In 1998, the amount of gold recovered from electronic scrap in the US was equivalent to the recovered from more than 2 million tons of gold ore and waste.

It takes approximately 241 kg of fossil fuel, 22.7 kg chemicals (including metals) and 1790 litres of water to produce one desktop computer.

(USGS Fact sheet)
CHAPTER - 6

RESOURCE RECOVERY FROM EOL-PC
(SURFACE MINING/URBAN MINING)

Metals play a key role in furthering the progress of mankind. Nation's economy and social status is solely determined by the mineral wealth and other natural resources. For centuries, metals are extracted from the naturally occurring minerals. The minerals which form primary resources for metals and many non metals are finite and non-renewable in nature. Therefore, the economical use, and conservation of these primary natural resources through substitution and recycling for sustainable development are a matter of great concern. Increase in metal prices in the last few years may be directly related to the developments in the electronics industry.

6.1. Recyclability unique feature of metals:

Recyclability is the unique feature of metals. In fact, they can be recycled any number of times without losing their intrinsic properties and hence can be used over and over again!

In India, the E-waste, including EOL-PCs, estimated to contain about 15 million tonnes of steel which is equivalent to the annual production of Steel Authority of India (SAIL), and more than 10,000 tonnes of plastics and glass. Personal computers consume 3% of gold, silver and 13 % of Pd, of the total global annual production. Besides, modern electronics contains nearly 60 different elements, of them many are valuable and few are hazardous (Hazard Coming Up: 2010. C.E.M. Meskers 2009). In 1994, an estimated 20 million PCs (about 7 million tonnes) became obsolete. Cumulatively, about 500 million PCs may contain 2,872 tons of plastics, 718 tons of lead, 1363
tons of Cadmium and 287 tons of mercury. The quantity of obsolete computers may touch a figure of 8 million tons at an average annual growth rate of about 51%. This figure is estimated to increase by 500% by 2015! (Hemath Gaule: 2010 and Toxics Alert: Oct 2010).

6.2 Metals without mining: Urban Mining/Green Mining.

Resource recovery from end of life products is critical to closing the loop towards a steady supply of non-virgin materials for manufacture and for sustainability (H. Scott Mathews et al 1997). It is the information stored in the EOL-PCs that cannot be retrieved but, the resources used in the production of hardware have infinite life and can be reused/recycled/recovered. The equipment is rich in terms of metals and non-metals and can be economically recovered in an eco and environment friendly way. Therefore, EOL-PCs, which form major portion of E-waste, can be treated as secondary resource to recover many metals economically. Recovery of metals from such secondary resources is now known as 'surface mining' or 'urban mining'.

6.3 Methodology to retrieve metals from EOL-PCs:

In the present study, to recover metals the principles followed are

- manual Physical methods for dismantling,
- No incineration,
- Safe disposal of hazardous materials to the scientific landfill
- Optimum recycling efficiency and zero landfill.
The flow sheet diagram illustrates the manual dismantling of EOL-PC into subassemblies, identification and segregation of recyclable metals, nonmetals and hazardous substances (Fig. 6.1).

Fig: 6.1 Flow sheet for manual dismantling of EOL-PC
CPU, Keyboard, Mouse and printer require almost the same methodology for resource recovery. Where as HDD of CPU, CRT Monitor require special skill and methodology to recover the resources.

Dismantling is done manually using simple and common tools such as manual/automatic screwdrivers, hammers and pliers. While dismantling, all Personal Protection Equipments are used (Fig.6.2).

To maintain clean environment a dust chamber is provided at the dismantling area.

Various circuit boards collected are shredded and Processor pins also are chopped off using indigenous low cost equipment. Gold bearing contactors/pins etc. are detached from the circuit boards using electrically operated chiselling machines (Fig.6.3). These are kept in identified places to be processed for the recovery of valuable metals chemically.

6.4. Dismantling of HDD:

Dismantling to recover resources and from HDD requires intellectual property rights of the owner is protected i.e. the data stored in the hard disc is permanently erased by Degaussing. After dismantling HDD, resources like Aluminum, motor coil, boards, reader, magnetic discs etc. are separately collected.

