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Economics

E-SOCIETY NEXUS E-WASTE: NEED SCIENCE WITH HUMAN FACE

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ABSTRACT Wastes are the results of industrialisation and urbanisation, modernisation and consumerisation, chemicalisation and agriculturalisation, technologisation and population explosion. Wastes are of different kinds, which include household wastes, commercial wastes, industrial wastes, agricultural wastes, sewage wastes, municipal wastes, bio-medical wastes, radioactive wastes, and e-wastes. e-Wastes refer to any old, obsolete, end-of-life appliances which have been disposed-off by their owners. e-Wastes are man-made mountains of 21st Century. These wastes are carefully managed by adopting sustainable principles through reuse, recycle, reduce, renew, refuse and recover. Present and Future generations face many environmental challenges like global warming ozone layer depletion, acid rain, desertification, loss of biodiversity, clouds bursting and e-wastes. A sustainable society can be created through the sustainable use of resources of different kinds. The key message of this paper is to create e-Wastes free society so that Sustainable Development Goals can be achieved.

KEYWORDS : e-Waste, Sustainable Development Goals and Environmental Challenges

Introduction

Human civilization has been witnessing a host of revolutions of different kinds *viz.* the Industrial Revolution (IR) of the 17th and 18th centuries and the Digital Revolution (DR) of the 20th and 21st Centuries. These revolutions have been producing both positive externalities and negative externalities. Positive externalities are the advantages, merits and pros derived from revolutions. which enhanced the quality of life in terms of comfort, security, and easy and faster acquisition and exchange of information. Negative externalities are the disadvantages, demerits, and cons of these revolutions faced by the society in the form of untold sufferings, pollution of different kinds, pollutants and degradation of biotic and abiotic environment. It is well-known fact that the environmental resources of mother earth perform a number of functions such as production function, information function, carrier function and regulatory function. These functions are disturbed, diluted and degraded by the ecological misbehaviour of human society. Failures to live in harmony with nature have brought humanity to the brink of a global environmental catastrophe (Krishna Iyer, 1999). Men's greed attacks nature, the environment and ecology and wounds nature backlashes on the human future. Production and consumption activities of human society have been producing enormous quantities of waste of different kinds such as household wastes, commercial wastes, industrial wastes, agricultural wastes, sewage wastes, mining and quarrying wastes, municipal wastes, medical wastes, radioactive wastes, and the latest is e-Wastes.

The Wastes are generated by many economic and non-economic variables and affluence of society including rising per capita GDP. rising disposable income, changing pace of lifestyle along with the availability of choices, increasing per capita energy consumption, expanding per capita consumption expenditure, declining prices of electronic gadgets influenced by robust demand, shortening life-span of products, adventing new S&T. promoting R&D, up-grading technological innovations and inventions, replacing obsolescence's and outdated technologies, escalating population explosion, urging urbanization, promoting rapid pace of industrialization, encouraging the culture of consumerism, launching chemicalization, swelling mechanization. adopting LPG (Liberalization, Privatization and Globalization). Thus, quick scanning of revolutions along with development leads anyone to conclude that society enjoys multiplicity of benefits from nature and its derivatives including S&T, particularly from the electronic goods invented, discovered and innovated by scientists and technologists. But, on the other, uncultured and mismanaged consumption, use and utilization of these revolutions generated mountains of waste including the trash of GenNext e-waste that produce unimaginable and undesirable. consequences on mother earth.

