

A Review on Waste Management in Green Computing

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Abstract

Green Computing, a recent trend and developing industry, is working to create a more sustainable future. Reusable resources are provided through green computing, which is now employed by many different technologies. Green technology is sustainable and eco-friendly. Computer use is growing quickly, which means that computers are using more energy. As a result of higher energy consumption, more eco-harmful carbon footprints are being released into the environment. Due to this issue, many companies having proper way of waste management has started to implement the green computing technologies. This study reviews the different approaches of green computing like energy minimization, virtualization, reduction in use of hazardous substances, and cloud computing. This paper also explains the green computing and its needs. The concern of waste management, which is an approach of green computing can be achieved this way.

Keywords: Green Computing, Waste Management, Environmental hazards, Sustainability

1. Introduction

Due to the growth of the tech sector over the past 20 years or more, the majority of countries now own mobile phones in addition to other gadgets, and newer, better electronic devices appear on the market every few months. These electronics and computing resources have increased dramatically in this period of information and communication technology. Excessive usage of electronic equipment has led to a variety of negative side effects, including high energy consumption, global warming, the growth of e-waste, environmental

degradation, etc. Due to these factors, the entire world focuses on the waste management and green computing.

1.1 Green Computing

Green computing is the study and use of ecologically sound computing and information technology. It is described as the study of developing, engineering, using, producing and disposing of computer equipment in a way that minimises their environmental impact. Green computing is often referred to the Green IT or Green Technology. It involves using the computer and other electronics devices in an eco-friendly and energy efficient ways. In 1992, the Environmental Protection Agency introduced the Energy Star programme, which gave green computing techniques increased recognition.

There are various objectives for green computing, including reducing the use of hazardous materials, reliability of power, minimizing climate change during the product's lifetime, maximising energy efficiency, and to design a proper algorithm that will increase the computer efficiency. The following four strategies are used to promote green computing ideas at all levels are Green Use, Green Design, Green Disposal, and Green Manufacturing.

Green computing mainly consists of the four important areas shown in Figure 1 and discussed as follows.

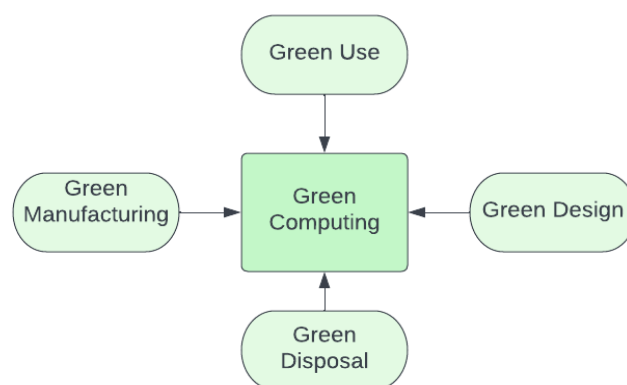


Figure 1: Components of Green Computing

- 1. Green Use:** Green Use is using computer and other information systems in an energy-efficient manner and with consideration for the environment.

2. **Green Design:** Green Design is designing energy efficient and eco-friendly components like computers, servers, projectors, printers, cooling system and other digital devices.
3. **Green Disposal:** Green Disposal is a recycling unwanted computers and other electronic devices as well as refurbishing old computers.
4. **Green Manufacturing:** Minimizing waste during the production of electronic components, computers, and other related systems with minimal or no environmental effect is Green Manufacturing.

1.2 Needs and Importance of Green Computing

Nowadays, everyone uses computers and IT services since they are quicker and easier to use, but as a result of their growing use, they utilise more energy, which ultimately leads to the massive release of hazardous carbon compounds and gases like carbon dioxide. To reduce their impact, the green computing comes into being. There are many reasons of using green computing such as, to save the environment at a lower cost, to decrease the hazards of future life and high energy consumption, etc.

Green Computing is important to maintain safety and cleanliness of our environment. There are different advantages of green computing such as, waste production, cost effective, better resource utilization, energy saving, reliable, and eco-friendly. It has several drawbacks as well. These computers are more expensive, and technology is not readily available -it changes rapidly. Out of these previously mentioned features of green computing, this study concentrates on the problems of waste management and recycling.

