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E-Waste Management is an Emerging Challenge in the Globe: A Pilot Study in Indian Scenario

Shalabh Agarwal*
Department of Computer Science
St. Xavier's College(Autonomous)
Kolkata, India
e-mail: shalabh@sxccal.edu

Surajit Bhowmik
Department of Computer Science
St. Xavier's College(Autonomous)
Kolkata, India
e-mail: bhowmik1994@gmail.com

Aneesh De
Department of Computer Science
St. Xavier's College(Autonomous)
Kolkata, India
e-mail: aneeshde@hotmail.com

Asoke Nath
Department of Computer Science
St. Xavier's College(Autonomous)
Kolkata, India
e-mail: asokejoy1@gmail.com

Abstract— The socio and environmental impact of rapid increase of electrical and electronic waste or E-waste at global level has been evaluated in detail all over the globe. As a case study the authors have chosen Indian scenario to analyse various issues regarding generation, storage, transportation and disposal of e-waste. The threat of electronic waste (e-waste) destroying the ecological health is threatening large over India. E-waste from old computers is set to jump 400 per cent within the next five years, while it is expected to increase seven times from 2007 levels within the next five years. In 2005 it was estimated that 1.47 lakh tonnes of E-waste was being generated in the country in 2005. Seven states including Delhi, Maharashtra, Tamil Nadu, Andhra Pradesh, UP, West Bengal, Punjab and Karnataka generated 70 per cent of the total amount of e-waste. It was found that eight lakh tonnes of e-waste was generated in India in 2012. According to an official report Delhi is presently generating 32 tonnes of e-waste a day with 1,500 trucks required every day to lift the waste. No land has been allocated for its dumping and other neighbouring states are also not willing to give land for dumping e-waste. With a great deal of this waste being handled by the unorganized sector, health issues of workers handling the waste have become vital. Many people are suffering from breathing problems such as asthma and bronchitis. In the present paper the authors have given a summary report on present scenario of e-waste production and its impact on social and environmental issues of the globe as well as in India.

Keywords— e-waste, environmental impact, health issues, breathing problems, ICT

I. INTRODUCTION

Waste Electrical and Electronic (WEEE) or E-waste is one of the fastest growing waste streams in the world. Nowadays, with the vision 2020, there are many challenges that need to be faced to realize the vision. Two of the critical challenges are Human Resources Development and Information and Communication Technology (ICT) development [1]. E-waste [2] policies for waste management is different from the policies applicable for traditional waste types because the E-waste stream also contains highly toxic substances, which have a dangerous impact on both, health and environment [3](Guo et al., 2010) and valuable raw materials which can be recovered[4]. E-waste may contain hazardous substances such as lead, mercury, PCB, asbestos and CFC's that pose a risk to human health as well as the environment. The amount of E-waste is growing rapidly, due to the wide use of this equipment, both in developed countries and in developing countries. E-wastes contain valuable material that can be recovered as secondary resources to conservation of energy and reduction in greenhouse gas emissions. Under such circumstances, lack of properly formulated micro and macro scale E-waste management plans may lead to serious local and global catastrophes in the near future. At present in eight Asian countries (India, Pakistan, Bangladesh, Bhutan, Nepal, Sri Lanka, Malaysia and Indonesia), E-waste disposal is performed in a highly disorganized and uncontrolled manner. Several layers of society have indicated that lack of knowledge in handling E-waste and the absence of proper policies and guidelines at state level are basic reasons of E-waste mismanagement. E-wastes are substances or objects, which are disposed of or are intended to be disposed of, or are required to be disposed of by the provisions of national laws. Additionally, wastes are items which people are required to discard, by law because of their hazardous properties. Our daily activities have given a rise to a large variety of different wastes arising from different sources. Thus, municipal waste is waste generated by households and consists of paper, organic waste, metals, etc. The wastes generated by production processes, households and commercial activities are hazardous waste. Biomedical waste is waste generated by hospitals and other health providers and consists of discarded drugs, waste sharps, Text of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, UNEP, Geneva, Switzerland, microbiology and biotechnology waste, human anatomical waste, animal waste, etc. Radioactive waste is any material that contains a concentration of radio nuclides greater than those deemed safe by national authorities, and for which, no use is foreseen. Other sources of waste include end-of-life vehicles, packaging waste, tyres, agricultural waste, etc. These waste substances are hazardous in nature, in the long run, as they are ignitable, corrosive, reactive, toxic, explosive, poisonous or infectious. Hence, they pose a substantial or potential threat to public health and the environment.

