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E-waste Management: An Approach to Green Computing

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Abstract *— This paper intends to portrait how E-waste management and Green Computing helps to make the environment carbon-free and energy-efficient. Anything that runs on electricity that you have decided to get rid of constitutes E-waste. Eco-friendly and environmentally responsible usage of computers and their resources are said to be Green Computing. Here we discuss various sources of e-wastes, problems caused by them, their effects, different steps for proper handling of these toxic and harmful wastes to make the development process sustainable and green. The goal is to reduce the hazardous impact of electronic waste and preserve the environment through the proper disposal of e-waste. Thus, green computing attains the aim of going green set by the IT industries in terms of public relations and reduced cost. The objective of Green IT is to find and promote new ways of reducing pollution, discovering alternative technologies, and creating more recyclable products; E-waste utilization an approach to green computing is a way to achieve this.*

Index words **— E-waste, Green IT, Sustainable development, Going green, Green Technology, Energy efficiency, Green use, Energy star.**

I. INTRODUCTION

The tremendous technological development in the 21st century brought many advantages. However, the growth of the technologies demands high energy accompanied by intention e-waste and hazardous emissions. As technology is increasing exponentially, contributes more towards global warming and climate change. For these reasons, the world focuses on going green by taking initiatives for green computing through e-waste management. E-waste is one among the fastest-growing waste streams on the earth. Already, we produced something like quartile million tons of e-waste annually. Electronic waste is composed of electrical equipment that is outdated, unwanted, or broken. Anything that runs on electricity that you have decided to get rid of results in e-waste. Globally, we only recycle 10% of our e-waste, a variety that is as shocking because it is depressing. As for the 90% we do not recycle, it finishes up getting landfilled, incinerated, or illegally traded.

Green computing is a well-balanced and sustainable approach towards the achievement of a greener, healthier, and safer environment without compromising the technological needs of the current and future generations. The main goal of green computing is to maximize energy efficiency during the product's lifetime. It involves activities that emphases on the tactical deployment of IT to vigorously and ethically align organizations' aims and objectives with environmental protection in mind during the complete industrial operations.

The outline of this paper is structured as Section II describing the e-waste and e-waste management concepts. In section III the green computing and various aspects of green

computing are described. Finally, a conclusion is made followed by references.

II. E-WASTE AND E-WASTE MANAGEMENT

E-waste acronym for electronic waste may be referred to as the hardware products nearing the end of products useful phase. A well-known "Bathtub curve" helps in the reliability study of a hardware product. The life of hardware products consists of three phases: - Burn-in phase, Useful life phase, and wear-out phase.

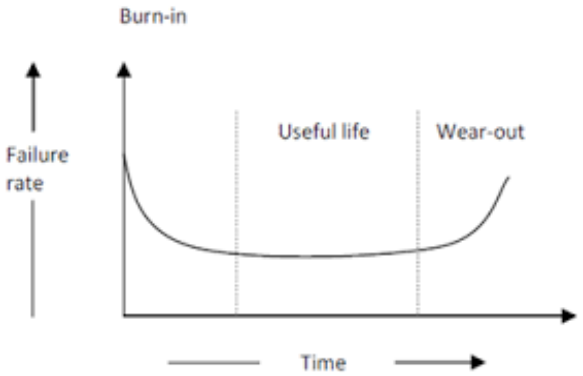

Fig. 1. Bathtub curve

The initial phase is said to be the burn-in phase, where the failure intensity is high. After completing testing and fault fixing, the intensity rate gradually comes down initially and stabilizes after some time. The second phase is the useful life phase, where the failure intensity is approximately constant. The third phase is called the wearing out phase because in this phase the failure intensity will increase due to the wearing out of the hardware components.