6.5. Dismantling of CRT:

Dismantling of CRT requires skill and special precautions to be taken. First Yoke, an integral part of CRT is collected separately to recover pure copper from it Fig.(6.4). Later, electron gun is detached carefully in a specially designed closed chamber to release vacuum inside the CRT and to prevent possible implosion of hazardous Phosphor. Metal shadow mask is taken out and sent for
recycling. Leaded front and funnel glass of CRT are collected in separate containers kept under the chamber.

6.6 Sorting and identification of resources:

Resource recovery in the present study is confined to metals such as Fe, Al, Cu, and nonmetals such as Polymers and leaded glass by physical method and Ag, Au, Pd, and Sn by chemical method and therefore focussing on these metal identification and sorting of resources is done generally at the time of dismantling. CPU once dismantled, the parts obtained are sorted out into CPU cabinet, Hard Disc Drive (HDD), Floppy Disc Drive (FDD), Compact Disc Drive (CDD), Switched-Mode Power Supply (SMPS), Motherboard, hazardous Lithium battery etc.

6.7. Classification of Resources:

Resources that are available by dismantling of EOL PCs are broadly classified in to recyclable resources and hazardous disposables.

6.7.1 Recyclable Resources

- metal casings form CPU, HDD, FDD, CDD, keyboard, mouse and printer;
- Al, Cu, Fe from SMPS and CRT Yoke;
- Metals and polymer from cables and connectors from CPU and CRT monitor;
- Mother board (Circuit Board) and Low value circuit boards of CRT monitor for the recovery of concealed metals;
- Precious metals from processor and various cards viz., sound cards, video cards etc.;
- Polymers mainly from Monitor, keyboard, mouse, printer
- The cullets of front glass and funnel glass collected can be used to make a new CRT again. ("cradle to cradle").
6.7.2 Hazardous Disposable

The materials that are hazardous and non-recyclable like Lithium Batteries, LEDs and Phosphor collected during dismantling are stored in ‘hazardous waste storage room’ till they are disposed off to the scientific landfill.

6.8 Recovery of resources: Physical Method:

Bulk of the recyclable, base metals like Mild Steel, Al, Cu, polymer and glass which are directly identified and recovered only by visual inspection using properties like colour, lustre and by magnetic property recovered during the dismantling and are quantified using a calibrated digital balance to estimate recovery efficiency. Metal Lead can be identified by “Spot test” as it leaves an impression on the paper as though we write on the paper (Andrew Holmes, 1999).

Fig. 6.2 Resource recovery from SMPS

Fig. 6.3 Removal of gold coated pins/contacts
Later, electron gun is detached carefully to release vacuum inside CRT. This prevents possible implosion of hazardous Phosphor. Metal shadow mask is taken out is sent for recycling.

6. 9. **Sorting and identification of resources**

Identification and sorting of resources is done generally during the dismantling only. CPU once dismantled, the parts obtained are sorted out CPU cabinet, Hard Disc Drive (HDD), Floppy Disc Drive (FDD), Compact Disc Drive (CDD), Switched-Mode Power Supply (SMPS), Motherboard, hazardous Lithium battery etc.

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Fig. 6.4 Copper recovered from Yoke of CRT

**Fig.6.5** Sorting by visual inspection  **Fig.6.6** Cullets recovered from CRT
The overall process of collection of EOL-PC from Multi National Companies (MNCs), Govt. offices, and other sources, transportation to the scientific recycling facility, manual dismantling, sorting out of the resources in to metals, mainly recyclable Iron, Copper, Aluminium, recyclable polymer, leaded glass and non-recyclable hazardous phosphor is illustrated in the following Fig.6.7

