



## Formulation of an Ideal Technical Solution for E-Waste Reverse Engineering for 2050 to Sustain Environmental Safety

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### ABSTRACT

Research and development in electronics and its allied subjects have changed life styles of modern society. Though modern man has got many physical and mental comforts from exponential revolution in consumer electronics products, they did bring in some hazardous side effects on environment and human health. Disposal of E-waste has become a major problem across the world and is growing at alarming proportions. The accumulation of e-waste causing biggest harm to environment is the dumping of hazardous materials. The main aim of this theoretical concept research paper is to study, analyse, discuss existing E-waste recycling methodologies and conceptualise and formulate an ideal permanent technical solution for E-waste hazards faced by all nations across the world. Future projections of ever increasing E-waste for India, China, Europe, USA and the world for 2050 are included in this paper. In this paper a known novel recycling technical solution is re-invented through which 100% E-waste is processed to extract each and every material used in the fabrication process. An attempt is made to present and discuss an ideal technical solution which will give rise to discarding of E-waste into environment is either nil or minimal. At the same time it is expected to result in employment generation with marginal profits and surely acceptable to all players of consumer electronics industry. Implications of implementation of proposed ideal technical solution, commercial and societal are also included here.

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### Introduction

Industrial revolution followed by the advances in the electronics and its allied subjects viz; computers, information and communication technologies during last century have radically revolutionalized human life styles. Information and communication technologies with further tremendous advances in consumer electronics products have changed the way we think, consume and operate our daily lives. Electronic waste, e-waste, e-scrap or Electrical and Electronic Equipment (WEEE) describes discarded electrical or electronic devices[1]. Unwanted, obsolete or unusable consumer electronic products such as computers, computer peripherals, televisions, VCRs, DVD Players, stereo equipment, hand cell phones are commonly referred to as 'electronic waste.

The last three decades have seen electronics industry as the world's largest and fastest growing industry, especially in Asian countries mostly China and India. However, this booming development and usage of electronic and electrical equipments has also created a new type of waste called e-waste. Faster obsolescence and subsequent up-gradation, new electronic products are forcing consumers to discard old products, which in turn accumulate huge amounts of e-waste.

E-waste contains hazardous materials [2] such as brominated flame-retardants, PVCs and heavy metals like lead, cadmium and mercury, which are known to cause harm to the environment and human lives. Hazardous substances are contained within components such as printed circuit boards, cables, wiring, plastics, casings, displays monitors, cathode ray tubes (CRT), batteries, capacitors, resistors, relays and connectors and so on the land filling of these hazardous

materials risks the leaching of heavy metals like lead, cadmium and mercury into ground water or evaporation of mercury into air. Thus polluting the precious environment and society.

At present e-waste is the biggest and fastest growing waste stream, contributing more than 5% of total solid waste across the world. The e-waste menace has become a real world problem since it is affecting environment and society across the globe.

#### 1.1 Overview of Existing Recycling Methodologies

In general E-waste treatment and disposable methodologies prevailing are land filling, Incineration, recycling and reuse. In land filling and Incineration methodologies hazardous materials continue to release toxins in to environment causing human health hazards. Details of E-waste management in India and major parts of world are enumerated as follows.

Land filling is one of the most widely used methods [10] for disposal of e-waste. The degradation processes in landfills are very complicated and run over a wide time span. Land filling of e-waste risks are as follows.

- (i) Teaching of hazardous materials into soil and ground water such as broken lead containing glass, cone glass of cathode ray tubes and cadmium.
- (ii) Cadmium and mercury are emitted in diffuse form or via the landfill gas combustion plant.
- (iii) Landfills are prone to uncontrolled fires, which can release toxic fumes.

Incineration [10] is a controlled and complete combustion process, in which the e-waste is burned in specially designed incinerators at a high temperature at 900-1000 degrees Celsius. The disadvantages of incineration process are as follows.

- (i) Emission to air of substances escaping flue gas cleaning and large amount of residues from gas cleaning and combustion.
- (ii) E-waste incineration plants contribute significantly to the annual emissions of cadmium and mercury.
- (iii) Heavy metals not emitted into the atmosphere are transferred to slag and exhaust gas residues and can re-enter the environment on disposal.

Hence the e-waste incineration will increase these emissions it is very highly disadvantages and not a suitable method in disposal of e-waste. The land filling is not an environmentally sound treatment method for e-waste for substances, which are volatile and not bio-degradable. Therefore, there is a necessity to come up with a viable solution for e-waste recycling to make e-waste either nil or minimal.