E-waste contains a laundry list of chemicals that are harmful to human beings and the environment. Disposal of e-waste possesses extra care because mishandling during disposal will end up with the chemicals that should be decomposed with air, water, and soil. All the electronic goods become obsolete, within two or three years of purchase. This global mountain of waste is expected to continue growing at 8% per year. Rapid changes in technology, changes in media, falling prices, and planned obsolescence have resulted in a fast-growing surplus of electronic waste around the globe. Computers and several other devices are associated with our day-to-day living. All these devices are consuming quite an amount of energy. On the other hand, technological advancements and short innovation cycles have increased the obsolesce rate of these devices, contributing to the e-waste streams [**3**].

Fig. 2. Examples of e-wastes

E-waste management refers to the process of managing e-wastes through a proper disposal way. E-waste is not just a waste. It contains highly toxic substances, such as mercury, lead, BFRs, etc. so the handling of e-waste should be given prior importance than anything.

The life cycle of e-waste can be divided into four phases [**1**]:

1. Phase I – Production of EEE (Electrical and Electronic Equipment).
2. Phase II – Generation of UEEE (Used Electronic and Electrical Equipment).
3. Phase III – Decision for fate.
4. Phase IV – E-waste Processing

A. Categories of e-waste

- Large Household Appliances:
  Washing machines, Dryers, Refrigerators, Air conditioners, etc.

- Small Household Appliances:
  Vacuum cleaners, Coffee Machines, Irons, Toasters, etc.
- Office, Information & Communication Equipment:
  PCs, Laptops, Mobiles, Telephones, Fax Machines, Copiers, Printers etc.
- Entertainment & Consumer Electronics:
  Televisions, VCR/DVD/CD players, Hi-Fi sets, Radios, etc.

- Lighting Equipment:
  Fluorescent tubes, sodium lamps etc. (Except: Bulbs, Halogen Bulbs)
- Electric and Electronic Tools:
  Drills, Electric saws, Sewing Machines, Lawn Mowers etc. (Except: large stationary tools/machines)
- Medical Instruments and Equipment
- Automatic Issuing Machines

B. Impacts of e-waste

The impacts of improper disposal of electronic wastes on the environment are little known, these impacts nonetheless possess very real threats and dangers to the global environment at large [**6**]. Uncontrolled burning and disposal are causing environmental and health problems due to processing electronic waste. Electronic waste is of concern largely due to the presence of toxic substances. The production of semiconductors, printed circuit boards, disk drives and monitors used in computers uses many hazardous chemicals. Printer toners and inks contain toxic materials such as cadmium. Computer Central Processing Unit (CPU) contains massive metals such as cadmium, lead, and mercury. Printed Circuit Boards (PCB) contain heavy metals such as antimony, silver, chromium, zinc, lead, tin, and copper [**4**].

Lead found on printed circuit boards and in computer monitor glass cause damage to the central and peripheral nervous systems, blood systems, and kidneys in humans. Mercury found in printed circuit boards and LCD screen backlights would affect a baby's growing brain and nervous system. Adults also suffer from organ damage, mental impairment, and a variety of other symptoms. Cadmium found in chip resistors and semiconductors causes various types of cancer and accumulates in the kidney. BFRs acronym for Brominated Flame Retardants found in the printed circuit board and some plastics may also increase the risk of cancer.

When electronics containing heavy metals such as lead, barium, mercury, lithium, etc., are improperly disposed of, these heavy metals leach through the soil to reach the groundwater channel which eventually causes water pollution. These types of chemicals are not biodegradable – they persist in the environment for the distant future, increasing the risk of exposure.

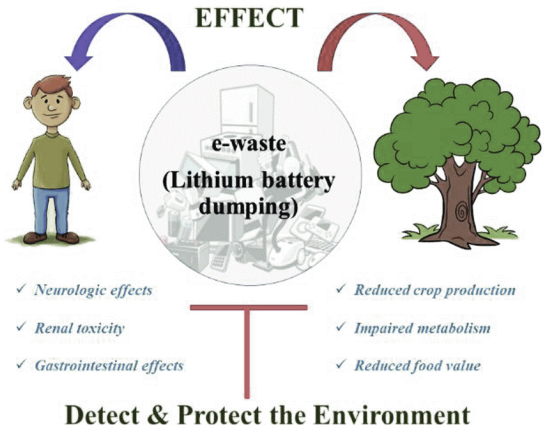

Fig. 3. Impact of e-waste in human beings and environment.