2. Waste Management

Waste is any substance that is discarded. It is an important raw resource that is at the incorrect location. Many wastes are now being utilised either totally or inefficiently, which poses serious risks to human environment. The term "e-waste" is sometimes used to describe electronic devices that are nearing the end of their "useful life". E-waste may be defined as the discarded common electronic devices such as the laptop, computers, TV, mobile phones, refrigerators, video recorders, scanners, etc. Electronic equipment can be rebuilt using parts of the e-waste components. These electronic items can be reused, recycled, resold, repaired and disposed. The below figure shows some examples of e-waste.



Figure 2: Examples of E-waste

One of the waste sources with the fastest global growth is e-waste. E-waste management is the process of disposing electronic trash in a responsible manner. E-waste is not only a trash; since it contains highly dangerous materials including mercury, lead, and BFRs, treating e-waste should be given priority above anything else. The issues with e-waste are, data security in electronic waste, industrial revolution, effects of e-waste on the environment, and advancement in information technology.

The four stages of the e-waste life cycle are as follows: [11]

1. Phase I: Phase I is a Production of EEE (Electrical and Electronic Equipment)
2. Phase II: The second phase involves the Generation of UEEE (Used Electronic and Electrical Equipment).
3. Phase III: The third phase is the decision for fate.
4. Phase IV: Processing of E-waste is the final phase.

3. Related Works

In recent years, green computing and e-waste management has become an important topic. Several studies in this topic have been conducted using various methodologies. The e-

waste management comparison of the different green computing techniques is shown in table 1, that includes the features and advantages.

Mukherjee et al., [1] reviewed the green data center solutions using the virtualization technology which helps to improve the energy efficiency, cost effectiveness and security. The proposed virtualization technology provided the solution to maintain the system effectively. It provided the better effective system management. Some illustrious solutions, such as server consolidation and other illustrious green computing techniques were discussed.

Osial et al., [2] discovered the waste management for green concrete solutions with the green additive that is used to reduce the time, and lower construction cost. The green concrete production was used to reduce the energy consumption. This paper recommends a line of inquiry for the creation of eco-friendly materials for a sustainable future.

Ighravwe et al., [3] discussed the green fuzzy deployment method with the WASPAS approach that maintains the preventive green quality function deployment based on the customers aspirations and needs. The preventive maintenance programme is at zero liability and lower cost. The proposed green quality deployment provided the solution to maintain the performance and sustainability.

Salem et al., [4] introduced the green biosynthesized selenium nanoparticle (Se-NPs), that were evaluated as antibacterial and antibiofilm activities against multidrug-resistant gram-positive and -negative bacteria which can be used to increase energy saving, later in fighting resistant bacteria and is eco-friendly. The green biosynthesized selenium nanoparticle (Se-NPs) was polydisperse, and highly crystalline. The proposed method was used to decrease the viability of bacteria and increase the concentration of Se-NPs.

Maroof et al., [5] explained the waste disposal by using the Biodegradation of Low-Density Polyethylene (LDPE) which enables to reduce the CO₂ estimation and is eco-friendly as well as minimized the effect in the environment. The study reviewed the fungal species which can be used in biodegradation of complex plastics.

Table 1: E-Waste Management Comparison of the different Green Computing Techniques

Reference	Techniques	Tool and methods	Features	Benefits
Mukherjee et al. [1]	Virtualization Technology	Green Data Center Solutions	Effective system management	<ul style="list-style-type: none"> • Secure • Energy efficient
Osial et al. [2]	Green Concrete Solutions	Green Additive	Reduction in energy consumption	<ul style="list-style-type: none"> • Lower construction costs • Concrete production • Reduced time
Ighravwe et al. [3]	Green quality function deployment	WASPAS, Fuzzy Deployment Method	Maintenance of performance and sustainability	<ul style="list-style-type: none"> • Lower cost • Zero liability
Salem et al. [4]	Multidrug-resistant Gram-positive and -negative bacteria	Green Biosynthesis selenium nanoparticle	<p>Decreased the viability of bacteria</p> <p>Increased the concentration of Se-NPs</p>	<ul style="list-style-type: none"> • Eco friendly • Highly crystalline • Energy saving

