
ii. Particle shape
iii. Feeding rate/ RPM
iv. Optimum operations

Figure3 shows the non- ferrous metal distribution (which forms the backbone of financial viability of recycling system) as a function of size range for PC scrap. It can be seen that aluminum is mainly distributed in the coarse fractions (+6.7 mm), but other metals are mainly distributed in the fine fractions (−5 mm).

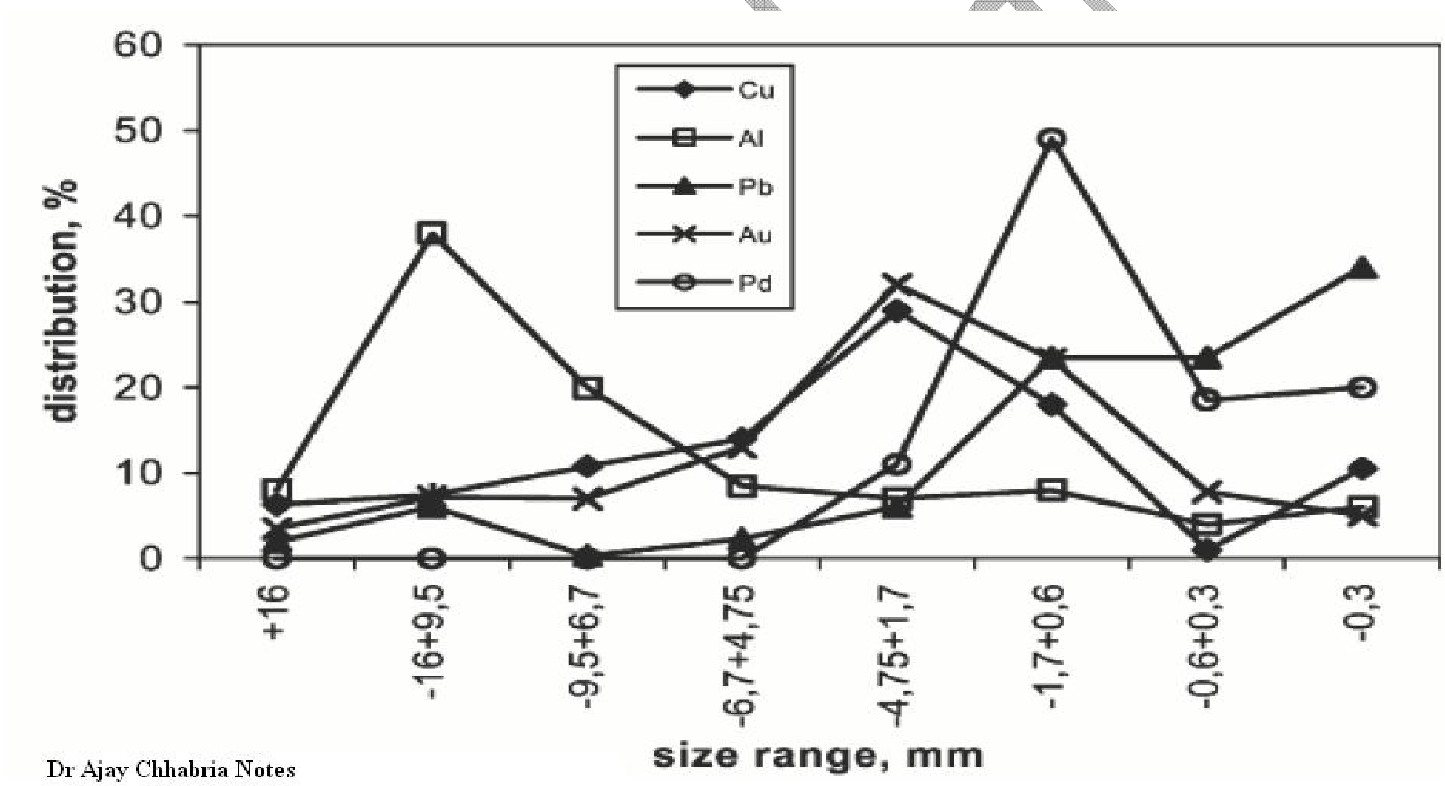


Figure3: Non- Ferrous Metal Distribution Vs Size range for PC scrap

Size properties are essential for choosing an effective separation technique. Therefore, eddy current separator is best for granular nonferrous materials having size greater than 5mm. The eddy current separation will ensure better separation of Al fraction in comparison to fraction containing Cu, Ag and Au.

