Review Article

Reduce E-waste through green computing virtualization

Rohan Saini[1], Sharvan Kumar Garg[2], Sanjive Tyagi[3].

1. **PG Student**
2. **Professor**
3. **Associate Professor**
Computer Science and Engineering,
Subharti Institute of Technology & Engineering,
Swami Vivekanand Subharti University, Meerut.

Abstract. Green computing encompasses a wide range of technologies, including virtualization, green data centers, cloud computing, grid computing, and power efficiency. This study focuses on the urgent need to reduce e-waste, which virtualization might help with. The goal of virtualization is to cut the total cost of expensive equipment; this not only makes the budget tighter but also heralds the e-product age. The purpose of this article is to illustrate the effects of e-waste, emphasize the significance of minimizing waste, and demonstrate how virtualization is crucial to attaining these goals. We'll also look at virtualization potential and key functions in environmentally friendly computing. The concept of virtualization has emerged as a result of technological advancements made to cut down on energy use and increase the number of data centers and virtual environments.

Keywords: Electronic waste; virtualization; recycle; energy optimization; green computing.

Address for correspondence: Rohan Saini. Department of Computer Science and Engineering Faculty of Engineeringand Technology, Subhartipuram , NH-58, Meerut, 250002, UP, India.

E-Mail: rohansaini200027@gmail.com **Contact: +91-73510-64854**

1. Introduction

Future changes to our daily lives will be greatly impacted by cloud computing, which is quickly emerging as a crucial information and communication technology. It is indicative of an emerging trend in computing, particularly given the increased focus on energy management across the board in the Information Communication Technology (ICT) industry. Notably, the energy consumption of data centers has received a lot of attention lately (1). This is because massive data centers are so common in a variety of businesses, which from an environmental standpoint can lead to the generation of e-waste and the discharge of hazardous gases and excess heat. Modern cloud-based systems use a lot of electricity and produce a lot of CO_2. The fact that many servers don't have effective cooling mechanisms makes this problem worse (2) The field of E-waste control within Green Computing has developed as a key and heavily explored area as a result of the increasing demand for enormous data storage and processing capabilities. In its quest to maximize different IT resources, cloud computing has offered ground-breaking techniques for reviving servers and data centers, thereby improving energy efficiency. However, it's critical to recognize that power consumption by IT resources is significant, which could result in energy shortages and affect the world's climate. With recycling emerging as an environmentally benign method, it is crucial to discover solutions that not only encourage energy conservation but also reduce operational and hardware expenses. Green IT is of utmost relevance for addressing environmental issues in the IT industry (3). Its primary objective is to ensure that computing and energy consumption are as efficient as possible, with minimal impact on the environment (4). Its main goal is to maximize energy and processing efficiency while having the least possible negative environmental effects [4]. Green computing accomplishes this by using eco-friendly energy sources, lowering energy consumption during computing operations, optimizing resource usage during busy and idle periods, mitigating the negative effects of computing resources, reducing computing waste, and enabling a more energy-efficient use of computing power (5). The most recent virtualization methods add to these improvements. The technological components of green computing include virtualization, green data center technologies, cloud computing, grid computing, power optimization, and e-waste management. Through the process of virtualization, resources are effectively divided into one or more execution environments (6). The growing demand for capacity from users necessitates improved performance and capacity. Virtualization has revolutionized the IT environment, enabling businesses to optimize their hardware utilization and reduce expenses (7). A significant advantage of virtualization is its alignment with green computing principles. This paper focuses on the reduction of electronic waste and advocates for conserving overall hardware resources through virtualization. Not only is virtualization costly, but it also contributes to increased electronic waste and energy consumption in data centers.

2. Background

The importance of cloud computing has gained tremendous popularity amongst IT managers throughout diverse groups [1]. earlier than the term "Cloud Computing," other standards like "Grid Computing" [8], "computer inside the Cloud" [9], and "Dreaming in the Cloud" [10] have been discussed within the enterprise. The cloud computing model provides usual and on-demand get right of entry to to a shared pool of configurable computing assets, which includes networks, garage, servers, programs, and services. these sources may be hastily allocated and launched with minimal control involvement or interaction with provider carriers [11]. the issue of power intake in facts era device has acquired increasing interest in latest years. there may be a growing attention of the need to efficaciously control strength intake in the course of the whole statistics and communications era (ICT) zone [12]