Maroof et al. [5]	Biodegradation	Low-Density Polyethylene (LDPE)	Complex plastics are degraded	<ul style="list-style-type: none"> • Eco-Friendly • Reduced CO₂ emission
Xia et al. [6]	Interpretive Structure Modelling	Green technology adoption	Sensible and efficient green codes supporting sustainable development	<ul style="list-style-type: none"> • Independent of technologies • Improved sustainability
Ma et al. [7]	Reduce hazardous air pollutants	Green technological innovation	<p>Increase the transmission</p> <p>Enable the long-term control of haze.</p>	<ul style="list-style-type: none"> • Cost effective • Energy saving • Reduced CO₂ emission
Thilakarathne et al. [8]	Energy Efficient Computing	Green Internet of Things	Minimize the harmful effects on the human health and environment.	<ul style="list-style-type: none"> • Energy efficient • Decrease the use of dangerous materials
Sathyanarayana et al. [9]	Non-Conventional	Green Energy Management	Used to monitor maximum	Increase system efficiency and

	Energy sources	System	power	reliability
Fitriani et al. [10]	ERP System Implementation	Non-Medical Waste Management System	Standardized the electronic product recycling market	Technology independent

Xia et al., [6] analysed the green technology adaption enterprises where the interpretive structure modelling provides the improving sustainability and was independent on the technologies. The appropriate framework of interpretive structure modelling may help to clarify how the sustainability elements are introduced to green technology adaption. This study provides the details about the sensible and efficient green codes supporting sustainable development.

Ma et al., [7] suggested that the green technological innovation can reduce hazardous air pollutants which helps to provide the energy saving and green economy effects, cost effectiveness and reduced CO₂ estimation. The paper pertained that the green technological innovation serves the increase in transmission of hazardous air pollutants and enable the long-term control of haze.

Thilakarathne et al., [8] presented the energy efficient computing using Green Internet of Things which can decrease the use of dangerous materials and provide energy efficiency. This paper reviewed the using of green internet of things which can minimize the harmful effects on the human health and environment and keep the environment safe.

Sathyanarayana et al., [9] proposed the green energy management system approach to create the non-conventional energy sources. It also knows as the renewable energy source which helps to increase system efficiency and reliability. The proposed approach can be used to monitor maximum power, and the design enables the two sources to provide load independently or concurrently.

Fitriani et al., [10] contributed towards the non-medical waste management system by using ERP system implementation which helps to determine the amount of waste generated and monitor the non-medical waste. It also was technology independent. The main goal of the proposed algorithm was to standardize the electronic product recycling market.

4. Discussion

On the basis of the above comparisons, e-waste management using green computing must be eco-friendly, energy efficient, technology independent, cost effective, and reduce CO₂ emission. These are the important features of the techniques. After analysing all available e-waste management techniques and segregating into four major categories, and identifying the best options for each component based on five criteria, it accomplishes the e-waste management in green computing successfully. The effective implementation of all these suggested solutions will advance green computing. Table 2 shows the ideal solutions for each green computing component based on the characteristics.

Table 2: Components of Green Computing

Components	Ideal Solutions	Impacts
Green Use	Reduced Use of Hazardous Materials	1. Energy efficient 2. Cost effective 3. Minimized energy consumption while maximizing output
Green Design	Energy Efficient Computing	1. Reduced CO ₂ emission 2. Energy saving

Green Disposal	Using Gram-Negative Bacteria for Degradation	1. Energy-saving and economical 2. Independent of Technologies 3. Eco-Friendly
Green Manufacturing	Function Quality Deployment	1. Impact the recycling of e-waste 2. Increased the potential use 3. Eco-Friendly

5. Conclusion

Excessive usage of electronic devices has led to a variety of negative side effects, including high energy consumption, global warming, the growth of e-waste, environmental degradation, etc. Due to these factors, the entire world focuses on the waste management and green computing. This research paper shows the definition of green computing, needs and the importance of green computing. Green computing's main goal is to reduce the energy consumption, and reduce the harmful effect and garbage of e-waste from our environment. Different approaches of green computing like energy minimization, virtualization, reduction in use of hazardous substances, and cloud computing are discussed in this article. As the result, the proposed study identifies the ideal solution for each component based on four criteria, which makes the e-waste management in green computing successful. This can be considered as the potential future scope in this area.

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Sindhu B has completed her B.Ed in commerce, M.com in finance, M.B.A in HR. She has 12 years of teaching experience in commerce and management and cultural co-ordinator at Bangalore City College and Baldwin Methodist College. She is pursuing her Ph.D. under the department of commerce, at the University of Mysore. Her research is on study of training and development in IT companies. She has served as exam evaluator in Bangalore City University. She has participated in many national and international conferences.