Like hazardous waste, the problem of e-waste has become an immediate and long term concern as its unregulated accumulation and recycling can lead to major environmental problems endangering human health. The information technology has revolutionized the way we live, work and communicate bringing countless benefits and wealth to all its users. The creation of innovative and new technologies and the globalization of the economy have made a whole range of products available and affordable to the people changing their lifestyles significantly. New electronic products have become an integral part of our daily lives providing us with more comfort, security, easy and faster acquisition and exchange of information. But on the other hand, it has also led to unrestrained resource consumption and an alarming waste generation. Both developed countries and developing countries like India face the problem of e-waste management. The rapid growth of technology, up gradation of technical innovations and a high rate of obsolescence in the electronics industry have led to one of the fastest growing waste streams in the world which consist of end of life electrical and electronic equipment products. It comprises a whole range of electrical and electronic items such as refrigerators, washing machines, computers and printers, televisions, mobile phones, I-pods, etc., many of which contain toxic materials. Many of the trends in the consumption and production processes are unsustainable and pose a serious challenge to the environment and human health. The countries of the European Union (EU) and other developed countries have, to an extent, addressed the issue of e-waste by taking policy initiatives and by adopting scientific methods of recycling and disposal of such waste. The EU defines this new waste stream as 'Waste Electrical and Electronic Equipment' (WEEE). As per its directive, the main features of the WEEE include definition of 'EEE', its classification into 10 categories and its extent as per voltage rating of 1000 volts for alternating current and 1500 volts for direct current. The EEE has been further classified into 'components', 'sub-assemblies' and 'consumables'. Since there is no definition of the WEEE in the environmental regulations in India, it is simply called 'e-waste'. E-waste or electronic waste, therefore, broadly describes loosely discarded, surplus, obsolete, broken, electrical or electronic devices. In the present work, the authors have made an in depth study of what e-waste is and how it is growing in a country like India and how it causes some fatal diseases, in the above backdrop, to assess the present situation of E-waste management in an industrialized country, with the view of developing a feasible management model. Various issues at global level are analysed and discussed, giving special attention to India, which has been selected as a case study.

II. E-WASTE GENERATION IN INDIA

All over the world, the quantity of electrical and electronic waste generated each year, especially computers and televisions, has assumed alarming proportions. In 2006, the International Association of Electronics Recyclers (IAER) projected that 3 billion electronic and electrical appliances would become WEEE or e-waste by 2010. This would be equal to an average e-waste generation rate of 400 million units a year till 2010. Globally, about 20-50 MT (million tonnes) of e-waste is disposed of each year, which accounts for 5% of all municipal solid waste. Although no definite official data exist on how much waste is generated in India or how much is disposed of, there are estimations based on independent studies conducted by the NGOs or government agencies. Central Pollution Control Board (CPCB) estimated India's e-waste at 1.47 lakh tonnes or 0.573 MT per day. A study released by the Electronics Industry Association of India (ELCINA) at the electronics industry expo – "Componex Nepcon 2009" had estimated the total e-waste generation in India at a massive 4.34 lakh tonnes by end 2009. The CPCB has estimated that it will exceed the 8 lakh tonnes or 0.8 MT mark by 2012. There are 10 States that contribute to 70 per cent of the total e-waste generated in the country, while 65 cities generate more than 60 per cent of the total e-waste in India. Among the 10 largest e-waste generating States, Maharashtra ranks first followed by Tamil Nadu, Andhra Pradesh, Uttar Pradesh, West Bengal, Delhi, Karnataka, Gujarat, Madhya Pradesh and Punjab. Among the top ten cities generating e-waste, Mumbai ranks first followed by Delhi, Bengaluru, Chennai, Kolkata, Ahmedabad, Hyderabad, Pune, Surat and Nagpur. The main sources of electronic waste in India are the government, public and private (industrial) sectors, which account for almost 70 per cent of total waste generation. The contribution of individual households is relatively small at about 15 per cent; the rest being contributed by manufacturers. Though individual households are not large contributors to waste generated by computers, they consume large quantities of consumer durables and are therefore, potential creators of waste. An Indian market Research Bureau (IMRB) survey of 'E-waste generation at Source' in 2009 found that out of the total e-waste volume in India, televisions and desktops including servers comprised 68 per cent and 27 per cent respectively. Imports and mobile phones comprised of 2 per cent and 1 per cent respectively. Recycling Plant in Roorkee opened in January 2010. Despite 23 units currently registered with the Government of India, Ministry of Environment and Forests/ Central Pollution Control Board, as e-waste recyclers, having environmentally sound management facilities, the entire recycling process more or less still exists in the unorganized sector. The Ministry of Environment and Forests (MoEF) has notified the Hazardous Wastes (Management, Handling and Transboundary Movement) Rules, 2008 for effective management of hazardous wastes, including e-waste in the country. But these rules do not apply to the radioactive wastes such as Cobalt – 60 which are covered under the Atomic Energy Act, 1962.