2.1 History E-waste

E-waste management has a long history and has developed in reaction to the rising number of electronic devices and the corresponding increase in electronic trash. Here is a quick rundown of the significant turning points in the history of e-waste management 1970s-1980s: Early electronic gadgets and the development of personal computing contributed to the production of electronic garbage. However, there was little awareness of and regulation surrounding the disposal of electronic devices during this time.1990s: As the use of electronic gadgets increased, environmental concerns began to spread. Electronic waste transportation is governed under the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, which was established in 1989., contained rules governing the cross-border transportation of hazardous waste, including electronic waste. Early 2000s: [12] Due to the rapid improvements in technology and the rising popularity of consumer electronics, the production and disposal of electronic waste significantly increased in the early 2000s. It has been more well-known that incorrect e-waste disposal poses environmental and health risks.2003 saw the introduction of the Waste Electrical and Electronic Equipment (WEEE) Directive by the European Union. The framework for the appropriate handling, recycling, and recovery of electronic waste in member nations was established by this directive. The Electronic Waste Recycling Act was approved in the US in 2006, creating a framework for the collection and recycling of specific electronic waste items.2010s: Around the world, many nations and areas started to enact or reinforce laws relating to the management of electronic trash. Extended producer responsibility, which holds manufacturers accountable for the end-of-life disposal of their products, was the focus of numerous projects [13]. This update sought to make the collecting, handling, and recycling of electronic waste even better.2020s: Ongoing initiatives to address electronic waste are still underway, with a growing focus on circular economy ideas, which encourage the reuse and recycling of electronic components [14].

3. Literature Review

3.1 E-waste :

E-waste, short for electronic waste, refers to discarded electrical or electronic devices and equipment. It encompasses all components and assemblies [15] that make up these devices, which are disposed of either due to obsolescence or at the end of their operational life.

3.2 E-waste affects humans and the environment.

Electronic trash (e-waste) management and disposal practices can have serious negative consequences on the environment and human health. Some of the major effects are as follows: Exposure to toxic chemicals: Hazardous compounds like lead, mercury, cadmium, and flame retardants called brominates are frequently found in e-waste. These compounds have the potential to pollute the food chain and expose people through eating when they leak into soil and water. respiratory issues E-waste burning or incineration emits toxic chemicals and heavy metals into the atmosphere [16].

3.3 Recycling E-waste

Recycling of electronic waste (e-waste) is a critical step towards reducing its environmental impact and conserving valuable resources. Here are the key aspects of e-waste recycling: Collection and Sorting: Collection Centres: E-waste can be collected through designated drop-off points,[17] recycling centers, or scheduled collection events organized by municipalities or private entities. Sorting and Categorization: Once collected, e-waste is sorted into different categories based on the type of electronic equipment. This helps in streamlining the recycling process. Dismantling and Depollution: Dismantling: E-waste is disassembled into its constituent parts, including plastics, metals, and electronic components. This is typically done manually or through automated processes. Depollution: Hazardous substances such as batteries, capacitors, and mercury-containing components are safely removed to prevent environmental contamination. Material Recovery: Plastics: Plastics from e-waste are shredded, cleaned, and processed for reuse in manufacturing new products. Metals: Ferrous and non-ferrous metals like iron, aluminum, copper, and gold are extracted and sent to smelters for refining and reuse. -hand products or donated to communities in need. Secure Data Destruction: Data Wiping or Destruction: Before recycling, data stored on electronic devices is securely wiped or destroyed to protect sensitive information. Responsible Disposal: Proper Waste Management: Any residual waste that cannot be recycled is disposed of in an environmentally responsible manner, following local regulations and guidelines. Compliance and Regulation: Legal Compliance: E-waste recycling facilities must adhere to local and international regulations and standards to ensure safe and environmentally friendly practices [18]. Education and Awareness: Public Awareness: Educating the public about the importance of responsible e-waste recycling helps encourage participation and compliance. Research and Innovation: Technological Advancements: Ongoing research aims to develop more efficient recycling methods and technologies to improve the sustainability of e-waste management.

3.4 E-waste and Virtualization

By developing technologies that significantly reduce carbon emissions by drastically reducing energy usage, computing has achieved tremendous advancements in environmental conservation. N Computing has effectively reduced electricity consumption by 88 million kilowatts yearly when compared to an equivalent number of traditional PCs with over 500,000 virtual PC seats deployed across 70 countries. This accomplishment translates into a significant reduction of 55,000 metric tons of atmospheric carbon emissions. Therefore, virtualization is essential for reducing electronic waste and reducing the worldwide environmental effect of IT operations, resulting in a more sustainable environment.