Wastes: Manmade Mountains of 21st Century

Wastes are substances or objects, which are disposed of or are intended to be disposed of. or are required to be disposed of. Additionally, wastes are such items which people are required to discard, because of their hazardous properties. Our daily activities give rise to a large variety of different wastes arising from different sources. Household Waste is the waste we produce in our homes; this will be a varying mixture of, for example, food waste that is biodegradable, plastics which are not biodegradable but combustible, metals which are neither biodegradable nor combustible but are recyclable, glass which is neither biodegradable nor combustible and is difficult to recycle. paper which is biodegradable, combustible and recyclable etc. Commercial Waste which is predominantly office waste emanating from the sector is similar in consistency to domestic waste and is increasingly being regarded with domestic waste as MSW. Industrial Waste contains all the elements of commercial waste but with the additional by-products of liquid effluents, and oils, which are increasingly being regarded as hazardous. Construction and Demolition (C&D) Waste generally differs considerably from the foregoing waste streams in that it contains a high proportion of minerals which are not biodegradable or combustible and which are often not worth recycling. Agricultural Waste varies hugely depending on the type of farming in a particular area: arable farming produces a greatly different waste stream from livestock farming, for example. Agricultural waste is the catch-all phrase for waste streams as different as cattle dung, poultry litter, used fencing, asbestos, and plastic wrapping, all of which have to be dealt with in very different ways. Sewage Waste refers solely to the biological waste produced by human beings. However, unlike the dung of most animals, because of our modern diets, human sewage contains trace elements which are deemed to be undesirable. Mining & Quarrying (M&Q) Waste is nearly all mineral waste, which is neither biodegradable nor combustible and is difficult to recycle. 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, microbiology and biotechnology waste, human anatomical waste, animal waste, etc. Radioactive Waste is any material that contains a concentration of radionuclides greater than those deemed safe by national authorities,

and for which, no use is foreseen. e-Waste refers to any old, obsolete, end-of-life appliances, using electricity which has been disposed off by their owners. It contains small quantities of precious metals, such as silver, gold and platinum, and non-renewable resources, such as tin, nickel, zinc and copper. It may also contain hazardous materials such as mercury, lead, arsenic, beryllium and cadmium, as well as other materials such as plastics and glass. For example, Gold is used in computers to ensure rapid and accurate transmission of digital information through the computer. Gold meets these requirements better than any other metal. Therefore, the annual demand for gold in electrical and electronic equipment is some 300 tonnes on average. This extraction alone produces 5.1 million tonnes of CO_2 (at the rate of 17,000 tonnes of CO_2 per tonne of gold). Other metals like copper, cobalt, tin, indium, silver, palladium, platinum and ruthenium used in electrical and electronic equipment account for an annual CO_2 emission level of 23.4 million tonnes, almost 1/1000 of the world's CO_2 emissions. These 23.4 million tonnes do not include CO_2 emissions from metals used in electrical and electronic equipment like steel, nickel or aluminium, nor other CO_2 emissions associated with the manufacturing or use of electrical and electronic equipment. These waste substances are in the long run hazardous in nature as they are ignitable, corrosive, reactive, toxic, explosive, poisonous or infectious. According to UNEP, 20-50 million tons of e-waste is yearly generated worldwide. Each European citizen contributes an average of 14 kg each year and this amount is growing by 8.0 per cent per year. In India, approximately 2 lakhs tonnes of e-waste was generated in 2007. With the prediction that nearly 8 lakh tonnes of e-waste are generated in 2012. UNEP further say that the total e-waste generated in the EU is about 14. 15kg per capita whereas in India and China the per capita e-waste is less than 1kg.

e-Goods: Are Wealth or Waste for GenNext?

e-Goods or electrical and electronic equipment or 'EEE' means equipment which is dependent on electrical currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such current and designed for use with a voltage rating not exceeding 1000 volts for alternating current and 1500 volts for direct current. e-Goods (Fig. 1) play a significant role in the development of different economies, industries, institutions and society and they directly or indirectly enhance the quality of our lives.

Figure 1 - eGoods

e-Goods are considered wealth for a few nations involving massive exports of EEE and but at the same time wastes for the global environment, which faces different kinds of global environmental issues such as global warming, ozone layer depletion, acid rain, desertification, loss of biodiversity, cloud bursting and e-waste. e-Goods are wealth because, the world is increasingly dependent on electronic devices particularly digital devices like computers, cell phones etc. Generally, e-goods benefit economic sectors such as industry, transport, commercial, household, agricultural, social and service sectors. The efficiency and productive capacity of these sectors, in one way or another way, are highly dependent upon e-goods. Further, these sectors are also responsible for the creation and generation of waste resulting in unsustainable development as well as Dis-development.