III. IMPACTS OF E-WASTES

Electronic wastes can cause widespread environmental damage due to the use of toxic materials in the manufacture of electronic goods. Hazardous materials such as lead, mercury and hexavalent chromium are present in one way or another in wastes such as Cathode ray tubes (CRTs), Printed board assemblies, Capacitors, Mercury switches and relays, Batteries, Liquid crystal displays (LCDs), Cartridges from photocopying machines,

Selenium drums (photocopier) and Electrolytes. Although it is hardly known, e-waste contains toxic substances such as Lead and Cadmium in circuit boards; lead oxide and Cadmium in monitor Cathode Ray Tubes (CRTs); Mercury in switches and flat screen monitors; Cadmium in computer batteries; polychlorinated biphenyls (PCBs) in older capacitors and transformers; and brominated flame retardants on printed circuit boards, plastic casings, cables and polyvinyl chloride (PVC) cable insulation that releases highly toxic dioxins and furans when burned to retrieve Copper from the wires. All electronic equipment contains printed circuit boards which Sardinia 2007, Eleventh International Waste Management and Landfill Symposium stated hazardous because of their content of lead (in solder), brominated flame retardants (typically 5-10 % by weight) and antimony oxide, which is also present as a flame retardant (typically 1- 2% by weight). Landfilling of e-wastes can lead to the leakage of lead into the ground water. If the CRT is crushed and burned, it emits toxic fumes into the air. These products contain several rechargeable battery types, all of which contain toxic substances that can contaminate the environment when burned in incinerators or disposed of in landfills. The cadmium from one mobile phone battery is enough to pollute 600 m3 of water. The quantity of cadmium in landfill sites is significant, and considerable toxic contamination is caused by the inevitable medium and long-term effects of cadmium leaking into the surrounding soil. Because plastics are highly flammable, the printed wiring board and housings of electronic products contain brominated flame retardants, a number of which are clearly damaging to human health and the environment. The accrued electronic and electric waste in India is dismantled and sorted manually to fractions such as printed wiring boards, cathode ray tubes (CRT), cables, plastics, metals, condensers and other, nowadays invaluable materials like batteries. It is a livelihood for disorganized recyclers and due to lack of awareness; they are risking their health and the environment as well. The valuable fractions are processed to directly reusable components and to secondary raw materials in a variety of refining and conditioning processes. No sophisticated machinery or personal protective equipment is used for the extraction of different materials. All the work is done by bare hands and only with the help of hammers and screwdrivers. Children and women are routinely involved in the operations. Waste components which does not have any resale or reuse value are openly burnt or disposed of in open dumps. Pollution problems associated with such backyard smelting using crude processes are resulting in emissions and slag containing heavy metals of health concern. CRT breaking operations result in injuries from cuts and acids used for removal of heavy metals. Respiratory problems are also caused due to shredding, burning etc. They use strong acids to retrieve precious metals such as gold. Working in poorly ventilated enclosed areas without masks and technical expertise results in exposure to dangerous and slow poisoning chemicals. Polychlorinated biphenyls (PCBs) in older capacitors and transformers; and brominated flame retardants on printed circuit boards, plastic casings, cables and polyvinyl chloride (PVC) cable insulation can release highly toxic dioxins and furans when burned to retrieve copper from the wires. On a broader scale, analysing the environmental and societal impacts of e-waste reveals a mosaic of benefits and costs. It is claimed that e-waste recycling will produce greater employment, new access to raw materials and electronics, and improved infrastructure will result. These will further boost the region's advance towards prosperity. Yet the reality is that the new wealth and benefits are unequally distributed, and the contribution of electronics to collective growth is sometimes misleading. Most e-waste "recycling" involve small enterprises that are numerous, widespread, and difficult to regulate. They take advantage of low labour costs due to high unemployment rates, internal migration of poor peasants, and the lack of protest or political mobilization by affected villagers who believe that e-wastes provide the only viable source of income or entry into modern development pathways. They are largely invisible to state scrutiny because they border on the informal economy and are therefore not included in official statistics.