3.5 Virtualization Support in Green Computing

Resource usage is revolutionized by virtualization, especially in terms of energy effectiveness. In essence, virtualization's main goal is to make it possible for a single hardware piece to perform the functions of numerous separate pieces. Different user interfaces isolate various hardware components, enabling each to function independently. Numerous operating systems and applications can run on fewer servers by utilizing virtual infrastructure. This results in a significant decrease in the overall energy consumption needed for data centers and the cooling systems that are connected to them. This equates to a remarkable potential for energy savings, which is estimated at 7,000 Kilowatt hours per year per server. As a result, virtualization becomes the best method for using green computing, particularly in data centre operations. [19]

3.6. Role of Types of Virtualization in E-waste Reduction

Manage the spun words as you want to reduce digital waste and promote green computing strategies for a sustainable and ff surroundings, several kinds of virtualization are essential. these answers effectively cut down on aid use and improve security. hardware virtualization (also referred to as server virtualization): This type lets in many running structures and applications to run concurrently on a single server, substantially decreasing the need for separate systems and related hardware. This method substantially reduces the manufacturing of electronic waste by way of decreasing the want for hardware and controlling power and cooling tactics. software program virtualization: This system includes setting up and running numerous virtual environments on a host computer. software virtualization effects in energy savings, price financial savings, lower emissions of dangerous gases, and reduced e-waste era thru a reduction in hardware and software needs and an improvement in task sharing.

3.7 Challenges and Appropriate Solutions

a) comprehensive management of Virtualization kinds: dealing with server resources in actual-time, dealing with switching in digital environments, designing and implementing networks, complex virtual machine troubleshooting, making sure network guide for VM migration, addressing infrastructure problems, and supplying sturdy storage help for digital servers are among the challenges. solution: these issues can be resolved through implementing distributed digital switching mechanisms, imposing dynamic infrastructure control, and automating manual processes. this will enhance the effectiveness of virtualization and lower digital waste.

b) excessive power and strength intake: due to the increasing demands of statistics computation and applications, it's miles a challenging assignment to lessen strength consumption in cloud computing structures and statistics centers. To assure powerful functioning within predetermined periods, this will increase the want for disks and effective servers. by the usage of dependable and strength-efficient servers in place of regular cloud data facilities, excessive energy performance in cloud computing can be carried out. those servers use 5inner cooling answers that lessen the want for enthusiasts. this change is crucial because less strength used by inner servers' effects in extra savings for cooling systems and strength distribution in cloud facts centers.

3.8 Solutions to High Energy Consumption

•general cost of possession (TCO) Optimization: it is vital to lessen average energy dissipation inside these centers to reduce the TCO for cloud computing environments, which includes the energy charges of strolling a cloud facts centre. increasing strength supply capacity: it's essential to recollect the height energy capacity of energy resources for cloud facts facilities and to be privy to the restrictions of the energy transport community. the height energy draw on the server and information girdle levels is saved inside controllable bounds as a end result. Maximizing Cooling performance: Deploying laptop room aircon (CRAC) devices and air managing gadgets strategically is every other way to lessen strength fees related to cooling a cloud information centre. inside their heat exchanges, these machines use call for-pushed, variable frequency force (VFD) lovers. As a end result, various heat loads and variable airflow charges may be exactly matched. decreased strength use has a big effect on device availability, productiveness, and dependability in addition to considerable fee financial savings. moreover, it extensively contributes to defensive our environment by means of reducing the high energy costs and reducing the possibility of hardware gadget disasters delivered on via immoderate warmness generation.

4. Result

The research was conducted in North Imani constituency, Meru County, Kenya, which is categorized as a developing nation. The study focused on four manufacturing companies in the area. A total of 20 employees participated in the research, with five employees selected from each company for the study. Among the five respondents from each company, one was specifically chosen from the Information and Communication Technology (ICT) department. Data analysis was performed using statistical software SPSS and MS Excel. All of the sampled respondents confirmed that their

respective companies utilize ICT in their business operations. However, the study also revealed that none of the sampled companies had an established E-waste management plan or policy in place. The respondents mentioned that outdated ICT equipment was either stored in a designated room referred to as an archive, used as a storage area for old computers, or disposed of along with other company waste through the county's garbage collection service. In addition, some respondents mentioned that the outdated ICT equipment was sorted and sold as scrap metal.
Let us consider total power consumed is denoted by E then,
$E = n\ i=1\ E_i$ (1)
where, $E_i = N_w.e_w + N_r.e_r + e_s$ (2)
The number of tasks is considered as $i = 1$ to n and E_i is the energy consumption at each task i, therefore total energy consumption at all tasks is given by summation of E_i i.e. equation (1). Further E_i can be derived from