e-waste: Definitions by Institutions and Authors

e-Waste is a highly complex waste stream as it contains both very scarce and valuable as well as very toxic components. It also lacks a uniform international definition. Some of the frequently referred definitions in the e-waste literature are: OECD (2001) (www.oecd.org): "Any appliance using an electric power supply that has reached its end-of-life". EU WEEE Directive (2002): "Electrical or electronic equipment which is waste... including all components, sub-assemblies and consumables, which are part of the product at the time of discarding." Directive 75/442/EEC, Article 1 (a) defines "waste" as "any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force". Basel Action Network (www.ban.org): "e-Waste encompasses a broad and growing range of electronic devices ranging from large household devices such as refrigerators, air conditioners, cell phones, personal stereos, and consumer electronics to computers which have been discarded by their users". UNEP (2007): "e-waste is a generic term encompassing various forms of EEE that are old, end of life electronic applications and have ceased to be of any value to their owners. StEP (2009): "a term used to cover almost all types of electrical and electronic equipment that has or could enter the waste stream. Although e-waste is a general term. it can be often considered to cover almost any household or business item with circuitry or electrical components with power or battery supply" Sinha (2004): "an electrical power appliance that no longer satisfies the current owner for its original purpose". Peralta and Fontanos (2005): "e-waste as electronic products that no longer satisfy the needs of the initial purchaser". Davis and Heart (2008) and e-Waste Guide (2009): "e-waste as obsolete, end-of-life or discarded appliances that use electricity". Bandyopadhyay (2010): "any electrically powered appliance that fails to satisfy the current owner for its originally intended purpose". Accordingly, we refine the above definitions to refer to e-waste as: electronic equipment that is considered to be hazardous and does not, in its functional state, serve any purpose to any intending user unless the equipment has been refurbished.

e-Waste Estimation: Methodology

Each electronic item's participation in the annual e-waste production. E(kg/year) depends on each electronic item's mass, M(kg), its quantity (number) in the market and consumption, N and its average life cycle, L(year). Thus

E=MN/L

Table 1 e-waste types and estimated life cycle

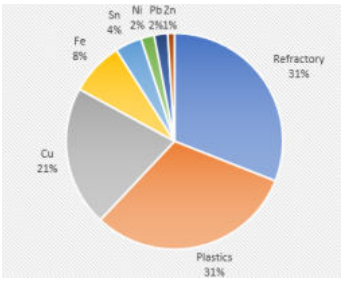
S.No.	Item	Mass of item (kg)	Estimated life (year)
1.	PC	25	3
2.	Fax machine	3	5
3.	Cell Phone	0.1	2
4.	Electronic games	3	5
5.	Photocopier	60	8
6.	Radio	2	10
7.	TV	30	5
8.	Videorecorder/ DVD player	5	5
9.	AC	55	12
10.	Dishwasher	50	10
11.	Electric cooker	6	10
12.	Food mixer	1	5
13.	Freezer	35	10
14.	Hair dryer	1	10
15.	Iron	2	10
16.	Kettle	1	3
17.	Microwave	15	7
18.	Refrigerator	35	10
19.	Toster	1	5
20.	Tumble dryer	35	10
21.	Vacuum cleaner	10	10
22.	Washing machine	65	8

Source: Compiled from various sources

e-Waste consists of all waste from electronic and electrical appliances which have reached their end-of-life period or are no longer fit for their original intended use and are destined for recovery, recycling or disposal. It includes a computer and its accessories monitors. printers, keyboards, central processing units: typewriters, mobile phones and chargers, remotes, compact discs, headphones, batteries, LCD/Plasma TVs, air conditioners, refrigerators and other household appliances.

The composition of e-waste is diverse and falls under 'hazardous' and 'non-hazardous' categories. Broadly, it consists of ferrous and non-ferrous metals, plastics, and glass. wood and plywood, printed circuit boards, concrete, ceramics, rubber and other items. Iron and steel constitute about 50.0 per cent of the waste, followed by plastics (21.0 per cent), non-ferrous metals (13.0 per cent) and other constituents. Non-ferrous metals consist of metals like copper, and aluminium and precious metals like silver, gold, platinum, palladium and so on. The presence of elements like lead, mercury, arsenic, cadmium, selenium, hexavalent chromium, and flame retardants beyond threshold quantities makes e-waste hazardous in nature. e-Wastes contain over 1000 different substances many of which are toxic and potentially hazardous to the environment and human health.