8. Particle shape is dependent on comminuting and separation. Since hammer mills and screens will be used in the proposed technology, the variations are expected to be the same as that of Best Available Technology (BAT).

9. The feeding rate can be optimized based on the speed and width of the conveyor.

CRT TREATMENT TECHNOLOGY
The salient features of CRT treatment technology are given below.

1. CRT is manually removed from plastic/ wooden casing.

2. Picture tube is split and the funnel section is then lifted off the screen section and the internal metal mask can be lifted to facilitate internal phosphor coating.

3. Internal phosphor coating is removed by using an abrasive wire brush and a strong vacuum system to clean the inside and recover the coating. The extracted air is cleaned through an air filter system to collect the phosphor dust.

Different types of splitting technology used are given below.

➔ NiChrome hot wire cutting
A NiChrome wire or ribbon is wrapped round a CRT and electrically heated for at least 30 seconds to causes a thermal differential across the thickness of the glass. The area is then cooled (e.g. with a water-soaked sponge) to create thermal stress which results in a crack. When this is lightly tapped, the screen separates from the funnel section.

➔ Thermal shock
The CRT tube is subjected to localized heat followed by cold air. This creates stress at the frit line where the leaded funnel glass is joined to the unleaded panel glass and the tube comes apart.

➔ Laser cutting
A laser beam is focused inside and this heats up the glass. It is immediately followed by a cold water spray that cools the surface of the glass and causes it to crack along the cut line.

➔ Diamond wire method
In this method, a wire with a very small diameter, which is embedded with industrial diamond is used to cut the glass as the CRT is passed through the cutting plane.

➔ Diamond saw separation
Diamond saw separation uses either wet or dry process. Wet saw separation involves rotating the CRT in an enclosure while one or more saw blades cut through the CRT around its entire circumference. Coolant is sprayed on to the surface of the saw blades as they cut. This is to control temperature and prevent warping.

➔ Water-jet separation
This technology uses a high-pressure spray of water containing abrasive, directed at the surface to be cut. The water is focused through a single or double nozzle-spraying configuration set at a specific distance.

3rd Level E-waste Treatment

The 3rd level E-waste treatment is carried out mainly to recover ferrous, nonferrous metals, plastics and other items of economic value. The major recovery operations are focused on ferrous and non ferrous metal recovery, which is either geographically carried out at different places or at one place in an integrated facility. The following sections describe the unit operations, processes, available technology and environmental implications.

1 Input/ Output and Unit Operations
The input, output and unit operations at 3rd level treatment are described in table 2.

Table 2: Input/ Output and unit operations for 3rd level treatment of e-waste

Input/ WEEE Residues	Unit Operation/ Disposal/ Recycling Technique	Output
Sorted Plastic	Recycling	Plastic Product
Plastic Mixture	Energy Recovery/ Incineration	Energy Recovery
Plastic Mixture with FR	Incineration	Energy Recovery
CRT	Breaking/ Recycling	Glass Cullet
Lead Smelting	Secondary Lead Smelter	Lead
Ferrous metal scrap	Secondary steel/ iron recycling	Iron
Non Ferrous metal Scrap	Secondary copper and aluminum smelting	Copper/ Aluminum
Precious Metals	Au/ Ag separation (refining)	Gold/ Silver/ Platinum and Palladium
Batteries (Lead Acid/ NiMH and Li ION)	Lead recovery and smelting Remelting and separation	Lead
CFC	Recovery/ Reuse and Incineration	CFC/ Energy recovery
Oil	Recovery/ Reuse and Incineration	Oil recovery/ energy
Capacitors	Incineration	Energy recovery
Mercury	Separation and Distillation	Mercury

The description of some of the 3rd level WEEE/ E-waste processes are described below.

2 Plastic Recycling
There are three different types of plastic recycling options i.e. chemical recycling, mechanical recycling and thermal recycling. All the three processes are shown in figure 6.3. In chemical recycling process, waste plastics are used as raw materials for petrochemical processes or as reductant in a metal smelter. In mechanical recycling process, shredding and identification process is used to make new plastic product. In thermal recycling process, plastics are used as alternative fuel.

The two major types of plastic resins, which are used in electronics, are “thermosets” and “thermoplastics”. Thermosets are shredded and recycled because they cannot be re-melted and formed into new products, while thermoplastics can be re-melted and formed into new products.

UNIT-III Legal Framework
The Hazardous Wastes (Management and Handling) Rules →
The Municipal Solid Wastes (Management and Handling) Rules →
Basel Convention →
European Union policy and regulation on e-waste →
US Policy for E-Waste →