

HIGH-TECH TRASH FROM OUR MODERN SOCIETY

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Introduction

Thirty or forty years ago, an average family would have owned very few electronic items in their homes. They might have owned a radio and a television, a refrigerator, a vacuum cleaner and perhaps a record player. However, an average family in the modern society would own significant number of electronic items such as computers, mobile phones, video recorders, music centers, as well as, equipment for kitchen like microwave ovens, washing machines, dishwashers,....the list goes on.... In offices and shops, an equally rapid electronic revolution has taken place adding items such as computer systems, telecommunication systems, photocopiers, security systems,....again the list goes on.... As a consequence there has been an increase in numbers and volumes of electronic items reaching the end of their useful life and becoming obsolete. These items are known as 'e-waste' or 'WEEE' (waste from electrical and electronic equipment).

E-waste is one of the fastest growing areas of the international waste stream increasing, according to European Union studies, at a level of approximately 3-5 % per annum or approximately three times faster than other individual waste streams (Schwarzer et al. 2005). The benefits of computer use are well known. However, often ignored, is the harm caused. This is disguised by the apparent advantages of the computer and the significant role it has played in the last 30 years in the transformation of social and economic life. It is often seen as one answer to achieving a reduced level of resource use. E-commerce growth alone may reduce resource consumption and waste disposal but this is more than compensated for by increased consumer spending, mostly slanted towards high energy and material consumption.

Computers that brought revolution in the realm of information and communication technology and transformed life in the second half of the 20th century has grown exorbitantly in numbers as well as in speed, memory and power and this has led to rapid product obsolescence. Software companies constantly generate new programs that fuel the demand for more speed, more memory and power. Today, it is frequently much cheaper and more convenient to buy a new machine to accommodate a newer generation of technology than it is to upgrade the old. As a result, the average lifespan of new model computer has decreased from 4.5 years in 1992 to an estimated 2 years in 2005 (Widmer et al. 2005). Cell phones have an average lifespan of less than a year, and in most cases stereo equipment is not even worth repairing anymore.

Besides the hardware materials, electronics products consume a great amount of packaging materials as they are very sensitive and have to be handled with care during the transit from the industry to the showroom/store in the supermarket and from the store to the customers. Electronics products are also generally transported to long distances within the country and even to overseas and require intensive packaging.

The aim of this paper is to provide an overview of the problem of e-waste and in particular of the major component of electronic waste, Computer Waste.

Computers and Toxics

In general computer equipment is a complicated assembly of more than 1,000 materials, many of which are highly toxic. The production of semiconductors, printed circuit boards, disk drives and monitors use particularly hazardous chemicals, and workers involved in chip manufacturing are now beginning to complain about cancer clusters. Printer inks and toners often contain toxic materials such as carbon black and cadmium. They are insidious health hazards. Computer Central Processing Unit (CPU) contains heavy metals cadmium, lead and mercury. Experiments confirm that CPUs frequently exceed the hazardous waste limit. Printed Circuit Boards (PCB) contain heavy metals antimony, silver, chromium, zinc, lead, tin and copper. There is hardly any other electronic product than the PCB for which the sum of the environmental impacts from raw material extraction to industrial refining and production, use and disposal is so extensive.

Lead is widely used as a major component of solders and as lead oxide in the glass of cathode ray tubes (CRTs) used in computer monitors, as well as in acid batteries. Lead is highly toxic to humans and can cause damage to the central and peripheral nervous systems, blood system, and kidneys. 40% of the lead found in landfills are supposed to come from used electronic items (Realf et al. 2004). Cadmium is classified as toxic with a possible risk of irreversible effects on human health. Like lead, cadmium can accumulate in the body over time causing long term damage to human parts. In e-waste cadmium occurs in certain components such as chip resistors, infrared detectors and semi conductors. e-waste also contains flame retardants such as polybrominated biphenyls (PBB) and polybrominated diphenylethers (PBDEs). In computers these are used in printed circuit boards, connectors, covers and cables.