Figure – 2 Composition of e-Wastes



Source: Compiled from various sources

The composition of e-wastes widely varies depending on the type of the products and their models and the presence of metals such as Fe (Iron). Cu (Copper), Al (Aluminium), Pb (Lead), Ni (Nickel) and precious metals like Ag (Silver). Au (Gold) and Pd (Platinum) are found. The older model of the e-scrap was found to contain a higher value of precious metals. There is wide variation in the weight composition of e-scraps and the average content is 40.0 per cent metals, 30.0 per cent plastic and 30.0 per cent refractory as shown in Fig.2. Among the metals copper, iron, tin, and lead. Aluminium and nickel are found in significant amounts while other metals like gold silver etc. are found in traces

e-Waste and its Impact on Health

The table given below reflects the harmful elements in the compositions of electrical and electronic appliances that can be hazardous to health and the environment.

Metal	Danger
Lead	Affects the kidneys, reproductive system and mental development
Plastic	Harms reproductive and immune system
Chromium	Damages the liver and kidneys and produces asthmatic bronchitis and lung cancer
Mercury	Affects the central nerves system, kidneys and immune system and impairs foetus growth harms infants
Beryllium	Causes lung diseases
Cadmium	Causes severe pain in the joints and spine, affects the kidneys and softens bones.
Acid	Cause respiratory problems and is corrosive to the eye and skin.

A recent UNEP study identifies three types of hazardous emissions from electronic products during the recycling process: primary emissions resulting directly from the hazardous substances contained in the waste; and, secondary and tertiary emissions resulting from the transformation of those substances through burning, smelting, or through the use of other hazardous substances in the recycling process. The environmental burden due to the production of electrical and electronic products ("ecological baggage") exceeds by far the one due to the production of other household materials. A UN study found that the manufacturing of a computer and its screen takes at least 240 kg (530 pounds) of fossil fuels, 22 kg (48 pounds) of chemicals and 1.5 tonnes of water more than the weight of a rhinoceros or a car (Kuehr and Williams, 2003).

e-Waste Reduction Strategies:

International Initiative: European Union developed two watershed laws the Restriction on Hazardous Materials (RoHS) and the Waste Electronic and Electrical Equipment (WEEE) directive to reduce the hazardous materials in electronic products and establish Extended Producer Responsibility (EPR) to require electronic manufacturers to accept life cycle responsibility for their products. EPR is a policy approach that holds manufacturers accountable for the full costs of their products at every stage in their life cycle, EPR is a strategy that requires producers to take back their products at the end of their useful lives or pay a recycling contractor to do 10 so, thereby internalising the cost of recycling or disposal in a manufacturers bottom line. When a company knows that it will bear the costs of product return and recycling, they are more likely to redesign its product for easier and safer handling at each step in the life cycle. This approach enforces the design strategy that takes into account the upstream environmental impacts inherent in the selection, mining and extraction of materials, the health and environmental impacts to works and surrounding communities during the production process itself, and downstream impacts during the use recycling and disposal of the products. In short, by requiring a company to take its products back, EPR aims to force the company to make the product cleaner in the first place.

Individual Producer Responsibility (IPR) applies to the management of new products put on the market. For historical waste, i.e. products put on the market before 13 August 2005, the financial responsibility is divided among producers in proportion to their market share of a specific type of equipment. The rationale behind producer responsibility is the "polluter pays" principle, which intends to include the costs of disposal and treatment in a product's price, thus reflecting the product's environmental effects (Nnorom & Osibanjo, 2008)

The Basel Convention on the Control of Transboundary Movements of hazardous Wastes and their Disposal is the most comprehensive global environmental agreement on hazardous and other wastes. It was signed by 173 countries on 22 March 1989 and entered into force on 5 May 1992. In the first decade (1989-1999), the Convention was primarily devoted to three agenda: setting up a framework for controlling the "transboundary' movement of hazardous wastes, that is, the movement of hazardous wastes across international frontiers; developing the criteria for "environmentally sound management (ESM); and putting into place a 'control system' based on prior written notification.