In the present study, resources that have been recovered and their abundance in EOL-PC are mentioned below and also in Table 6.1

i) CPU: 71% Fe, 4.5% Cu, 6.7% Al, 21% Polymer

ii) Monitor: 8.5% Fe, 6.2% Cu, 1.9% Al, 23% Polymer, 18% Silica

iii) Keyboard: 2.62% Fe, 1.3% Cu and 96% Polymer

iv) Mouse: 19.7% Fe, 71% Polymer

v) Printer: 18.2% Fe, 4.8% Cu, 0.03% Al 31% Polymer

Table 6.1 Resources Recoverable by physical methods

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Component</th>
<th>Wt. of Component kg</th>
<th>% Fe</th>
<th>% Cu</th>
<th>% Al</th>
<th>% Polymer</th>
<th>% Silica</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CPU</td>
<td>10.4</td>
<td>71</td>
<td>4.5</td>
<td>6.79</td>
<td>21</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Monitor</td>
<td>12.4</td>
<td>8.5</td>
<td>6.2</td>
<td>1.9</td>
<td>23</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>Keyboard</td>
<td>0.9941</td>
<td>2.62</td>
<td>1.3</td>
<td>0</td>
<td>96</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>Mouse</td>
<td>0.132</td>
<td>19.7</td>
<td>0</td>
<td>0</td>
<td>71</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Printer</td>
<td>7.6</td>
<td>18.2</td>
<td>4.8</td>
<td>0.03</td>
<td>31</td>
<td>-</td>
</tr>
</tbody>
</table>

Recycling efficiency of resources from CPU, keyboard, mouse, monitor and printer are CPU 98%, 99.7%, 99.98%, 99.3% and 91.86% respectively.

6.10 Recovery of metals by chemical method: Components which have precious metals in concealed form are segregated, size reduced and then kept aside for recovery of valuable metals.
Resource Recovery from EOL-PC

Fig: Collection of EOL-PCs, manual dismantling, segregation of recoverable resources—metals, polymer & glass

Ph. D. Thesis "Recovery of metals from EOL-PC"
The present study gold bearing components are sent to Umicore Precious Metal Refinery (UPMR) of Belgium (through E-Parisaraa, Bangalore who have all the official permission from KSPCB, CPCB and MoEF, New Delhi) to export circuit boards for the recovery of precious metals (Parthasarathy 2010).

Gold bearing components like SD RAM card, (Fig. 6.8) processor pins (Fig. 6.9) shredded mother board, SMPS board shown in are found to contain Ag 0.0528 %, Pd, 0.003343 %, Au, 0.0012 %, Sn 0.0689 %

![Gold bearing components: RAM, circuit board](image)

**Fig. 6.8** Gold bearing components: RAM, circuit board,

![Processor with Gold coated pin](image)

**Fig. 6.9** Processor with Gold coated pin
Table 6.2 Resources recovered by chemical methods

<table>
<thead>
<tr>
<th>Sl. no</th>
<th>Resource</th>
<th>Recoverable resources (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ag</td>
<td>0.0528</td>
</tr>
<tr>
<td>2</td>
<td>Pd</td>
<td>0.003343</td>
</tr>
<tr>
<td>3</td>
<td>Au</td>
<td>0.0012</td>
</tr>
<tr>
<td>4</td>
<td>Pb</td>
<td>0.027</td>
</tr>
<tr>
<td>5</td>
<td>Sn</td>
<td>0.0689</td>
</tr>
</tbody>
</table>

6.11 Discussion:

- EOL-PCs are rich source of metals and nonmetals like glass and polymers.
- By manual dismantling not only resources can be identified, but also quantified accurately. Manual method of dismantling is most suited for small quantities of EOL-PC and also Indian conditions, where labour is not only cheap but available locally.
- By practicing scientific methods, non recyclable phosphor present in the CRT glass, LEDs, are safely disposed to scientific landfill. This is not practiced by backyard practitioners.
- Polymers recovered can be recycled at least six times.
- Metals recovered such as Fe, Al, Cu, Sn and Lead (solder) can be recovered with maximum efficiency in an environment friendly way.
- It is note worthy that in the present study, the resource recovery efficiency exactly matches with the characterisation, because most of the metals and non metals like leaded glass and polymers are present in their solid, pure state. Ecollected by manual dismantling and
Resource Recovery from EOL-PC

- segregation. During the entire recovery process there is no loss of material at all.

- There is no chance for incomplete resource recovery; no residues or remnants are left behind during or after the resource recovery. Hence there is no threat of soil, air, water pollution.

Conclusion:

In terms of recovery efficiency, eco and environmental protection, scientific method adopted in the present study for resource recovery is most preferred to unscientific method followed by backyard practitioners.