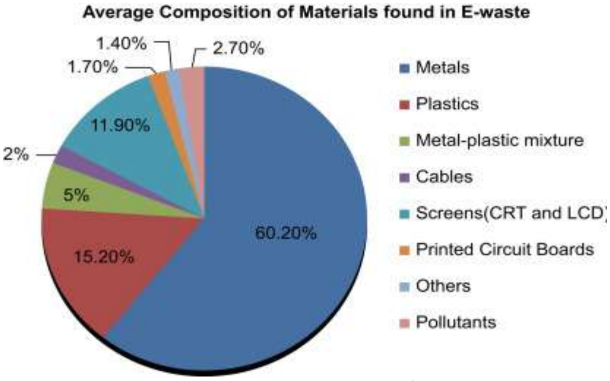

Figure 1: Average composition of materials found in E-waste

The data clearly illustrates that the predominant materials found in E-waste are Iron and steel, constituting 48% of the total. Plastics follow with 15%, while Copper, Aluminium, and Glass each make up 5% of the composition. Printed Circuit Boards account for 3%, and the least prevalent material is Rubber, standing at 1%. As depicted in Figure-1, the composition of E-waste encompasses a significant proportion of iron and steel, alongside aluminium, rubber, ceramic, copper, and various other chemically composed materials. This diversity presents challenges in the extraction and recycling process, as each material requires distinct methods for extraction. Heavier materials can be manually separated from discarded items, whereas smaller ones necessitate specialized equipment and attention. Moreover, the handling of chemically hazardous substances from electronic items demands the use of specific chemical deposition techniques to safeguard both handlers and the environment from any potential harm. The majority of electronic and electrical waste undergoes recycling through a system known as WEEE (Waste Electrical and Electronic Equipment). This system not only achieves a high recycling rate of 95-98% by weight but also ensures the thorough destruction of any remaining data on hard drives and memories. The manufacturing companies provided diverse explanations for their failure to segregate e-waste before disposal. A significant majority, 92% of the respondents, did not perceive it as crucial to differentiate e-waste from regular waste before disposal. Additionally, 5% asserted that the absence of designated litter bins for separation was a contributing factor. Lastly, a smaller fraction, 3% of the respondents, demonstrated a general indifference towards the disposal process. This apathy is evident in their response.

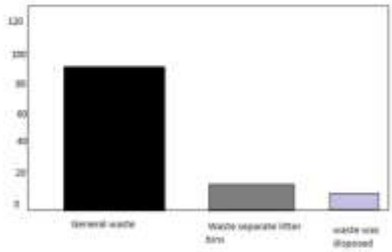

Figure 2: Reasons for lack of waste separation

The research findings revealed that none of the sampled manufacturing companies had implemented any environmental or e-waste policies, as depicted in Figures 2 and 3 below:

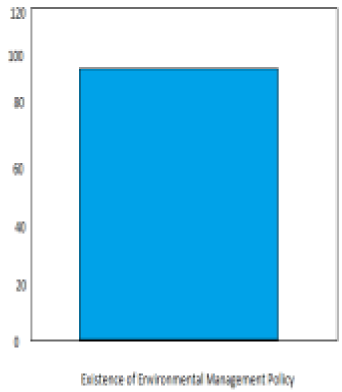

Figure 3: Existence of environmental management policy

E-waste is linked to a variety of negative health and environmental effects, including renal issues, brain damage, skin ulcers, lung cancer, birth deformities, and even mortality due to water and soil contamination. The study's findings, meanwhile, are troubling because only 25% of the respondents were able to name these harmful effects of e-waste. This lack of knowledge may be explained by the fact that only 10% of respondents were aware of what happened to the e-waste they dumped, and only 14% were concerned about what would happen to the e-waste. Among those who didn't show worry, 16% thought that e-waste had no substantial health or environmental repercussions, 8% felt it wasn't their responsibility, and the majority, 76% of the respondents, didn't care because e-waste carried no real potential for harm. These findings demonstrate the urgent need for efforts to raise public awareness of the negative effects of e-waste and the significance of responsible disposal methods. It also emphasizes the significance of putting in place appropriate e-waste management policies and practices to lessen these negative effects on health and the environment.

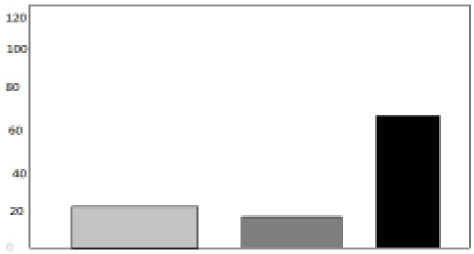

Figure 4: Reasons for Caring

Among those individuals who expressed concern about the fate of the e-waste they disposed of daily, only 3% did so because they were aware of the harmful effects on the environment. Similarly, another 3% felt that it was harmful to human health, as depicted.