The Bamako Convention on the Ban of the Import into Africa and the Control of Transboundary Movement of Hazardous Wastes was adopted by the twelve nations of the Organization of African Unity at Bamako, Mali in January 1991, and came into force in March 1999. The Convention aims to protect human health and the environment from dangers posed by hazardous wastes by reducing their generation to a minimum in terms of quantity and/or hazardous potential.

The Rotterdam Convention Like the Bamako Convention, the Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Chemicals and Pesticides in International Trade regulates trade in hazardous wastes but contains no commitment to reduce their use and release. Adopted in September 1998, the Rotterdam Convention came into force in February 2004. As of July 2007, it had 73 signatories and 117 Parties. As of date, there are 140 parties. India acceded to the convention on 24 May 2005. It is a multilateral treaty to promote shared responsibilities between exporting and importing countries in protecting human health and the environment from the harmful effects of hazardous chemicals.

India's Initiatives: India is a signatory to the Basel Convention on the control of the transboundary movement of hazardous wastes and disposal. The Ministry of Environment and Forest has issued a number of notifications related to the safe disposal of hazardous waste.

- Hazardous Wastes (Management and Handling) Rules, 1998/2000/2002
- MOEF guidelines for Management and Handling of Hazardous Wastes, 1991
- Guidelines for Safe Road Transport of Hazardous Chemicals, 1995
- The Public Liability Act, 1991
- Batteries (Management and Handling) Rules, 2001
- The National Environmental Tribunal Act, 1995
- Bio-medical Wastes (Management and Handling) Rules, 1998
- Municipal Solid Wastes (Management and Handling) Rules, 2000 and 2002

- Guidelines for Environmentally Sound Management of e-Waste 2008
- Draft e-Waste (Management and Handling) Rule 2009.

A collaboration programme entitled "Indo-Swiss-German e-Waste Initiative" has been formed. The major objectives and scope of the initiative include (1) management of e-waste in an environmentally sound manner so as to reduce risks to society as also to abate the pollution of the environment owing to unsafe e-waste handling: (ii) development of skills to all concerned through knowledge transfer by means of seminars, workshops and campaign; and (iii) initially the existing informal recyclers to be selected as the target groups for evolving methodologies to create an integrated formal category (Widmer R, 2006).

Stakeholder's Initiatives: The producers: This is based on the producer responsibility principle. This is possible by reducing sales margins, or increasing sales prices. The current producer responsibility principle across Europe has not always been an incentive to collect more. simply because stakeholders responsible for financing have no economic benefits;

Government: As e-waste is a societal problem and it has a long-term environmental impact, the management system could be effectively regulated by policy mechanisms. The government also can use civil society organisations and media as watchdogs and management systems could be judiciously financed by tax; and

Consumers: This is an extension of the "polluter pays" principle.
e-Waste Management: Challenges and Strategies

Basically, four ways e-waste has been treated till date. But none has been found to be fully satisfactory. The most common one has been storing e-wastes in landfills, but it is replete with all the dangers of leaching. Another method commonly used has been to incinerate or burn the goods concerned, but this process releases heavy metals such as lead, cadmium and mercury into the atmosphere. Reusing and Recycling are the other ways of dealing with e-waste. They have been preferable because they increase the lifespan of the products and therefore imply less waste over time. Re-use constitutes direct second-hand use, or use after slight modifications are made to the original functioning equipment like memory upgrades, etc. However, they end up as waste eventually as they have a limited life span.