IV. E-WASTE MANAGEMENT IN INDIA

Despite a wide range of environmental legislation in India there are no specific laws or guidelines for electronic waste or computer waste. As per the Hazardous Waste Rules, e-waste is not treated as hazardous unless proved to have higher concentration of certain substances. Though PCBs and CRTs would always exceed these parameters, there are several grey areas that need to be addressed. Basel Convention has Waste electronic assemblies in A1180 and mirror entry in B1110, mainly on concerns of mercury, lead and cadmium. Electronic waste is included under List-A and List-B of Schedule-3 of the Hazardous Wastes (Management & Handling) Rules, 1989 as amended in 2000 & 2003. The import of this waste therefore requires specific permission of the Ministry of Environment and Forests. As the collection and re-cycling of electronic wastes is being done by the informal sector in the country at present, the Government has taken the following action/steps to enhance awareness about environmentally sound management of electronic waste. Several Workshops on Electronic Waste Management was organised by the Central Pollution Control Board (CPCB) in collaboration with Toxics Link, CII etc. Action has been initiated by CPCB for rapid assessment of the E-Waste generated in major cities of the country. A National Working Group has been constituted for formulating a strategy for E-Waste management. A comprehensive technical guide on "Environmental Management for Information Technology Industry in India" has been published and circulated widely by the Department of Information Technology (DIT), Ministry of Communication and Information Technology. Demonstration projects have also been set up by the DIT at the Indian Telephone Industries for recovery of copper from Printed Circuit Boards. Although awareness and readiness for implementing improvements is increasing rapidly, the major obstacles to manage the e-wastes safely and effectively remain. These include the lack of reliable data that poses a challenge to policy makers wishing to design an e-waste management strategy and to an industry wishing to make rational investment decisions. Only a fraction of the e waste (estimated 10%) finds its way to recyclers due to absence of an efficient take back scheme for consumers.

The lack of safe e-waste recycling infrastructure in the formal sector and thus reliance on the capacities of the informal sector pose severe risks to the environment and human health. The existing e waste recycling systems are purely business-driven that have come about without any government intervention. Any development in these e-waste sectors will have to be built on the existing set-up as the waste collection and pre-processing can be handled efficiently by the informal sector, at the same time offer numerous job opportunities. It has analysed e-waste recycling frameworks and processes in different parts of the world (Switzerland, India, China, South Africa) in its first phase (2003-04) and all results of the project are documented on the website http://www.ewaste.ch/. Sardinia 2007, Eleventh International Waste Management and Landfill Symposium. In table-1 the authors have shown the effect of different e-waste on human health.

TABLE-1
EFFECTS OF COMPUTER E-WASTE ON HUMAN HEALTH

S. No.	Constituent	Source in Computer E-waste	Effect on Human health
1	Lead (Pb)	Solder in printed circuit boards, glass panels, gaskets in computer monitors and CRT's	Damage to central and peripheral nervous systems, blood systems and kidney damage. Affects brain development of children.
2	Cadmium (Cd)	Chip resistors, semiconductors and old CRT's	Toxic irreversible effects on human health. Accumulates in kidney and liver. Causes neural damage. Causes Teratogenic effects.
3	Mercury (Hg)	Relays and switches, printed circuit boards	Chronic damage to the brain. Respiratory and skin disorders due to bioaccumulation in fishes. Damage to central nervous system Mercury can be passed to infants through breast milk
4	Hexavalent chromium (Cr) VI	Corrosion protection of untreated and galvanized steel plates	Asthmatic bronchitis. DNA damage. Carcinogenic (cancer causing)
5	Plastics including PVC	Cabling and computer housing	Burning produces dioxin which causes: Reproductive and developmental problems; Immune system damage; Interfere with regulatory hormones
6	Brominated flame retardants (BFR)	Plastic housing of electronic equipments and circuit boards.	Disrupts endocrine system functions Impaired learning and memory functions
7	Barium (Ba)	Front panel of CRTs	Short term exposure causes: Muscle weakness; Damage to heart, liver and spleen.
8	Beryllium (Be)	Motherboard	Carcinogenic (lung cancer) Inhalation of fumes and dust. Causes chronic beryllium disease or Beryllicosis. Skin diseases such as warts.