Figure 5: Reasons for Caring

This study highlights the intricate nature of electronic appliances, which comprise a multitude of materials that can be both toxic and valuable during their use before disposal. While the majority of materials, such as aluminium, iron, plastics, and glass, collectively make up more than 80% of E-waste by weight, precious and hazardous materials exist in smaller quantities but remain highly significant, as detailed by Thakur et al. (2016). Although the material composition of various appliances often exhibits similarities, the proportions of different components can vary widely. Precious metals like gold, silver, copper, platinum, etc., present opportunities for profitable E-waste recycling. Conversely, the responsible recycling of hazardous E-waste containing carcinogens such as lead and arsenic is imperative, as improper handling poses severe health and environmental risks. The volume of E-waste generated is rapidly increasing, exacerbated by illegal exports and inappropriate donations of electronic equipment, especially computers, from developed to developing countries. The utilization of electronic devices results in a range of environmental effects, primarily due to the emissions of gases, including carbon dioxide and other toxic substances. These effects give rise to significant health concerns, such as respiratory diseases, as well as broader environmental issues like global climate change and acid rain (Archana et al., 2011). Computers have an environmental footprint throughout their lifecycle, from manufacturing to use and disposal. While developed nations have established protocols for managing E-waste, many developing nations lack adequate systems. The adoption of green computing practices can help mitigate these adverse effects, whether in developed or developing nations (Jaiswal et al., 2015). The study's findings reveal that only 25% of E-waste is formally recycled in dedicated recycling centers, often lacking sufficient worker protection. Moreover, over 80% of the respondents demonstrated insufficient knowledge about the E-waste recycling process. Nevertheless, 75% of the respondents expressed belief in the positive environmental impact of E-waste recycling. The study also identifies that 50% of the ICT staff consider green computing as a potential solution to E-waste management. Notable benefits of green computing include its environmentally friendly nature, energy-saving attributes, and the potential to reduce environmental pollution, thereby improving public health. However, while green computing offers numerous advantages, the study also identifies several challenges. These include the limited availability of green computing technology in local markets due to inadequate technological infrastructure, high initial and operational costs, and the difficulty of implementing green computing across organizations and society due to limited technological knowledge among users. To address these challenges, existing laws and policies must be updated to integrate technological advancements in green computing, especially in manufacturing and SMEs. Furthermore, companies should establish policies that promote the use of green computing for E-waste management devices and delivering short- and long-term benefits to organizations. Through the adoption of public cloud data centre services, manufacturing companies can lower IT costs and environmental impact. The government can play a role in facilitating E-waste collection b. Additionally, community members should receive training to understand the benefits of green computing. Overall, the adoption of green computing can result in cost savings, energy conservation, reduced environmental impact, and enhanced environmental sustainability. Cloud computing and virtualization strategies can significantly enhance green computing practices in small and medium-sized manufacturing enterprises. Virtualization, in particular, enables the creation of software equivalents to hardware, reducing reliance on electronic y organizing special collection events, establishing permanent drop-off sites, utilizing retail stores, and implementing scheduled pick-ups from E-waste generating companies. Additionally, open-source cloud solutions can be tailored to specific manufacturing and user requirements, minimizing dependence on electronic devices and promoting green computing practices. In summary, when coupled with virtualization and cloud solutions, green computing holds significant potential for mitigating environmental impact and advancing sustainability within the manufacturing sector.

4. Conclusion

This paper delves into the escalating demand for electronic devices within manufacturing and small to medium-scale enterprises, shedding light on the resulting surge in electronic waste generation. It also explores viable measures to mitigate the adverse impacts of this electronic waste. The management of electronic waste and the adoption of green computing technologies are indeed important strategies to mitigate the environmental impact of the IT industry. However, your provided text appears to be a segment of text discussing this topic and does not seem to be a question or request for specific information. If you have any specific questions or need information related to electronic waste management, green computing, or any other topic, please feel free to ask, and I'll be happy to provide you with relevant information or help with your inquiries., holding significant potential to curb the environmental and human impacts of electronic waste in manufacturing industries, especially in developing nations. While green computing shows promise in reducing electronic waste," Further research is needed to promote the extensive implementation of cloud and virtualization solutions in the manufacturing sector across developing regions of Africa. These endeavours have the potential to generate significant advantages for both the environment and the economy."

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