C. Disposal of e-waste

In developing countries like India, China, Nigeria the formal recycling is getting a boost from the government and local NGOs. Even though a lion's share of the e-waste generated in these countries is recycled, refurbished, and reused by the informal sector and the semi-informal sector. This on one hand ensures recyclability and reusability thereby enhancing the life cycle of the electronic product.

The various methods for e-waste disposal are Reuse, Incineration, Recycling, and Landfilling. Reuse refers to the usage of equipment that has been upgraded. Inkjet cartridges and laser tones are used after refilling. Incineration is a complete

and combustion process in which the waste is burned in specially designed incinerators at a high temperature in the range of 900 to 1000 degrees Celsius. Recycling is the process of developing new products from a product that has originally served its purpose. All the computer hardware components can be recycled. Landfilling is one of the widely used but not recommended methods for the disposal of e-waste. Electronic waste often contains heavy metals and other toxic substances which can contaminate ground and water resources.

Some organizations take care of this e-waste in an efficient and eco-friendly way. Services of these organizations include disposals, asset tracking, portfolio planning, certified DoD data erasure, and comprehensive electronic waste recycling. E-waste, Recycle force, A&S Metal Recycling, Inc., Hope services, and Ben Lomond Transfer stations are some of the organizations that aim to the proper disposal of electronic wastes. Realizing the growing concern over e-waste, the Central Pollution Control Board (CPCB) of the Government of India has formulated 'The e-waste rules,2011' and are effective from 01-05-2012. The implementation and monitoring of these guidelines shall be done by the State Pollution Control Board concerned.

D. Proposed solutions

It is high time that everyone's responsibility to take care of the beauty of nature. We should set apart electronic waste from regular trash to preserve the earth's resources for future generations. The proposed solutions for e-waste are:

- Every individual should be made aware of how to classify and cast out e-waste separately.
- Energy-saving monitors should be used, and they should be turned off when not in use.
- Give prior importance to paperless work. Take printouts only in unavoidable situations.
- Virtualization should be implemented wherever possible.
- Give more importance to recycling and reusing products.
  Handover e-waste to the organizations that take care of these waste materials in an organized manner.

E. E-waste management in India

Electronic waste typically refers to the hardware products that came to the end of the product's useful life. Examples of e-wastes are computer monitors, motherboards, air conditioners, etc. According to the Global e-waste monitor conducted in 2017, India generates about 2 million tons of e-waste annually and is ranked fifth among the e-waste producing countries.

Only 20 percent of worldwide e-waste is recycled. The UN report indicates that thanks to poor extraction techniques, the entire recovery rate of cobalt from e-waste is merely 30 percent.

As per the report of the Union Environment Ministry, some organizations are storing e-wastes in hazardous conditions and others cannot even handle such wastes. India now has 178 registered e-waste recyclers, accredited by the state governments to process e-waste expeditiously.

III. GREEN COMPUTING

Green computing is the environmentally responsible and eco-friendly use of computers and their resources. In broader terms, it is also defined as the study of designing, engineering, manufacturing, using, and disposing of computing devices in a way that reduces their environmental impact.

Many items manufacturers and vendors are continuously investing in designing energy-efficient computing devices, reducing the use of dangerous materials, and encouraging the recyclability of digital devices. Green computing practices a government-initiated labeling program named Energy Star created by the United States Environmental Protection Agency (EPA) in the early 1990s to recognize and

promote energy-efficient products. The program has also been put forward by Australia, New Zealand, Canada, Japan, and Europe. Electronic devices that carry the Energy Star logo generally take up 20 to 30 percent less energy than required by federal standards. The Energy Star logo is a world standard symbol for energy efficiency.

Fig. 4. Energy star logo

Green Computing is also known as green information technology (green IT). Green Computing aims to attain economic viability and improve the way computing devices are used. Green IT practices include the development of environmentally sustainable production practices, energy-efficient computers, and improved disposal and recycling procedures.