Effect of Computer E-Waste on the Environment

1) If proper Landfilling methods are not undertaken while disposing of E-Waste, the leakages from these wastes pollute the groundwater.
2) Leakages from Computer E-Waste affect the soil fertility and the overall productivity of the land.
3) Acids and Sludge obtained from melting computer chips, if disposed on the ground causes acidification of soil.
4) Incineration of E-Wastes may emit toxic fumes and gases thereby causing Air pollution.
5) Mercury from E-wastes lead to bio-accumulation of the substance in the food chain and hence causes bio-magnification of the substance in living organisms, thereby having adverse effects on them (mainly heterotrophy). For example, high levels of mercury are suspected to impair the loon's reproductive success as well as cause growth related problems.

V. E-WASTE STRATEGIES AND APPLICATIONS

Due to this complex composition of valuable and hazardous substances, specialized and often "high-tech" methods require to process E-waste through the methods that maximize resource recovery and minimize potential harm to human or the environment. Unfortunately, the use of such specialized methods is rare with much of the world's E-waste traveling far distances, mostly to developing countries, where crude techniques are often used to extract precious materials or recycle parts for further use. Such "backyard" techniques will pose a threat to poorly protected workers and their local natural environment. Moreover, they are very inefficient in terms of resource recovery, as recycling in these instances usually focuses on a few valuable elements ,such as, gold and copper (with often poor recycling yields), while most other metals are discarded and inevitably lost. In this respect, it may be demonstrated that, resource efficiency is

another important dimension in E-waste discussion in addition to the ecological, human security, economic and social aspects.

A. Methods of Disposal

In 1990s, governments of the EU, Japan and some of the US states set up E-waste 'recycling' systems, whereas, a large member of countries did not have the capacity to deal with the sheer quantity of E-waste they have generated or with its hazardous nature. So therefore, they began exporting the issue to developing countries, where laws to protect workers and the environment are inadequate or is not enforced. It is also cheaper to 'recycle' waste in developing countries; the cost of glass-to-glass recycling of computer monitors in the U.S. is ten times more than in China. Demand in Asia for electronic waste began to grow, when they found out that they could extract valuable substances, such as, copper, iron, silicon, nickel and gold during the recycling process in scrap yards. A cell phone, for instance, contains 19 percent copper and eight percent iron. Almost two million tonnes of E-waste were landfilled in 2005. While toxic materials comprise only a small amount of this volume, it does not take much lead or mercury to contaminate the soil of an area or water supply. One should keep this in mind, when deciding what to do with those old electronic devices.

1) Landfill: According to the US EPA , more than 4.6 million tonnes of E-waste ended up in the U.S. landfills in 2000. Toxic chemicals in electronic products can leach into the land over time or are released into the atmosphere, impacting nearby communities and the environment. RegulationS have been declared to prevent electronic waste being dumped in landfills due to its hazardous content in many European countries. However, the practice still continues in numerous countries. In Hong Kong, for example, it is estimated that 10-20 percent of discarded computers penetrate into landfill.

2) Incineration: This product releases heavy metals, such as lead, cadmium and mercury into the air . Mercury released into the atmosphere can bioaccumulate in the food chain, particularly in fish - the main route of exposure for thegeneral public. If the products contain PVC plastic, highly toxic dioxins and furans are also released. Brominated flame retardants generate brominated dioxins and furans when E-waste is burnt.

3) Recycling: Although recycling can be an appropriate way to reuse the raw materials in a product, the hazardous chemicals in E-waste can be harmful to workers in the recycling yards, as well as their neighboring communities and environment. Electronics recycling is carried out in built recycling plants under controlled conditions in developed countries, for example, in many EU states. In order to avoid brominated furans and dioxins being released into the atmosphere, plastics from E-waste are not recycled. However, such constraints are not available in developing countries. Recycling is conducted by hand in scrapyards, often by children.