Safe Management of e-waste

According to the United States Environmental Protection Agency (US EPA) more than 2 million tonnes of e-waste end up in landfills every year (Schwarzer et al. 2005). Concern is growing worldwide about electronic wastes leaching lead (Pb) and other heavy metals that may seep into groundwater supplies. Experiments confirm that every type of electronic device leaches lead (Pb) above the hazardous waste levels. Leaching into soil and groundwater will occur regardless of whether the landfill is sealed or not. It has become a common knowledge that all landfills leak. Even the best 'state of the art' landfills are not completely tight throughout their lifetimes and a certain amount of chemicals and metal leaching will occur. Carbon dioxide building up in the landfills increases the acidity of the leachates, thereby increasing the solubility of toxins such as the heavy metals. It has been found that significant amount of lead (Pb) ions are dissolved from broken lead containing glass such as the cone glass of cathode ray tubes, when mixed with acid waters which commonly occur in landfills.

In view of the emission of dioxins and furans resulting from incineration of e-waste (containing considerable amounts of plastics, brominated and chlorinated compounds) incineration of e-waste is potentially a dangerous method. Copper in e-waste works as a catalyst for dioxin formation. Incineration of brominated flame-retardants at a low temperature (600-800° C) may lead to the generation of extremely toxic polybrominated dioxins (PBDDs) and furans (PBDFs). Also significant quantities of PVC are contained in electrical and electronic wastes which makes the flue gas residues and air emissions particularly dangerous. Incineration of e-waste also results in high concentrations of metals, including heavy metals in the slag, in the fly ash, in the flue gas, and in the filter cake.

Reuse of e-waste means using any old and obsolete product or equipment with or without minor repair and reasonable upgrading, if possible. This is very much relevant with electronic wastes specially the computers, audio and video equipments, whose model is changing very fast and new, more sophisticated, improved and upgraded versions continue to invade the market and consumer's mind. The unfortunate part is that the price of the new models and upgraded versions is continuously falling giving more temptation to the consumers for discarding the old ones and replacing with the new.

The best way to reuse computers is to sell them to the employees of the organizations or the students of institutions at very reasonable price or donated to charitable organizations, schools, orphanage centers, old people homes, asylums etc. Institutions and organizations in the rich developed nations (where computer models are changing fast) should develop a system based on ethics for donating their old computers to the needy organizations in the developing countries.

There are several advantages to giving or discount selling of computers and laptops to employees. In an age of job-hopping, this additional benefit may reflect a commitment by management to employees, garnering greater employee loyalty. Donating computers to charitable organizations, schools and needy people must provide the company / organization with tax benefits that may exceed the expected value from selling it via the secondary market.

Computers can be recycled to dismantle the equipment or a product and retrieve the valuable components / materials from it for their reuse in other equipment or re-manufacture a new equipment / product. The difficulty with electronic waste and many other end of life electronic products is that they are made from a huge range of component materials that are useless for further manufacture until the product is dismantled and the component materials are separated. This is most of the time a very difficult and expensive process.

Most major computer manufacturers in world e.g. Dell, Hewlett-Packard (HP), Compaq, Gateway have begun to address e-waste problems with their own end-of-life management programs which offers a combination of trade-in, take-back and recycling programs. Dell and Gateway lease out their products thereby ensuring they get them back to further upgrade and lease out again.