A. How to achieve green computing?

To advocate green computing at all possible levels, the four complementary approaches mentioned below are employed:

- **Green Design** – Designing objects and services that comply with the environment such as energy-efficient computers, printers, green data centers, etc.
- **Green Manufacturing** – The discovery and development of new products that reduce or eliminates the use or generation of hazardous substances in manufacturing.
- **Green Use** – Using resources in an eco-friendly manner that reduces the usage of hazardous materials.
- **Green Disposal** – Re-making an existing resource or recycling e-waste with little to no impact on the environment. As computing becomes increasingly relevant, finite natural resources are rapidly being diminished, and energy costs are rising. This makes "Green Computing" an important and timely issue.

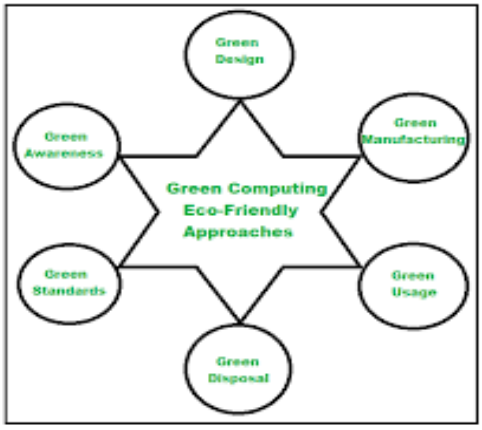

Fig. 5. Green computing approaches

B. Environmentally sound practices for green computing

Government regulatory authorities are actively working to promote green computing concepts by introducing several voluntary programs and regulations for their enforcement. The work habits of computer users and businesses are often modified to attenuate the adverse impacts on the worldwide environment. Here are some steps which will be taken [**7**]:

- Power down the CPU and every peripheral during extended periods of inactivity.
- Increase the usage of liquid-crystal-display (LCD) monitors rather than cathode-ray-tube (CRT) monitors.
- Power-up and power-down energy-intensive devices like laser printers to their need.
- Buy energy-efficient notebook computers rather than desktop computers.
- Use the power-management features to show off hard drives and displays after several minutes of inactivity.
- Minimize the utilization of paper and properly recycle paper.
- Dispose of e-waste consistent with federal, state, and native regulations.
- Employ energy sources for computing workstations, servers, networks, and data centers.
- Instead of buying a new computer, try refurbishing an existing device.

C. Advantages of Green IT

- Green computing can save energy.
- Green computing can economize at the end of the day.
- More sophisticated recycling processes
- Waste reduction
- Reduction of the resource depletion problem
- Less pollution
- Less greenhouse gas emissions
- More efficient hardware use
- Sustainable IT practice
- Increases pressure to travel green within the IT industry.
- Reduction of health risks for customers
- Better working conditions
- Teleworking may improve flexibility.

D. Disadvantages of Green IT

- Significant upfront costs
- Plenty of knowledge may be required.
- Green IT may conflict with profit optimization goals.
- May slow down computer networks.
- Technological change may make older IT systems outmoded.
- Acceptance inside companies may be rather low.
- Lacking awareness of the public
- Green IT is going to be susceptible to questions of safety.
- It may not be manageable for little businesses.
- Maintenance may be difficult.
- Many technologies are not that green as they seem.

E. How companies can implement Green computing

E-waste recycling - Non-biodegradable materials cause some of the most drastic effects on the environment. Recycling such products ensures you mitigate the consequences of their disposal on the environment. E-waste in our offices comprises all digital devices that are no longer useful to the organization. These products are often as little as a mouse or as large as industrial printers. Whenever the devices get damaged beyond repair or obsolete, they are often thrown away. Digital devices are often made from plastics and metals that are non-biodegradable. But for the record, most of these materials can be recycled [**5**]. As a result, you help reduce emissions produced from plastic production and can save our natural resources. Both SMBs and enormous enterprises should search for an e-waste recycler to require care of all their digital waste.