**2.E-Waste Data Projections for 2050.**

In 2012 world populations stands at 7.03 billion and by 2050 it is expected to reach 12 billion. 70% of world population will be owning cell phones and other house hold consumer electronic devices.

The population projections for India [3], China [4], USA [5] and the entire world [6]-[9] are as shown in the table.1 below till 2050.

Country	2020 popln (Billions)	2030 popln (Billions)	2030 popln (Billions)	2050 popln (Billions)
India	1.326	1.460	1.571	1.657
China	1.423	1.454	1.376	1.320
USA	0.325	0.351	0.392	0.438
World	7.900	8.800	9.800	10.60

**Table.1 Population trends for 2050**

Rapid technology change, mass production, low initial cost, booming economies, high obsolescence rate have resulted in huge quantities of e-waste accumulation around the globe. Along with massive consumption and illegal export by developed countries to China, India and other African countries have added another dimension to e-waste problem. It is a crisis of not only the e-waste quantity alone but also another crisis born from harmful toxic ingredients, posing a great threat to the occupational health in the society as well as to the society. With the current rate of population growth and production of consumer electronics devices, one can imagine the e-waste levels which are going to become unmanageable by 2050 if necessary measures are not initiated. Hence new implementable technical solutions for recycling are necessary to minimise E-waste dumping in to the environment and prevent human health hazards.

The E-waste is growing at an unsustainable rate and is the most toxic component of municipal waste. Three categories of WEEE account for almost 90% of the e-waste generation with brief details as given below.

- (a) Large house hold appliances 42.1%
- (b) ICT Equipment 33.9%
- (c) Consumer electronics gadgets 13.7%

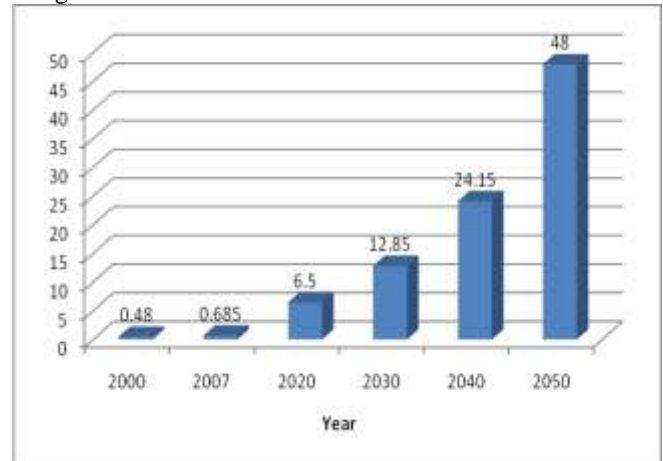
The e-waste growing trends are as shown in table.2.

Country	2020 (M T)	2030 (MT)	2040 (M T)	2050 (M T)
India	6.5	12.85	24.15	48.0
China	15.84	32.3	64.84	121.0
USA	13.75	18.46	27.5	41.0
World	103.9	169.0	270.8	345.0

**Table.2 Growing trends of E-Waste for 2050.**

**2.1 E-waste Data Projections for India**

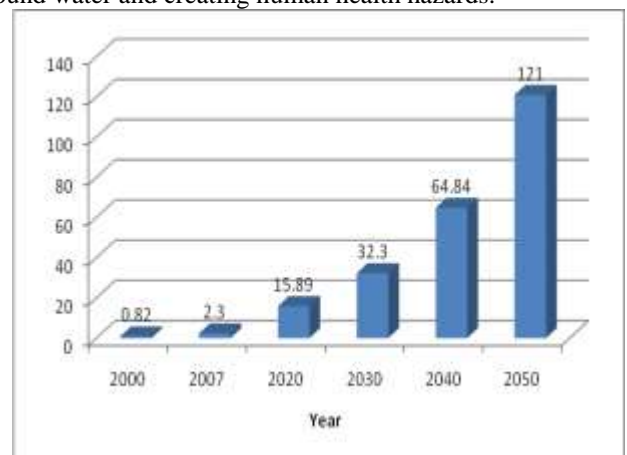
India is expected to generate about 6.5 million tonnes of E-waste [11] by 2020 and 48 million tonnes by 2050. Details of E-waste projections for India are as shown in figure 1. In India e-waste is growing at the rate of 10% and constitutes 3% of municipal solid waste. At present recovery of useful components for reuse, recovery of precious metals such as gold, silver, copper and other metals, rest is discarded in to environment. Otherwise various methodologies used in India are decontamination, dismantling, hammering (pulverization), shredding and density separation using water. There are about 47 recycling companies accounting for only 27% of E-waste leaving 83% into environment.