A report by Basel Action Network and the Silicon Valley Toxics Coalition '*Exporting Harm: The Techno-Trashing of Asia*' asserts that 50 to 80 % of e-waste collected for recycling in the U.S. is exported to developing nations. BAN produced a film on the report which shows the Guiyu village in Guangdong province in China as 'electronics junkyard'. Some 100,000 men, women and children make US \$1.50 a day dismantling e-waste by bare hands to retrieve the valuable metals and materials. Circuit boards are melted over coal grills to release valuable metals giving highly toxic dioxin fumes. Riverbank acid baths are used to extract gold. Lead-containing cathode ray tubes from monitors and televisions are not of much market value and hence are dumped in some wastelands. Toner cartridges are pulled apart manually, sending clouds of toner dust into the air. Soil and drinking water at Guiyu are contaminated by lead much above WHO limits- soil by 200 times and water by 2,400 times. Water has to be trucked from 30 km away. At one point of time both China and India were willing to take the e-waste for almost free. For poor countries of the world it is an untenable choice between 'poverty and poison' (Puckett et al. 2002).

In November, 2002 officials from eight Asian nations met in Tianjin, China, under the auspices of Basel Convention to prevent their nations from being made the dumping grounds of hazardous e-waste in the name of free trade (export and import) for recycling discarded electronic products. It was represented by India, Malaysia, the Philippines, Singapore, Sri Lanka, Thailand, and Vietnam. Resource persons came from Canada, Japan, the U.S. and the Secretariat of the Basel Convention. Financial support was provided by Australia, Japan and Canada.

European Union Directives on Extended Producer Responsibility (EPR) for Electronic Products

In 2001, the European Union adopted a system called 'Extended Producer/Manufacturer Responsibility' that requires the electronics manufacturers to 'take-back' their used products and assume full responsibility for the production of cleaner electronics items, phasing out of hazardous materials in production process, and also dismantling the products more easily for recycling at the end of their useful life by trading-in the products. EPR involves producers and original equipment manufacturers behaving more responsibly and see that their products have least impact on the human health and the environment throughout their life. It includes upstream as well as the downstream impacts, the former arising from the extraction of raw materials from environment, use of water, energy and chemicals in the production process, while the latter arising from the use of manufactured products by the consumers and then their disposal after use as e-waste. EPR encourages producers to prevent waste & pollution at source, reduce resource and energy use at every stage of the product life-cycle through improvement in product design and process technology (eco-efficient), so that the products last longer and don't need to be replaced and recycled very often. (Bapat, 2005)

When the manufacturers are made accountable for take-back, dismantling and recycling, they will produce equipments and products that contain fewer hazardous materials and do not need expensive treatments. In other words the manufacturers have to embrace the philosophy of 'cleaner production' in their industries. Thus, EPR is about making the 'producers pay' for their faults if they do not behave. It is very much like the 'polluters pay' principle.

EU Directives on 'Waste Electrical and Electronics Equipment' (WEEE) (2003)

In January 2003, the EU Parliament enacted Directives on 'Waste Electrical and Electronics Equipment' (WEEE) based on the concept of EPR. It has two components-

(1) The first requires the industries to 'take-back' for recycling all end-of-life electronics product. This includes nearly any product with a battery or a cord, computers, phones, mainframes, and peripherals. It puts full financial responsibility on producers to set up collection, recycling and disposal systems. Following are the conditions for recycling & disposal:

- i. Between 70 - 90 % by weight of all collected equipments must be recycled or re-used. In the case of computers and monitors, 70 % recycling must be met.
- ii. Recycling does NOT include 'incineration' or retrieval of materials by burning of e-waste. For final disposal, however, after recycling, incineration is allowed for the rest 10 - 30 % e-waste.
- iii. Before final disposal of the remaining e-waste either by incineration or in the landfills, the hazardous materials like lead, mercury, chromium, cadmium, asbestos, beryllium,

PCBs, halogenated flame-retardants (PBBs & PBDE) and the radioactive substances must be removed from any end of life equipment.

- iv. Producers can send their WEEE for recycling treatment in another country but NOT to non-EU countries where no or lower treatment standards than in the EU exist.