Only using products with the energy star label - Companies are always looking for ways to cut costs and opting for cheaper products is often a solution.

No one pays much attention to environmental protection or energy-saving during the purchase. However, energy-saving devices are more durable as well as sustainable in the environment. Before purchasing office or remote working devices, look for the Energy Star Rating used to show the level of energy efficiency. Any IT infrastructure you want to set up for your workplace should ensure this rating.

Working remotely - 2020 has seen such a huge shift in the workplace. Previously, there was a 115% hike in the remote workforce between 2005 and 2017 but nothing like we have seen in 2020. Based on Global Analytics Report 2017, working remotely takes about 600,000 cars off the road annually. As a result, the amount of greenhouse gas emissions because of daily commutes decreased in a significant manner. The study shows that there will be a reduction of 54 million tons of emissions in the U.S if all telecommuters worked from home for at least 3 days. Remote working is currently becoming a trend as most companies have realized how important it is for business sustainability. Also, home offices consume less space and resources minimizing energy consumption.

Using cloud computing - One of the advantages of green computing is ensuring that companies can do the most important chunks of labor using the smallest amount of possible energy. And this is often where green cloud

computing comes in. Green cloud computing is taking advantage of cloud technologies to try to do more work but with less amount of energy. To get a far better grasp of the concept, we've to first check out how work was done before the cloud.

People had to travel to an office to access their computers with specific RAMs, processing speed, and storage for them to figure, whether you utilized all the resources. Additionally, all computers need to be hooked to an on-site data center with bulky computer systems that might consume such a lot of power to run. While using cloud computing, businesses have access to technologies like remote desktop and remote access. An employee can access all company data and systems using their personal computer, phones, and tablets. There is no need for a physical data center as company data is stored on a server within the cloud. There is more work through with minimal resource utilization.

F. Green computing in India

In response to the world revolution in the field of green IT, India is also moving towards embracing it with open arms. Adopting green IT and sustainability solutions are emerging as key concerns for businesses, investors, and technologists across industries and policymakers in India. The operational cost of creating energy-efficient resources available is pressuring CIOs in Indian companies to develop strategies to optimize ICT utilization, including companywide energy management, while not compromising on the growth or deployment of newer technologies. Amongst government policy initiatives also plans such as the National Action Plan on Climate Change (NAPCC) which outlines the nation's strategy to manage greenhouse gas (GHG) emissions and Indian Economic Survey and India's 12th Five Year Plan which websites Inclusion of Green IT shows the importance given thereto by the Indian Diaspora. Given below are several rules which are set for IT and therefore the telecom industry in India to follow for a greener future. As per the advocacy put forward by the Task Force formed for growth of IT, ITES and manufacturing in India are as follows [**2**]:

- Standardization – There is a need for interoperable open standards for all the devices including networking equipment which is a prerogative of BEE and DIT. Need to standardize IT equipment and benchmarks for data centers for a cleaner and greener environment is required.
- Government Procurement – Government agencies should include the standards for energy consumption as the technical standards in government purchases, and with the establishment of mutually agreeable standards for a greener computing environment between BEE and the IT industry, it should be made mandatory in all government purchases.
- Setting up a center of excellence – The government of India should set up COE (Centre of Excellence) in the top technical institutions and universities. The centers can become the testing grounds and prototypes/pilot evaluation stages for clean green technologies.
- Tax Incentives – Investing in clean technology is a costly affair when the organization is an early mover/adopter. Tax incentives on the production of cleaner technologies and for the user of the same are needed for better adoption.
- The impetus of green computing has been envisioned for the telecom center too, with government initiatives especially DoT's Recommendation on the adoption of Green Technologies in the Telecom Sector.
- At least 50% of all rural towers and 20% of the urban towers are to be powered by hybrid power (Renewable Energy Technologies (RET) + Grid power) by 2015; Further 75% of rural towers and 33% of urban towers are to be powered by hybrid power by 2020.
- Every telecom product, equipment, and service that corresponds to the telecom network should be certified "Green Passport" by the year 2015 Telecommunication Engineering Centre shall certify telecom products, equipment, and services based on their ECR ratings.