4) Exportation: E-waste is routinely exported to developing countries by developed ones, often in violation of the international law. Inspections of 18 European seaports in 2005 found the amount of 47% of waste destined for export, including E-waste, which was illegal. In the UK , at least 23,000 metric tonnes of undeclared or 'grey' market electronic waste was illegally shipped to the Far East, India, Africa and China. It is estimated that, 50-80% of the waste collected for recycling is being exported in this way in the US. This practice is legal because, the US has not ratified the Basel Convention.

B. Challenges on management of E-waste

There is no logical and strict legislative framework to determine the collection and disposal of E-waste generated from commercial buildings. In order to have a developed country, more effort is needed, so as to legislate on protection of the environment, particularly, lack of infrastructure for the collection of the end of life products, as well as, facilities to dispose such an environmentally sound manner in the EE sector .Control over raw materials, used in manufacturing is significantly important to reduce waste generation. Reduction of hazardous materials will ultimately lead to a reduction in the quantity of waste generate with the advent of inventory management.

C. Recovery and Reuse

Waste can be recovered on-site, or off-site recovery facility or through industry exchange. Physical and chemical techniques, such as electrolysis, reverse osmosis and filtration could be used to reclaim a waste material. Metals, such as copper, in PCB manufacturing could be reclaimed using electrolytic recovery. Many parts of discarded computers and television sets can be re-employed for newer products either in the same state or by passing through a revamping process. However, at present in many of the developing countries (even in developed countries) there are no proper mechanisms to collect the material in such a way that the stocks can be classified and deliver to processing centres for re-using. Such mechanism will not only reduce the addition of waste into the surrounding but also increase the job opportunities to the public.

D. Sustainable Product Design

The following are recommendations we make for sustainable eco-friendly product:

1) Designing products with less hazardous and less quantities of materials: eg: Reduce material for new computer design by flatter, lighter and more integrated components.

2) Use of renewable materials and energy: eg. Bio-based materials, as Bio-plastics made from plant-based polymers and the use of solar energy.

3) Use of no-renewable materials that are safer: Designers should ensure that such a product is manufactured for reuse, repair/or upgradability.

4) Use of bio-degradable materials in non-conducting parts of equipment such as Biodegradable polymers equipment covers and PCB bases.

E. E-waste policy and regulation

The Policy shall address all issues ranging from production and trade to final disposal, including technology transfers for the recycling of electronic waste. Manufactures of products must be made financially, physically and legally responsible for their products. Policies and regulations that cover Design for Environment (DfE) and better management of restricted substances may be implemented through measures such as

1) specific product take-back obligations for industry
2) financial responsibility for actions and schemes
3) greater attention to the role of new product design
4) material and/or substance bans including stringent restrictions on certain substances
5) greater scrutiny of cross-border movements of Electrical and Electronic Products and e-waste

The key questions about the effectiveness of legislation would include:

1) What is to be covered by the term electronic waste?
2) Who pays for disposal?
3) Is producer responsible for the answer?
4) What would be the benefits of voluntary commitments?
5) How can sufficient recovery of material be achieved to guarantee recycling firms a reliable and adequate flow of secondary material?

A complete national level inventory, covering all the cities and all the sectors must be initiated.

VI. CONCLUSION AND FUTURE SCOPE

Solid waste management, which is already a mammoth task in India, is becoming more complicated by the invasion of e-waste, particularly computer waste. There exists an urgent need for a detailed assessment of the current and future scenario including quantification, characteristics, existing disposal practices, environmental impacts etc. Institutional infrastructures, including e-waste collection, transportation, treatment, storage, recovery and disposal, need to be established, at national and/or regional levels for the environmentally sound management of e-wastes. Establishment of e-waste collection, exchange and recycling centers should be encouraged in partnership with private entrepreneurs and manufacturers. Model facilities employing environmentally sound technologies and methods for recycling and recovery are to be established. Criteria are to be developed for recovery and disposal of E-Wastes. Policy level interventions should include development of e-waste regulation, control of import and export of e-wastes and facilitation in development of infrastructure. An effective take-back program providing incentives for producers to design products that are less wasteful, contain fewer toxic components, and are easier to disassemble, reuse, and recycle may help in reducing the wastes. It should set targets for collection and reuse/recycling, impose reporting requirements and include enforcement mechanisms and deposit/refund schemes to encourage consumers to return electronic devices for collection and reuse/recycling. End-of life management should be made a priority in the design of new electronic products.

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