(2) The second Directive ‘Restriction on Hazardous Substances’ (ROHS), calls for phasing out of heavy metals mercury (Hg), cadmium (Cd), lead (Pb) hexavalent chromium (Cr VI) and the two classes of brominated flame-retardants e.g. (Polybrominated Biphenyls & Polybrominated Diphenyl Ethers) in all electronics and electrical items by July 2006, with a number of exemptions. The Directive encourages research into alternative materials which are good substitutes and also environmentally benign.

The 15 Member States of the EU in general welcome the Directive which will enter into force in 2006. Netherlands, Denmark, Sweden, Austria, Belgium, Italy, Finland and Germany are already ahead with legislation. Member States shall encourage producers to integrate an increasing quantity of recycled materials in new products and make sure that producers design equipment that includes labels for recyclers that identify plastic types and location of all dangerous substances. They must also collect information from manufacturers on a yearly basis about quantities of electronic equipment put on the market, both by number of units and by weight. By ensuring this feedback to the producers and by making them financially responsible for end of life waste management, manufacturers will have financial incentive to re-design their electronic products with less hazardous and more recyclable materials. It is envisaged that the extra costs of e-waste management by companies will be reflected in 1 – 3 % higher retail price on some items. Based on the ‘polluter pay’ principle, consumers who buy electronic products must pay the full price of that product (i.e. manufacturing cost + cost of recycling and disposal when it is discarded as e-waste) rather than the general taxpayer who may never purchase that particular product. The Directive also emphasizes for an efficient system for the consumers to return the discarded electronic items free of charge for recycling to be a success.

Australian Scenario of e-waste

In Australia, e-waste is one of the fastest growing waste streams. (Meihardt Infrastructure & Environment Pty Ltd, 2004) state over 2.4 million desktop and notebook type PCs are being sold each year; from 1998 until 2001, printer sales (68 percent inkjet) ranged between 1.08 to 1.85 million units a year; between 2001 and 2003 sales of scanners decreased from 365,000 to 206,600; and, multifunction devices (MFD) sales reached 300,000 units in 2003. LCD technology is overtaking CRTs in stand alone sales.

(Meihardt Infrastructure & Environment Pty Ltd, 2004) provide a guesstimate on the computer waste stream that has resulted from previous sales of PCs. They state there are currently between 5-23 million computers stored around Australia. Future waste streams arising from new sales (see **Table 1**) are estimated at 1.7 million annually by 2006.

Table 1. Recycling, Storage and Landfill of WEEE

Disposal Option	2001	2006	2011
Recycled	281,700	494,000	509,600
Landfilled	926,500	1,632,800	1,694,700
Sent to storage	1,331,000	1,792,800	1,839,800

Source: Meinhardt Infrastructure and Environment Group, 2004

It is estimated that Australia is currently one of the top ten countries using information and communication technology, ranking tenth in the world for spending per capita and fifth in the world for spending as a percentage of gross domestic product. Around half of all Australian households now have a computer and over 36% use the Internet at home. There are an estimated 9.2 million computers in use around Australia. It is expected that over this year a further 2.1 million computers will enter the market, while 3 million will reach the end of their life. It is also estimated that in 2006 there will be around 1.6 million computers disposed of in landfill, 1.8 million put in storage (in addition to the 5.3 million already gathering dust in garages and other storage areas) and 0.5 million recycled in Australia alone (Australian Broadcasting Commission, 1995).

Australia lags behind Europe, Japan, Taiwan and a range of other Asian countries as well as parts of the United States where a number of programmes incorporating product stewardship and extended producer responsibility exist and provide outcomes consistent with the responsible management of hazardous waste. Australian State and Federal Governments are still working to impose regulation directed towards extended producer responsibility upon computer manufacturers and retailers with a view to managing this now huge and growing waste stream. Currently there are efforts towards a Co-Regulatory Framework for Product Stewardship, a Federal and State Government and industry cooperative push for industry to take primary responsibility for computer related products