**Figure -1 e- waste projections for India**

**2.2 E-waste Data Projections for China**

China is expected to generate 15.84 million tonnes of E-waste by 2020 and 121 million tonnes by 2050. Details of E-waste projections for China are as shown in figure 2. There are about 500 villages in Guiyu, E-waste town in china recovering gold and silver and discarding 80% into environment, polluting ground water and creating human health hazards.



**Figure -2 : e waste projections for China**

**2.3 E-waste Data Projections for USA**

USA is likely to generate 13.75 million tonnes of E-waste by 2020 and 41 million tonnes of E-waste by 2050. Details of E-waste projections for USA are as shown in figure 3. There are 500 recycling companies in USA alone but only 20% of E-waste is recycled and rest of the 80% either exported or discarded into environment.

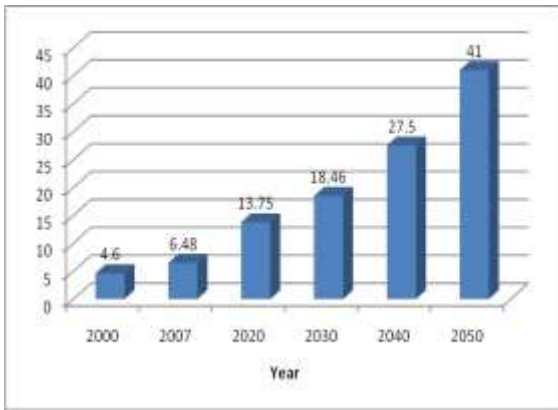


Figure -3 e- waste projections for USA

2.4. E-waste Data Projections for World

World is expected to generate 103.9 million tonnes of E-waste by 2020 and 345 million tonnes by 2050. Details of E-waste projections are as shown in figure 4. World average stands at 20% of recycling of e-waste as of now and rest 80% is discarded into environment.

Present recycling process involves dismantling and removal of different parts of E-waste containing dangerous substances, plastics, ferrous and non ferrous metals, their separation and segregation. Recyclers use strong acids to remove precious metals such as gold, silver and copper. The value of recycling from the element could be much higher if appropriate technologies are used. The recyclers working in open areas. Poorly ventilated enclosed areas without mask and technical expertise and machinery results in exposure to dangerous and slow poisoning chemicals. There is an urgent need to find suitable newer recycling and technical solutions for reducing the pumping of hazardous materials into environment to protect environment, ground water contamination and human lives.

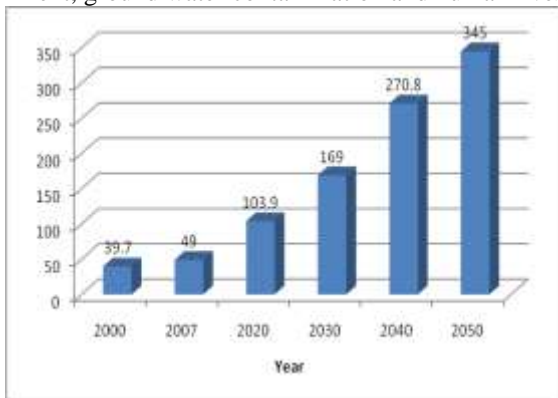


Figure -4 e- waste projections for World

3. Proposed Methodology

Performance and profit making should not be the main criteria for any Electronics and Communication products. Also along with this the ill effects they bring after discarding into environment must be addressed to reduce hazardous materials causing harm to human lives. Disposing of E-waste such as computer peripherals, storage media, printers, monitors, consumer electronics, networking equipment and communication equipment should be such that it is efficient and effective at the same time with minimum or no impact on environment.

This paper conceptualizes and proposes newer approaches for recycling and technology management of E-waste to address the future safety of environment and human lives. Also proposes further research for identification of machineries and

industrialization sites for setting up of chain of small scale industries.

Any major manufacturing facility is generally has a chain of ancillary or small scale industries producing spares and accessories for the major facility. The E-waste contains hazardous and non hazardous materials. For example personal computer generally composes of 26% silica gel glass, 23% plastic, 20% ferrous metals, 14% Aluminium and 17% others like gold, silver, copper, lead, zinc, mercury and cadmium. The block diagram of the proposed E-waste reverse engineering methodologies is as shown in fig. 5. The salient features of proposed recycling and technology management methodologies envisaged in this paper are as follows.