- All service providers should declare to TRAI, the carbon footprint of their network operations and therefore the declaration of for an equivalent should be done twice a year.
- Service providers should embrace a Voluntary Code of Practice encompassing energy efficient Network Planning, infra-sharing, deployment of energy-efficient technologies, and adoption of Renewable Energy Technology (RET) to scale back carbon emissions.
- Service providers should evolve a “Carbon Credit Policy” in line with carbon credit norms with the last word the objective of achieving a maximum of fifty over the carbon footprint levels of the bottom Year (2011) in rural areas and achieving a maximum of 66% over the carbon footprint levels of the bottom Year in urban areas by the year 2020.

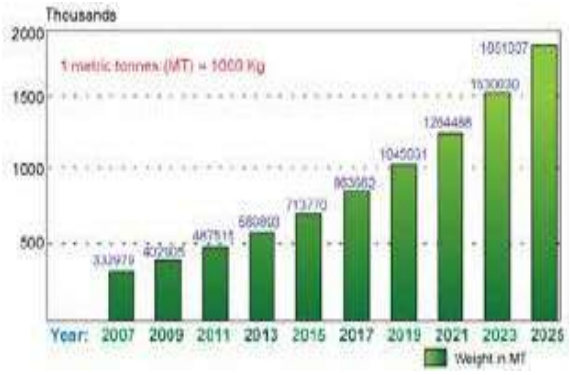

Fig. 6. Graph showing growth of e-waste in India.

IV. CONCLUSION

It is our duty today to seem upon environment-friendly approaches for our sustainable future. Invention, Innovation, and Adaptation of green technologies are that the need of the hour. The risk related to handling this e-waste involves green technologies for end-of-life disposal. e-Waste management practices comprise varied means of ultimate disposal of end-of-life equipment which have different impacts on human health and therefore the environment.

By going "green" in technology we help promote an eco-friendly and cleaner environment, alongside our own benefits by reducing costs, conserving energy, lowering waste. Green computing has come a long way, but with so many innovations coming along regarding preserving the environment, it is safe to say that green computing is a great development. Green computing aims to reduce the garbage and harmful effect of e-waste from our environment. The main goal of e-waste management is to keep the society and environment as a worthy place for living. As there are hindrances and challenges that we face while working with green computing and e-waste together. But the ever-increasing technology has made it easier to work in the field of green computing and e-waste management. All organizations, companies must take e-waste management as compulsory for making green computing an initiative. Otherwise, the world will have to face several problems. It is hoped that there will be a lot of progress that must have done in this field.

V. ACKNOWLEDGMENT

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REFERENCES

[1] Akther, T., & Ahmed, I. (2020). Review on E-Waste Management Strategies for Implementing Green Computing. *International Journal of Computer Applications, 177*(44), 45-52. doi:10.5120/ijca2020919975

[2] Chowdhury, S. N., Kuhikar, K. M., & Agnihotri, A. (2015). Green computing: an overview with reference to India. International Journal of Electrical, Electronics and Computer Systems

[3] Debnath, B., Roychoudhuri, R., & Ghosh, S. K. (2016, August 04). E-Waste Management – A Potential Route to Green Computing.doi:10.1016/j.proenv.2016.07.063

[4] Lotlikar, S. (2017). Survey and Analysis of Literature in “E-waste Management”. *International Journal Of Mechanical Engineering And Information Technology, 05*(01), 1835-1842. doi:10.18535/ijmeit/v5i1.01
[5] Shibly, Ahamed. (2015). Green Computing: - Emerging Issue in IT. 10.13140/RG.2.1.1729.4248.
[6] Stewart, R. (2010). Waste management. *Management, Recycling and Reuse of Waste Composites*, 39-61. doi:10.1533/9781845697662.1.39
[7] T, V. K. (2014). Green Computing – An Eco friendly Approach for Energy Efficiency and Minimizing E-Waste. International Journal of Engineering Research, 3(5), 356-359. doi:10.17950/ijer/v3s5/516