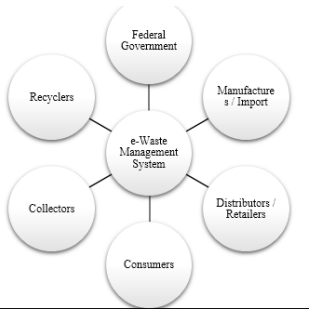
Extension of life span is a key strategy in managing the gamut of environmental impacts (energy use, chemical use, waste treatment, etc.) associated with computers. Another way to state this is that for computers, the conventional 3R (reduce, reuse, recycle) hierarchy of waste management is tilted even more towards reduce and reuse compared to most other goods. The e-Waste management can be easily solved with innovative technology and engineering. The e-waste problem, as of now, is purely an urban problem which is closely related to urban resources, consumption patterns, job and income levels and other socio-economic and cultural issues. Environmental legislation, consumer pressures and the 'polluter pays' approach to waste management are all increasing the pressure on electronic goods manufacturers to consider the environmental impact of their product at all stages of its life cycle, including ultimate disposal.

Besides the above, three key strategies are essential for e-waste management and they are Product Specific Approach - Green PLM: Producers of electrical and electronic goods have been increasingly looking into green Product Lifecycle Management (PLM). Green PLM the entire lifecycle of the product. By adopting a Green PLM approach, the producer can ensure that revisits the production process, promotes optimization and considers the environmental impacts of that process re-engineering is focused on energy saving. Under the Green PLM framework, each step of production is designed to be efficient and will reduce production cycle time and waste. With this approach, producers can improve material re-usability, re-manufacture and at the same time reduce waste and associated energy and emissions.

Industry Specific Approach - Reverse Logistics in Consumer Electronics: Reverse logistics refers to the return of goods from the consumer to the supplier. The reverse logistics pathway refers to the chain or series of step that has to be undertaken to ensure that the goods return to the supplier to recover, remarket, recycle and reuse. Realignment of Marketing Strategies: producers/re-furbishers of electrical and electronic goods will need to align their marketing strategies to ensure that they market recycled products. This will ensure a selling forum for refurbished or second-hand usable products. There should be an increase in vendor and customer awareness and producers need to promote discounts for customers' returns on end-of-lifecycle products. Increased marketing of green raw materials and green production processes will help producers to embrace Green PLM pathways.

The best e-waste management can be found in European Union. (Fig 3) This system is to be responsible for their products over the entire lifecycle of their products from design to use to disposal. In other words, Extended Producer Responsibility (EPR), can be defined as "the producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle". For instance, the e-waste management of the European Union is the best example for all countries of the world, given in the following diagram.

Figure 3 e-Waste Management in European Union



Federal Government: Overseeing the whole process and initiating the basic regulation and guidelines

Manufactures/Import: Responsible physically for managing the daily operation of the system

Distributors / Retailers: Retailers are also responsible physically for the EEE products with the manufactures

Consumers: Consumers are responsible for returning the discarded EEE to collectors

Collectors: location of collection collects all WEEE kind for free and responsible to prevent the illegal exportation

Recyclers: The administration of the government is responsible to operate the facility of recycling; Recyclers must follow to protect employee health.

Conclusion

Global environmental issues and problems have to be solved by promoting economics. social, technological, and environmental and energy sustainability with help of Environmentally Sound Technologies (ESTs). ESTs "are not just individual technologies, but, the total system which includes know-how, producers, goods and services, and equipment as well as organizational and managerial procedures". They protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technology for which they are substitutes. Agenda 21 of UNCED of 1992 called on governments to adopt ESTS and transfer ESTS from haves (industrialized) to have-nots (developing) for which the governments of the world must give top priority in this concern. Further, Public Private Partnership (PPP) is to be encouraged to develop techniques and technologies that reduce harmful environmental impacts. In this context, new and efficient technologies are essential to increase the capabilities, in particular of developing countries, to achieve sustainable development, sustain the world's economy protect the environment, and alleviate poverty and human suffering. For dealing with e-waste-the by-product of e-society-serious efforts is needed on the part of technocrats in designing e-waste policy in consultation with industry and the public in the areas of public education, technological investment, small business development, recycling impact assessment, informal collection and

recycling, health and safety. monitoring and information sharing, import of second-hand products. To save the present and future generations, what we need today is sustainable development, for which scientists should see the face of the human, develop science and technology, do research and development and demonstrate their talents and skills in creating an e-waste free society.

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