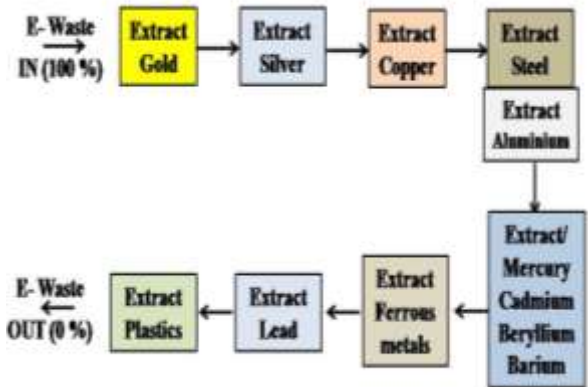


Figure.5 Block Diagram of Ancillary (Small Scale) Industrial setup

- (a) Identify and Select the key cities which are generating large quantities of E-waste
- (b) Identify suitable area near IT parks(consumer electronics industries) in those cities.
- (c) Set up chain of ancillary or small scale industrial belts for extracting all the materials used and found in the E-waste.
- (d) Extract the materials one by one with respective ancillary or small scale industrial set up. After extraction of gold the e-waste content moves to next stage where silver is extracted, then to copper, aluminium, lead, Barium, Mercury, Beryllium, Steel, zinc, cadmium, nickel, ferrous metals, plastics and so on.
- (e) There is a need to consider design of this chain of ancillary or small scale industrial set up for processing and extraction of materials suitably depending on the content and on their hazardous or non-hazardous nature.
- (f) Most of the materials used are procured from existing bigger industries, hence they must set up mini models for extraction of respective materials for reuse.
- (g) E-waste needs to be centrally transported to these centres and inputted to the chain of ancillary or small scale industrial set up for processing and extraction of respective materials found in the E-waste.
- (h) The final out come from the ancillary or small scale industrial set up of this kind should be minimal from the E-waste or nil amount of materials so that no harm/minimal harm is envisaged to environment or for human lines.

4. Discussion

The inference from this research paper is that the issue of hazardous material discarded in to the world through E-waste is assuming alarming proportions. It is estimated that on global scale approximately 20 kg of this material is put into market every year per inhabitant and an estimated 50 million tonnes of E-waste is produced every year.

It is estimated that 80% of e-waste is put in to landfills where as 20% is re-cycled for reuse.

The best example to be quoted here is the Guiyu, the world's largest e-waste site in China's Guangdong province. Here e-waste processing business, often with primitive and hazardous methods which has led to severe health problems to the township. It is expected that one tonne of computer e-waste contains more gold than 17 tonnes of gold ore. Due to this Guiyu township [12] has the unique way of gold and silver harvesting from e-waste where basic safety protocols are compromised and then the remaining e-waste is discarded in to landfills or so. Some of the land fills can be reclaimed decades later [13], but there are multiple issues involved. If the locations are concentrated with toxic materials, like this Guiyu as an example, we might have to wait for centuries before the land could be safe for human living.

Guiyu in China, Delhi & Bangalore in India, as well as the Agbogbloshie site near Accra, Ghana [14] have e-waste processing areas. Uncontrolled burning, disassembly and disposal causes a variety of environmental problems such as ground water contamination, atmospheric pollution, or even water pollution either by immediate discharge or due to surface runoff. Additionally health problems including occupational safety and health effects among those directly or indirectly involved due to the primitive methods of processing the e-waste. Thousands of men, women and children are involved highly polluting, primitive recycling technologies, extracting metals, toners and plastics. Recent unconfirmed studies indicate that 7 out of 10 children in this Guiyu region have much lead in their blood.

There is a strong lesson from this example for countries like China, India, African Nations and the whole world to apply the concepts proposed in this paper as early as possible.

The first such ancillary or small scale E-waste reverse engineering industrial set up is required to be set up on war footing at Guiyu, in China where toxic E-waste has assumed alarming proportions which can only be ensured by UNO.

In India Ministry of Environment and Forests, Government of India is the nodal agency for policy, planning, promoting and coordinating environmental programme including e-waste [15]-[16]. An exclusive notification on e-waste (Management and Handling) Rules, 2010 have been made effective from 01 May 2012 to address the safe and environment friendly handling, transportation, storing, recycling and also to reduce the use of hazardous substances during manufacturing of electronics and electrical equipments. Central and state pollution control boards have also stepped in to effective management of e-waste. It is expected that these measures will be far away from effective addressing of the e-waste compared to ideal technical solution approach proposed in this paper.

The concept presented in this paper for recycling is certainly expected to solve and address the e-waste problem to the maximum extent possible for entire world on implementation since this is a real world problem.

#### 4.1. Implications of Proposed methodology

The proposed setting up of ancillary and small scale industrial set up for processing and extraction of E-waste at selected cities across the world will give rise to the following factors which will have to be accepted.

(a) Cost considerations for setting up of chain of ancillary/small scale industrial set up will certainly go high.