Research and Development Opportunities

There is little in the way of research on the Australian electronics industry as it pertains to EPR or product stewardship and policy on e-waste. Papers to date have mainly been consultancy reports focusing on product stewardship in the packaging and building sectors. States are leading the Commonwealth in research on the issue. Most work in the area of electronics has been done on the television industry. This is a very different set of problems to that existing in the computer industry particularly given the number of products involved; a much larger problem of manufacturer proliferation because of the ease of manufacture and the resultant white boxes (no brand name) making up approximately 50% of all computers sold at the retail and institution level and subsequently larger “orphan” problem; the trade in e-waste for recycling and export; constituent components and sheer weight of numbers of computers in use, in storage, being sold at auction or, just in existence.

There is virtually no research being carried out on issues existing within the electronics industry and no research entities are involved in this area at all. The area of policy development for the electronics industry is quite contemporary and to date, essentially ignored in Australia. This makes available significant opportunities for potential researchers on e-waste to establish a research stream focussing on issues within the electronics industry, particularly as they pertain to policy and technological solutions to electronic waste.

Areas of Further Research

Given the relative youth of the e-waste debate and the scarcity of rigorous research and literature on the topic, there is a clear need for research to address the problem of e-waste and other issues associated with product stewardship in the electronics industry. Griffith University's research team has identified following areas as key areas for further research:

- Design and life-cycle issues associated with and impacting on e-waste – transport etc;
- Reuse and remanufacture of e-waste components;
- The feasibility of an EU style EPR scheme in Australia;
- The use of CRT lead glass in fibreglass reinforcing;
- The Australian auction system and the refurbishing, resale and export of computers from Australia including the use of second country recycling facilities for the processing of Australian e-waste;
- Refurbishment, the community and welfare sector and product stewardship;
- The recycling, export, remanufacture and use of computer plastic in products destined for consumer use, with particular emphasis on plastic containing brominated flame retardants;
- The potential for cooperation in purchasing policy between State and Federal agencies and its ability to incorporate extended producer responsibility and other mandatory provisions to promote sustainable development - including the identification of factors inhibiting change in these agencies;
- Cooperation within the computer industry between software, component and computer manufacturers and barriers to reuse.

Conclusions

E-waste management in the developed nations specially the U.S. are heavily dependent upon the recycling technologies and systems of the developing countries, but in developing countries, the recycling and disposal for safe e-waste management suffers from inherent lack of proper regulations and monitoring systems. Exports of electronic waste (for recycling and recovery of valuable products) from rich developed nations (mainly the U.S.) to poor developing countries of Asia and Africa in the name of free trade are motivated by brutal global economics. Market forces dictates that toxic waste will always run downhill on an economic path of least resistance. A free trade in hazardous wastes leaves the poorer countries of the world with an untenable choice between 'poverty and poison'. Governments have started banning imports of such electronic scraps in the name of free trade. Great care has to be taken in the disposal of the computers as e-waste which has 'man-made brain'. Regardless of how old computers are disposed off (either donated or sold for reuse or recycled to recover the valuable materials), there are several important steps to take before handing them over for reuse or recycling or de-manufacturing and re-manufacturing. The 'hard-drive' must be removed and reformatted. Simply deleting files does not prevent them from being recovered from the hard drive. Sometimes files can be retrieved from the reformatted drives.

Electronics industries will be forced to embrace the philosophy of 'Cleaner Production' in electronics products and devices and minimize the generation of e-waste if people (consumers) resort to the philosophy of 'Cleaner Consumption'. Green buying in electronics product is the answer. The consumers should look for electronics products which are:

- Having a 'leasing' or 'take-back' options after becoming obsolete;
- Made with fewer toxic constituents;
- Made from more recycled contents and components;
- Designed for the environment such as 'easy to upgrade' and 'easy to dismantle (disassemble)' for recycling;
- Energy efficient with higher 'Energy Star' ratings;
- Presented with minimal packaging materials; and
- Having a certification of recognition from an independent certification group as environmentally preferable product.

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