(b) There will be resistance from the respective bigger industries for this set up.

(c) Imposition of strong legislation attracts protests from designers/manufacturers because they need profits.

(d) Even though large profits are not expected marginal profits are expected. But the service done to protect environment and greener earth and human lives goes a long way for human kind.

#### 5. Conclusion

The major contributed solution proposed in this paper is the idea of setting up of chain of ancillary and small scale reverse engineering industrial belts to ensure prevention of discarding of e-waste into the environment and society. At the same time entire e-waste is recycled for reuse which will be a profit making venture through employment generation. This solution is a boon for environment, society, consumer electronics industry, Government, Non Governmental Organizations (NGO's) Academic institutes and consumers alike.

Exporting of more electronics waste to South-East Asia and Haiti is a stronger correlation to trade without any concern to poverty or environmental concerns. Thousands of men, women and children are employed in refurbishing, repair and remanufacturing which are environmentally unsustainable. The technical solution proposed in this paper is objectively sustainable from all angles of trade. It generates employment, extracts all metals and e-waste discarding into environment is either nil or minimal.

Developing countries utilize methods that are more harmful and wasteful, as can be seen in Guiyu in Shantou region of China, which is the best example. An expedient and largely prevalent solution is simply to through the equipment onto open fire, in order to melt plastics and to burn away invaluable metals. This releases carcinogens and neurotoxins into air, contributing to an acid, lingering smog. These are toxic fumes which include dioxins and furans [17]. Also bonfire refuse is dispensed of quickly into drainage ditches or waterways or rivers [18] – [19].

This kind of environmental, soil and water pollution can be completely eliminated and overcome through implementation of the ideal technical solution proposed in this paper. Another noble contribution of this proposed technical solution is the environmental and social benefits that include diminished demand for virgin raw materials with their own environmental issues of extraction and minimal or nil use of landfills, thus ensuring environmental sustainability.

This technical solution is a noble method for e-waste processing and gives rise to following multiple benefits.

(a) High environmental and health benefits to society.

(b) High efficiency of extraction of all raw materials used in e-waste.

(c) Nil or minimal soil and water contamination due to nil chemical disposal.

(d) Nil or minimal toxic emissions since there is no burning of materials.

(e) Employment generation.

It may not be very easy to invest in the beginning but the existing material industries have to be convinced for the cause of environment and society to safeguard the future.

This paper recommends that India has to start the ancillary or small scale industrial set up at most e-waste producing cities in the first phase by 2030, considering the E-waste accumulation. They are Mumbai, Delhi, Bengaluru, Chennai, Kolkata, Ahmadabad, Hyderabad, Pune, Surat and Nagpur.

Since number of IT parks has come up in these cities, it is a novel idea for setting up of E-waste recycling industrial set up next to these parks. In the second phase by 2050 India has to plan setting up of these ancillary/small scale industrial E-waste recycling set up in Indore, Bhopal, Coimbatore, Trivandrum, Mangalore, Mysore, Lucknow, Patna, Gauhati and visakapatnam, Jaipur, Jodhpur. Similar ancillary reverse engineering industrial set ups are required to be set up in China, parts of Africa and across the world to sustain environmental safety for 2050, first set up must come up at Guiyu in China.

In addition to draw backs of present recycling processes, the existing dumping grounds in China, India, parts of Africa are full and overflowing beyond capacity and it is difficult to get new dumping sites due to scarcity of land by 2030 and by 2050. Therefore, the methodology proposed in this paper for setting up of chain of small scale reverse engineering industries across the major cities of the world for E-waste recycling is the best possible option, including for future needs.

This technical solution is a way forward for clear and precise solution for e-waste across the world and for all players of consumer electronics industry and also to sustain environmental safety. To resolve the growing crisis of e-waste, world needs specific and dedicated regulatory mechanism for which following points are required to be driven for environmental sustainability.

- Consumer Electronics Manufacturers have to accept the hazards to environment leaving the desire for large profits alone and set up ancillary or small scale industrial set up.
- Consumers also have to compromise on performance factor.
- Extended producer responsibility must be encouraged whereby those who produce e-devices are responsible and to give helping hand for the setting up of ancillary industrial set up.
- A strong standard legislation is required to be imposed on all concerned agencies.
- Discipline and ethics of all concerned and cooperation in recycling industrial set up goes a long way in ensuring environment pollution control.

## 6. Future Scope

Future scope exists for further research for identification of comprehensive machinery and methodology for small scale industrial set up for effective e-waste reverse engineering for environment pollution control. Scope also exists for development of suitable machinery and new extraction techniques for E-waste recycling.

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